ECOLOGY AND MANAGEMENT OF *ARUNDO DONAX*, AND APPROACHES TO RIPARIAN HABITAT RESTORATION IN SOUTHERN CALIFORNIA.

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Abstract

By far the greatest threat to the dwindling riparian resources of coastal southern California is the alien grass species known as *Arundo donax*. Over the last 25 years the riparian forests of coastal southern California have become infested with *A. donax* which has spread by flood-fragmentation and dispersal of vegetative propagules. *Arundo donax* dramatically alters the ecological/successional processes in riparian systems and ultimately moves most riparian habitats towards pure stands of this alien grass.

By current estimates there are tens of thousands of acres of *A. donax* along the major coastal drainage systems of southern California, including the Santa Ana, Santa Margarita, Ventura, Santa Clara, San Diego, and San Luis Rey rivers. The removal of *A. donax* from these systems provides numerous downstream benefits in terms of native species habitat, wildfire protection, water quantity and water quality.

Introduction

Arundo (L.) is a genus of tall perennial reed-like grasses (Poaceae) with six species native to warmer parts of the Old World. *Arundo donax* (L.) (giant reed, bamboo reed, giant reed grass, arundo grass, donax cane, giant cane, river cane, bamboo cane, canne de Provence), is the largest member of the genus and is among the largest of the grasses, growing to a height of 8 m (Figure 1). This species is believed to be native to freshwaters of eastern Asia (Polunin and Huxley 1987), but has been cultivated throughout Asia, southern Europe, north Africa, and the Middle East for thousands of years and has been planted widely in North and South America and Australasia in the past century (Perdue 1958, Zohary 1962). It was intentionally introduced to California from the Mediterranean in the 1820's in Los Angeles area as an erosion-control agent in drainage canals, and was also used as thatching for roofs of sheds, barns, and other buildings (Hoshovsky 1987). Subsequent plantings have been made for the production of reeds for a variety of musical instruments including bassoons and bagpipes. Today it is an invasive pest throughout the warmer coastal freshwaters of the United States, from Maryland to northern California.

Arundo donax is a hydrophyte, growing along lakes, streams, drains and other wet sites. It uses prodigious amounts of water, as much as 2,000L/meter of standing *A. donax*, to supply its incredible rate of growth (Purdue 1958; Iverson 1994). Under optimal conditions it can grow more than 5 cm per day (Purdue 1958). *Arundo donax* stands are among the most biologically

productive of all communities. Under ideal growth conditions they can produce more than 20 tons per hectare above-ground dry mass (Perdue 1958).

Perhaps as much as 90% of the historic riparian habitat in the southern part of California has been lost to agriculture, urban development, flood control, and other human-caused impacts (Jones & Stokes 1987; Katibah 1984). The greatest threat to the remaining riparian corridors today is the invasion of exotic plant species, primarily *Arundo donax*. This alien grass readily invades riparian channels, especially in disturbed areas, is very competitive, difficult to control, and to the best of our knowledge does not provide either food or nesting habitat for native animals. *Arundo* competes with native species such as *Salix* (willows), *Baccharis salicifolia* Ruiz Lopez & Pavon (mulefat), and *Populus* (cottonwoods) which provide nesting habitat for the federally endangered bird, the least Bell's vireo (*Vireo bellii pusillus*), the federally threatened bird, the willow flycatcher (*Empidonax traillii eximus*) and other native species (Hendricks and Rieger 1989; Franzreb 1989; Zembal 1986 and 1990).

Ecological value of native riparian systems

Like most riparian systems, the cottonwood/willow riparian forest is a dynamic community, dependent upon periodic flooding to cycle the community to earlier successional stages (Warner and Hendrix 1985). Periodic floods of large magnitude and migration of the river channel are essential to depositing fresh alluvium where seeds and vegetative propagules of *Baccharis*, *Salix*, and *Populus* can germinate and take root (Gregory et al. 1991; Richter and Richter 1992).

Adequate moisture and an absence of subsequent heavy flooding is critical to the survival of the young trees through their first year. As these seedlings mature they increase channel roughness and alter flow during small flood events, increasing sediment deposition (Kondolf 1988; Richter and Richter 1992; Stromberg *et al.* 1993). Sediment deposition builds river terraces and, as they elevate, other plant species colonize resulting in further diversification in the floodplain community (Richter and Richter 1992).

When *Populus/Salix* riparian scrub, which may include such species as *Baccharis salicifolia*, *Vitis californica* (Benth.), *Rubus ursinus* (Cham. & Schldl.), and *Urtica dioica* ssp. *holosericea* (Nutt.) Thorne, reaches four or five years of age, it begins to exhibit the structural diversity required for breeding by the bird, the least Bell's vireo (Franzreb 1989, Hendricks and Rieger 1989). Least Bell's vireo, along with the riparian birds, southwestern willow flycatcher, yellow-breasted chat (*Icteria virens*), yellow warbler (*Denroica petechia*), and many other species may continue to use this diverse community for another ten to twenty years. Gradually the canopy of the maturing willows and cottonwoods begins to shade out the diverse understory of vascular plants required by these birds. Older riparian gallery forests will continue to be used by western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), Cooper's hawk (*Accipiter cooperii*), warbling vireo (*Vireo gilvus*) and other species (Zembal 1990; Zembal *et al.* 1985), but as the stand ages the diversity of the flora and fauna within the forest declines. Annual flooding, channel migration, and occasional large flood events maintain this cycle of succession and therefore maintains a mosaic of diverse natural communities (Gregory *et al.* 1991).

Arundo donax as a competitor

Within its introduced range, *A. donax* is an aggressive competitor. *Arundo donax* flowers in late summer with a large, plume-like panicle. Fortunately for California land managers, the seeds produced by *A. donax* in this country are seldom, if ever, fertile. It is not known if this is because of clonal isolation or because of the physiological effects of climate as has been observed in the related *Phragmites communis* Trin. (common reed) (Haslam 1958; Rudescu et al. 1965). *Arundo donax* is well adapted to the high disturbance dynamics of riparian systems as it spreads vegetatively. Flood events break up clumps of *A. donax* and spread the pieces downstream. Fragmented stem nodes and rhizomes can take root and establish as new plant clones. Thus invasion, spread, and therefore management, of *A. donax* is essentially an intra-basin and downstream phenomenon.

Once established *A. donax* tends to form large, continuous, clonal root masses, sometimes covering several acres, usually at the expense of native riparian vegetation which cannot compete. Root masses, which can become more than a meter thick, stabilize stream banks and terraces (Zohary and Willis 1992), altering flow regimes. *Arundo donax* is also highly flammable throughout most of the year, and the plant appears highly adapted to extreme fire events (Scott 1994). While fire is a natural and beneficial process in many natural communities in southern California it is a largely un-natural and pervasive threat to riparian areas. Natural wild fires usually occur during rare lightening storm events in late fall, winter, and early spring. Under these

conditions the moist green vegetation of riparian areas would normally act as a fire break. Human-caused wild fires, in contrast, often occur during the driest months of the year (July through October). Drier conditions in riparian zones at this time of year make them more vulnerable to fire damage. Because *A. donax* is extremely flammable, once established within a riparian area it redirects the history of a site by increasing the probability of the occurrence of wildfire, and increasing the intensity of wildfire once it does occur. If *A. donax* becomes abundant it can effectively change riparian forests from a flood-defined to a fire-defined natural community, as has occurred on the Santa Ana River in Riverside County, California. *Arundo donax* rhizomes respond quickly after fire, sending up new shoots and quickly outgrowing any native species which might have otherwise taken root in a burned site. Fire events thus tend to help push riparian stands in the direction of pure *A. donax.* This results in river corridors dominated by stands of giant reed with little biological diversity.

Arundo donax **as habitat**

All evidence indicates that *A. donax* provides neither food nor habitat for native species of wildlife. *Arundo donax* stems and leaves contain a wide array of noxious chemicals, including silica (Jackson and Nunez 1964), tri-terpines and sterols (Chandhuri and Ghosal 1970), cardiac glycosides, curare-mimicking indoles (Ghosal *et al.* 1972), hydroxamic acid (Zuñiga *et al.* 1983), and numerous other alkaloids which probably protect it from most native insects and other grazers (Miles *et al.* 1993, Zuñiga *et al.* 1983). Areas taken over by *A. donax* are therefore largely

Control Methods

A suite of methods is needed to control *A. donax* depending upon the presence or absence of native plants, the size of the stand, the amount of biomass which must be dealt with, the terrain, and the season.

The key to effective treatment of established *A. donax* is killing of the root mass. This requires treatment of the plant with systemic herbicide at appropriate times of the year to ensure translocation to the roots. Only one herbicide is currently labeled for wetlands use by the EPA; Rodeo®, a tradename formulation of glyphosate, produced by Monsanto Corporation. Glyphosate is a broad-spectrum herbicide which can be used on *A. donax*, *Tamarix ramosissima* (saltcedar), and most other monocots and dicots. It has proven very effective against *A. donax* (Finn and Minnesang 1990; Jackson 1994; USDA Forest Service 1993). Other herbicides might also be used as labels and conditions allow. Monocot-specific chemicals, such as Fusilade-DX® (fluazapop-butyl) and Post® (Sethoxidan), might be particularly useful for treating *A. donax* in stands with a substantial component of native dicots; however, neither is currently labeled for wetlands use.

The most effective treatment on *A. donax* is the foliar application of a two-to-five percent (2-5%) solution of Rodeo applied post-flowering and pre-dormancy at a rate of 0.5 to 1 L/hectare. During this period of time, usually mid-August to early November, the plants are actively translocating nutrients to the rootmass in preparation for winter dormancy which results in

effective translocation of herbicide to the roots. Recent preliminary comparison trials on the Santa Margarita River (Omori. 1996) indicate that foliar application during the appropriate season results in almost 100% control, compared with only 5-50% control using cut-stem treatment. Two to three weeks after foliar treatment. treatment the leaves and stalks brown and soften creating an additional advantage in dealing with the biomass: cut green stems might take root if left on damp soil and are very difficult to cut and chip. Treated stems have little or no potential for rooting and are brittle. They may be left intact on the ground or chipped *in situ* for mulch.

Cut-stem treatment requires more time and man-power than foliar spraying and requires careful timing. Cut stems must be treated with concentrated herbicide within one to two minutes in order to ensure tissue uptake (Monsanto 1989). This treatment is also most effective post-flowering. The chief advantage of the cut-stem treatment is that it requires less herbicide that can be more-or-less surgically applied to the stem. Because of its reduced efficacy, and due to the labor required, it is rarely cheaper than foliar spraying except on very small, isolated patches or individual plants.

A popular approach to dealing with *A. donax* has been to cut the stalks and remove the biomass, wait three to six weeks for the plants to grow to about one meter tall, then apply a foliar spray of herbicide solution. The chief advantage of this approach is that less herbicide must be applied to treat the fresh growth compared with tall, established plants, and that coverage is often better because of the shorter and uniform-height plants. However, cutting of the stems may result in the plants returning to growth-phase, drawing nutrients from the rootmass.

As a result there is less translocation of herbicide to the roots and less root-kill. Therefore many follow-up treatments must be made which negates any initial savings in herbicide and greatly increases the manpower costs.

Pure stands (>80% canopy cover) of *A. donax* or *T. ramosissima* are most efficiently treated by aerial application of an herbicide concentrate, usually by helicopter. Helicopter application can treat at least 50 hectares per day. Special spray apparatus produces extremely fine droplets (400 microns) of concentrated herbicide which actually reduces herbicide use, minimizes over-spray, and results in greater kill.

In areas where helicopter access is impossible, where *A. donax* makes up the understory, where patches are too small to make aerial application financially efficient, or where weeds are mixed with native plants (<80% cover), herbicides must be applied by hand. Street-vehicles with 400 liter spray tanks are a good alternative where road access is available, but small "quad-runner" vehicles equipped with 60 liter sprayers are the preferred approach where the streambed is not so rocky as to prevent access. Twenty liter backpack sprayers are the final alternative where the vegetation is too dense, or the landscape too rugged for vehicles to be effective.

Methods for vegetation removal include use of prescribed fire, heavy machinery (e.g. bulldozers), handcutting by chainsaw or brushcutter, hydro-axe, chipper, biomass burning or removal by vehicle. Removal of the biomass should only be done where the weed cover is so dense as to prevent recovery by native vegetation after treatment, or where cut vegetation might create a debris-dam hazard during flood events. Prescribed fire, or burning piles of stacked biomass, is the most cost-effective way of removing biomass as long as it does not threaten

native vegetation or other resources. Chipping is more costly in terms of equipment and labor, and cut, dried chips pose no threat for regeneration or for forming debris dams. Hauling of biomass by vehicle is extremely expensive and should only be done as a last resort. Most landfills will not accept *A. donax* and those that do will only accept if cut into short lengths and bagged into plastic trash bags, making the labor costs far too great. The use of heavy machinery such the Hydro-ax® is extremely expensive. The machines are very slow - a Hydro-ax can only cut about 3-4 acres per day.

Riparian restoration and management

One of the prime incentives for riparian habitat restoration has been endangered species recovery, including the federal Endangered Species Act (ESA). The ESA has focused attention on declining species and sought to protect those species in greatest risk by provisions against take (Under the ESA the term "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.). Focus of the legislation has been on individual protected species with little attention given to the dynamics of the natural systems of which these species are a part. There are important historical and legislative reasons for this approach. In the 1970's, when the ESA was drafted, ecologists and wildlife managers were highly focused on single species; system-oriented approaches were not widely applied. In addition, it is far easier to attach legal definition to something tangible, such as an individual animal, than it is to the more vague concept of ecological processes (Gregory *et al.* 1991).

been successful in terms of establishing a matrix of riparian habitat which is used by some native species, re-vegetating is the not necessarily the best way to create habitat.

The best way to address habitat loss in southern California riparian systems is through a comprehensive program of eradication of *A. donax, T. ramosissima*, and other invasive aliens, and relying on natural physical processes, especially flood dynamics, for the recovery of native natural communities and species. This approach might be just as easily argued for other high disturbance-adapted communities.

This strategy is based upon two of important factors. First, riparian habitats are flood-dynamic communities, dependent upon natural cycles of flood scouring and sediment deposition to create the proper conditions for community establishment (Gregory *et al.* 1991; Richter and Richter 1992; Stromberg *et al.* 1991). The Santa Ana, Santa Margarita, San Luis Rey, and many other southern California streams have all of the factors necessary for the recovery and maintenance of healthy riparian communities and riparian species. These watersheds retain flood regimes sufficient to move and sort sediment and extensive sources of seed and vegetative propagules for *Salix* and other native riparian plants. Second, the only real threats to the integrity of the system are (1) habitat fragmentation by development and (2) introduced exotic species which have altered the successional dynamics and stability of the natural communities. In other words, the native riparian communities of the Santa Ana and other major riparian corridors (and thus riparian-dependent species such as least Bell's vireo) are limited, not by the capacity of the community to regenerate, or the available area of riparian zones, but by the capacity of native species to compete with aggressive invasive exotic species, chiefly *A. donax.*

The majority of the limited resources available for riparian management on these rivers should therefore be directed at managing for the process of riparian systems: removing the key perturbation from the system, thereby allowing natural flood dynamics to operate and the natural communities to recover. Attempts to re-vegetate riparian species in floodplains that retain both native riparian species and flood regimes are redundant, and resources spent to this end are largely wasted. This is not to imply that riparian (and other habitat) re-vegetation efforts should not be applied; however, they should be applied judiciously and only in situations where specific management goals are achieved by carrying out a re-vegetation project (e.g. closing up an important corridor or re-establishing native species in a depauperate watershed). Relying on natural processes for the recovery of the riparian communities has the following major benefits:

a. Cost-effectiveness. Riparian forest restoration is extremely expensive, often on the order of tens of thousands of dollars per hectare. This necessarily limits the size, and therefore the biological value, of any funded restoration project. *Arundo donax* can be removed from most areas of a river for a fraction of the cost of revegetation, opening up areas for natural re-colonization by native riparian species.

b. Biological value. As indicated above, the high cost of re-vegetation limits the size of restoration projects. Additionally, artificially-produced riparian habitat lacks the high stem densities characteristic of naturally regenerating riparian habitat, making the actual biological value of re-vegetated sites questionable. Much higher value may be achieved by removing invasive exotics such as *A. donax* from the system. Areas opened up for

tributaries to prevent reinfestation of treated downstream sites from upstream sources. Removal of *A. donax* requires treatment with systemic herbicides in order to kill the large root mass.

Past practices of riparian restoration have focused on re-vegetation of small sites without consideration of natural riparian processes. Resources should be spent on managing for the natural dynamic processes of these systems on a watershed-wide scale. In coastal southern California the primary perturbation to the natural riparian succession process in invasion by *A. donax*, and its removal from river systems will have a far greater beneficial effect on most riparian species than planting of riparian vegetation.

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Figure 1. *Arundo donax*. Plant X 1/3; spikelet and floret X 3 (from Hitchcock and Chase 1950).

Incident Information

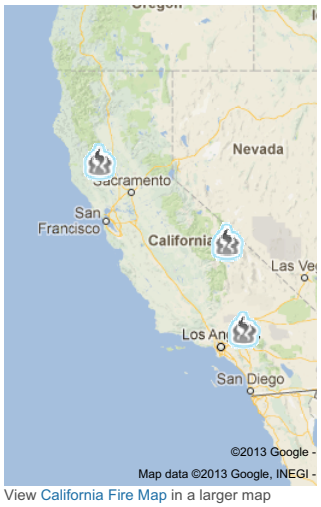
Last modified on Nov 01, 2007

BUCKWEED (AGUA DULCE) FIRE

Buckweed (Agua Dulce) Fire Incident Information:

Last Updated:	November 1, 2007 7:00 pm	FINAL
Date/Time Started:	October 21, 2007 12:55 pm	
Administrative Unit:	Los Angeles County Fire	
County:	Los Angeles County	
Location:	Mint Canyon Road and Sierra Highway	
Acres Burned:	38,000	
Containment	100% containment	
Structures Destroyed:	63 structures were destroyed and 30 structures were damaged.	
Evacuations:	Lifted	
Injuries:	Three civilians and one firefighter were injured	
Costs to date:	$7.4 million	
Phone Numbers	(323) 881-2411 (Buckweed Fire Information)	

California Statewide Fire Map



View California Fire Map in a larger map

BUCKWEED (AGUA DULCE) FIRE MORE INFO

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CAL FIRE Official Twitter Accounts

FresnoCoFire Belmont Inc final CAL FIRE/Fresno Co Fire rescue team assisted FSO. Victim rescued & transported to local hospital. Inc terminated appx 7pm.
13 hours ago · reply · retweet · favorite

FresnoCoFire Technical rescue reported water rescue. 19000 blk Belmont Ave. CAL FIRE/ Fresno Co Fire responding.
15 hours ago · reply · retweet · favorite

CALFIRE_SLO Firefighters at scene a multi-vehicle accident. 2 semi-trucks and 3 automobiles. 5 injuries. Hwy 46 near Almond Rd.
18 hours ago · reply · retweet · favorite

CAL_FIRE #SafetyTipTuesday: Taking a road trip this spring break? Stay alert to changing road conditions at all times.

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Incident Information

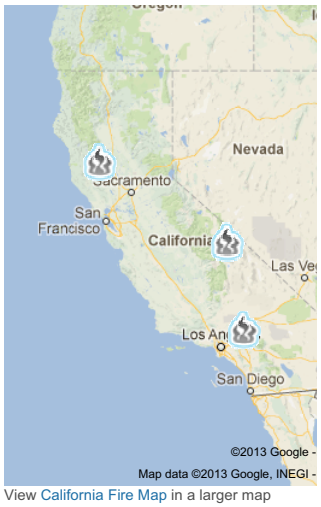
Last modified on Nov 01, 2007

RANCH FIRE

Ranch Fire Incident Information:

Last Updated:	November 1, 2007 6:30 pm	FINAL
Date/Time Started:	October 20, 2007 9:42 pm	
Administrative Unit:	Angeles National Forest	
County:	Los Angeles County	
Location:	Near Townsand Peak, southwest of Templin Highway and Interstate 5	
Acres Burned:	58,401 acres	
Containment	100%	
Structures Destroyed:	one home and nine outbuildings were destroyed	
Evacuations:	Lifted	
Cause:	under investigation	
Cooperating Agencies:	U.S. Forest Services, Los Angeles County	
Total Fire Personnel:	73	
Costs to date:	$9 million	
Major Incident Command Team:	Type 3 Team	
Phone Numbers	(626) 574-5208 (Ranch Fire Information)	

California Statewide Fire Map



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CAL FIRE Official Twitter Accounts

FresnoCoFire Belmont Inc final CAL FIRE/Fresno Co Fire rescue team assisted FSO. Victim rescued & transported to local hospital. Inc terminated appx 7pm.
13 hours ago · reply · retweet · favorite

FresnoCoFire Technical rescue reported water rescue. 19000 blk Belmont Ave. CAL FIRE/ Fresno Co Fire responding.
15 hours ago · reply · retweet · favorite

CALFIRE_SLO Firefighters at scene a multi-vehicle accident. 2 semi-trucks and 3 automobiles. 5 injuries. Hwy 46 near Almond Rd.
18 hours ago · reply · retweet · favorite

CAL_FIRE #SafetyTipTuesday: Taking a road trip this spring break? Stay alert to changing road conditions at all times.

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CALLEGUAS

MUNICIPAL WATER DISTRICT

Annual Water Quality Report

July 2012

Este informe contiene información muy importante sobre su agua potable. Tradúzcalo o hable con alguien que lo entienda bien.

Water Quality as Our Priority

Water quality continues to be a priority for Calleguas Municipal Water District. Our mission since the 1950s has been to provide our service area with a reliable supply of high quality, imported drinking water. A team of highly trained professionals works hard to ensure that Calleguas' water supply meets all state and federal water quality standards. This brochure provides information about the sources and quality of the water delivered by Calleguas in 2011. Included are details about where your water comes from, what it contains, and how it compares to State and Federal standards.

During the year, multiple tests for over 150 drinking water contaminants were performed on Calleguas' water supply to determine concentrations of mineral, physical, bacteriological, inorganic, organic, and radioactive constituents. Once again, we are proud to report our system did not violate any water quality standards. For additional information on the quality of water delivered by Calleguas, please contact Amy Maday at (805) 579-7117 or visit our website at www.calleguas.com.

Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the USEPA's Safe Drinking Water Hotline (1-800-426-4791).

Our Mission

. . . is to provide our service area with a reliable and adequate supply of quality supplemental water through the acquisition and distribution of both regional and locally-developed water in an environmentally and economically responsible manner.

Our Source Water

Originating in northern California, Calleguas' drinking water supply is conveyed over five hundred miles through the State Water Project's network of reservoirs, aqueducts, and pump stations. Metropolitan Water District of Southern California completed a source water assessment of its State Water Project supply. This source is considered to be most vulnerable to urban and storm water runoff, wildlife, agriculture, recreation, and wastewater. A copy of the assessment can be obtained by contacting Metropolitan by phone at (213) 217-6850. The State Water Project supply is filtered and disinfected at Metropolitan's Joseph Jensen Filtration Plant in Granada Hills. Following treatment, water is conveyed by pipeline through the San Fernando Valley to Calleguas' mile-long tunnel in the Santa Susana Mountains. The water is then distributed by Calleguas and its purveyors to over one-half million Ventura County residents, representing 80% of the County's population. Surplus supplies of imported water are stored in Lake Bard, the District's surface water reservoir near the city of Thousand Oaks, and the Las Posas groundwater basin underlying the city of Moorpark and surrounding area.

Through the Las Posas Aquifer Storage and Recovery (ASR) project, Calleguas stores water for later use during summer peak demand periods, droughts and emergencies. With an estimated storage capacity of 300,000 acre feet, the lower aquifer system of the Las Posas Basin is optimal for groundwater storage as it is largely confined by clay layers which provide protection from potential contamination sources overlying the aquifer. To date, 18 ASR wells are operational. Additional wells are under consideration to further increase the program's injection and extraction capacity. Visit www.calleguas.com for more information on the Las Posas ASR project and other Calleguas water supply reliability programs.

General Information About Source Water

The sources of drinking water (both tap water and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally-occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity.

Contaminants that may be present in source water before we treat it include:

Microbial contaminants, such as viruses and bacteria, that may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife.

- *Inorganic contaminants*, such as salts and metals, that can be naturally-occurring or result from urban stormwater runoff, industrial or domestic wastewater discharges, oil and gas production, mining, or farming.

- *Pesticides* and herbicides, that may come from a variety of sources such as agriculture, urban stormwater runoff, and residential uses.

- *Organic* chemical contaminants, including synthetic and volatile organic chemicals, that are by-products of industrial processes and petroleum production, and can also come from gas stations, urban stormwater runoff, agricultural application, and septic systems.

- *Radioactive* contaminants that can be naturally-occurring or be the result of oil and gas production and mining activities.

Our Treated Water

In order to ensure that tap water is safe to drink, the U.S. Environmental Protection Agency (USEPA) and the State Department of Public Health (Department) prescribe regulations which limit the amount of certain contaminants in water provided by public water systems. Department regulations also establish limits for contaminants in bottled water that must provide the same protection for public health.

Calleguas achieves these standards through vigilant watershed protection and treatment techniques used at Metropolitan's Jensen Plant as well as Calleguas' Lake Bard Water Filtration Plant. A good indicator of the effectiveness of our filtration system is the measurement of turbidity. Turbidity, or the cloudiness of water, is listed in the tables included in this report.

Water Quality Data

The tables below list all the drinking water contaminants that we detected during the 2011 calendar year. The presence of these contaminants in the water does not necessarily indicate that the water poses a health risk. Unless otherwise noted, the data presented in these tables is from testing done January 1 through December 31, 2011. The State requires that we monitor for certain contaminants less than once per year because the concentrations of these contaminants are not expected to vary significantly from year to year. Some of the data, though representative of water quality, is more than one year old.

Summary of Water Quality Results For 2011

CALLEGUAS MUNICIPAL WATER DISTRICT

			Imported Surface Water Treated by Metropolitan		Locally Stored Surface Water Treated by Calleguas		Las Posas Aquifer Storage and Recovery Program		
		Percent of Supply	*95%*		*4%*		*1%*		
Parameter	MCL [MRDL]	PHG (MCLG) [MRDLG]	Average	Range	Average	Range	Average	Range	**Major Sources in Drinking Water**
PRIMARY DRINKING WATER STANDARDS - Mandatory Health-Related Standards									
CLARITY (a)									
Turbidity (NTU) (TT)	Highest Single Value		0.05		0.08		(a)		Soil runoff
	% of samples <0.3		100%		100%		(a)		
DISINFECTION BY-PRODUCTS AND DISINFECTANT RESIDUALS									
Bromate (ppb) (b)	10	0.1	5.9	ND - 8.8	ND	ND - 7.1	(b)	(b)	By-product of drinking water disinfection
Haloacetic Acids (ppb) (c)	60	n/a	System Wide Range: 4 - 9, Highest RAA: 6						By-product of drinking water disinfection
Total Chlorine Residual (ppm)	[4]	[4]	System Wide Range: 1.8 - 2.0, Highest RAA: 1.9						Drinking water disinfectant added for treatment
Total Trihalomethanes (ppb) (c)	80	n/a	System Wide Range: 15 - 44, Highest RAA: 24						By-product of drinking water chlorination
INORGANIC CHEMICALS									
Aluminum (ppb)	1,000	600	82	61 - 99	ND	ND	60	60	Erosion of natural deposits, residual from water treatment process
Arsenic (ppb)	10	0.004	2.3	2.3	ND	ND	3.0	3.0	Erosion of natural deposits, runoff from orchards
Fluoride - Distribution System (ppm) (d)	2.0	1	System Wide Range: 0.7 - 0.9, Highest RAA: 0.8						Water additive that promotes strong teeth
Nitrate (as NO_3) (ppm)	45	45	1.8	1.8 - 2.2	ND	ND	ND	ND - 2.2	Runoff and leaching from fertilizer use, erosion of natural deposits
Selenium (ppb)	50	30	ND	ND	ND	ND	5	5	Runoff and leaching from fertilizer use, erosion of natural deposits
RADIOLOGICALS (e)									
Gross Alpha Particle Activity (pCi/L)	15	(0)	ND	ND	ND	ND	5	ND - 7	Erosion of natural deposits
Gross Beta Particle Activity (pCi/L)	50	(0)	ND	ND - 4	ND	ND	ND	ND	Decay of natural and manmade deposits
Uranium (pCi/L)	20	0.43	1	ND - 2	2	1 - 2	8	ND - 16	Erosion of natural deposits

ABBREVIATIONS, DEFINITIONS, and NOTES

n/a = not applicable
ND = None Detected
NTU = Nephelometric Turbidity Units
ppm = parts per million, or milligrams per liter (mg/L)
ppb = parts per billion, or micrograms per liter (µg/L)
pCi/L = PicoCuries per Liter

Maximum Contaminant Level (MCL) = The highest level of a contaminant that is allowed in drinking water. Primary MCLs are set as close to the PHGs (or MCLGs) as is economically and technologically feasible.

Maximum Contaminant Level Goal (MCLG) = The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs are set by the U.S. Environmental Protection Agency.

Maximum Residual Disinfectant Level (MRDL) = The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial pathogens.

Maximum Residual Disinfectant Level Goal (MRDLG) = The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.

Public Health Goal (PHG) = The level of a contaminant in drinking water below which there is no known or expected risk to health. PHGs are set by the California Environmental Protection Agency.

Primary Drinking Water Standard = MCLs and MRDLs for contaminants that affect health along with their monitoring and reporting requirements, and water treatment requirements.

Treatment Technique (TT) = A required process intended to reduce the level of a contaminant in drinking water.

Running Annual Average (RAA) = The average of all the samples taken for the year.

(a) The turbidity level of filtered water shall be less than or equal to 0.3 NTU in 95% of the measurements taken each month and shall not exceed 1.0 NTU. ASR water is not subject to these requirements.

(b) Compliance for treatment plants that use ozone is based on a running annual average of monthly samples. ASR water is not subject to these requirements.

(c) Compliance is based on a running annual average of quarterly distribution system samples. Values reported reflect the highest and lowest single value in the distribution system (range) and the highest running annual average.

(d) The Metropolitan Water District treats their water by adding fluoride to the naturally occurring level in order to help prevent dental caries in consumers. Fluoride level in the treated water is maintained within a range of 0.7 - 1.3 ppm, as required by CDPH regulations.

(e) Metropolitan results were taken from 2011 monitoring. Calleguas Las Posas ASR results were taken from 2009, 2010 and 2011 monitoring.

Summary of Water Quality Results For 2011

CALLEGUAS MUNICIPAL WATER DISTRICT

Parameter	Secondary MCL	Notification Level	Imported Surface Water Treated by Metropolitan		Locally Stored Surface Water Treated by Calleguas		Las Posas Aquifer Storage and Recovery Program		Major Sources In Drinking Water
		Percent of Supply	*95%*		*4%*		*1%*		
			Average	Range	Average	Range	Average	Range	
SECONDARY DRINKING WATER STANDARDS – Aesthetic Standards									
Aluminum (ppb) (a)	200		82	61 - 99	ND	ND	60	60	Erosion of natural deposits, residual from water treatment process
Chloride (ppm)	500		64	59 - 69	89	87 - 90	68	59 - 75	Runoff and leaching from natural deposits, seawater influence
Color (Units)	15		1	1	6	ND - 15	8	ND - 14	Naturally-occurring organic materials
Manganese (ppb)	50		ND	ND	ND	ND	ND	ND - 70	Leaching from natural deposits
Odor Threshold (Units)	3		2	2	ND	ND	ND	ND	Naturally-occurring organic materials
Specific Conductance (µS/cm)	1,600		500	420 - 530	638	633 - 644	602	515 - 754	Substances that form ions when in water, seawater influence
Sulfate (ppm)	500		56	54 - 58	70	70	90	56 - 147	Runoff and leaching from natural deposits
Total Dissolved Solids (ppm)	1,000		280	280 - 290	360	350 - 380	352	280 - 460	Runoff and leaching from natural deposits
Turbidity (NTU) (b)	5		0.03	0.03 - 0.09	0.04	0.04	0.3	ND - 0.6	Soil runoff
ADDITIONAL PARAMETERS (Unregulated)									
Alkalinity (ppm)	NS	NS	85	76 - 93	93	90 - 100	92	80 - 110	
Boron (ppb)	NS	1,000	190	190	200	200	200	200	
Calcium (ppm)	NS	NS	27	26 - 28	29	29	40	27 - 62	
Chlorate (ppb)	NS	800	26	26	ND	ND	ND	ND	
Corrosivity (AI) (c)	NS	NS	12.0	12.0	12.1	12.1	11.9	11.5 - 12.1	
Hardness (Total Hardness) (ppm)	NS	NS	110	110 - 120	130	130	159	117 - 229	
Magnesium (ppm)	NS	NS	12	12	14	14	14	12 - 18	
N-Nitrosodimethylamine (ppt)	NS	10	System-Wide Average = 5, Range = ND - 9						
pH (pH Units)	NS	NS	8.2	8.1 - 8.4	8.1	7.9 - 8.3	8.0	7.4 - 8.4	
Potassium (ppm)	NS	NS	3	3	3	3	3	3 - 4	
Radon (pCi/L) (d)	NS	NS	ND	ND	ND	ND	761	244-1087	
Sodium (ppm)	NS	NS	54	52 - 57	71	71	57	53 - 64	
Total Organic Carbon (ppm)	NS	NS	1.9	1.6 - 2.1	2.4	1.9 - 2.6	0.6	0.6	
Vanadium (ppb)	NS	50	3	3	ND	ND	3	3	

ABBREVIATIONS, DEFINITIONS, and NOTES

ND = None Detected NS = No Standard
NTU = Nephelometric Turbidity Units
ppm = parts per million, or milligrams per liter (mg/L)
ppb = parts per billion, or micrograms per liter (µg/L)
ppt = parts per trillion, or nanograms per liter (ng/L)
pCi/L = PicoCuries per Liter
µS/cm = microSiemen per Centimeter

Maximum Contaminant Level (MCL) = Secondary MCLs are set to protect the odor, taste, and appearance of drinking water.
Notification Level = The level at which notification of the public water system's governing body is required.
(a) Aluminum has both primary and secondary standards.
(b) The monthly averages and ranges of turbidity shown in the Secondary Standards section are based on source effluents.
(c) AI measures the aggressiveness of water transported through pipes. Water with AI <10.0 is highly aggressive and would be very corrosive to almost all materials found in a typical water system. AI ≥12.0 indicates non-aggressive water. AI between 10.0 and 11.9 indicates moderately aggressive water.
(d) Radon results were taken from 2009, 2010 and 2011 monitoring.

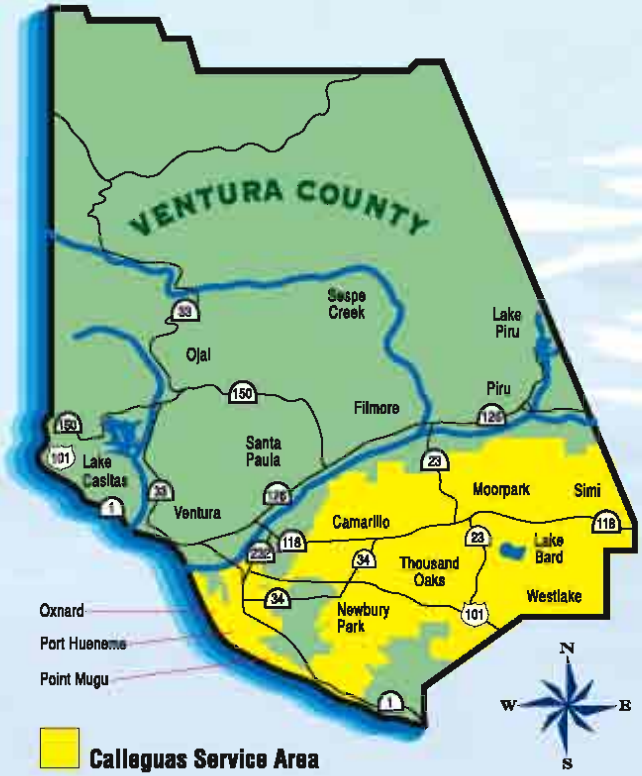
Information for Customers with Special Water Needs

Some people may be more vulnerable to contaminants in drinking water than the general population. Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. USEPA/Centers for Disease Control guidelines on appropriate means to lessen the risk of infection by *Cryptosporidium* and other microbial contaminants are available from the Safe Drinking Water Hotline (1-800-426-4791).

Constituents Tested For and Not Detected

In addition to the information provided in the Summary of Water Quality Results, Calleguas also monitored for, but did not detect, the following contaminants during 2011:

Antimony	Cyanide	Perchlorate	Total Chromium
Asbestos	Foaming Agents	Pesticides	Tritium
Barium	Herbicides	Radium 226	Volatile Organic Chemicals (VOCs)
Beryllium	Lead	Radium 228	Zinc
Cadmium	Mercury	Silver	
Chromium 6	MTBE	Strontium-90	
Copper	Nitrite	Thallium	



Information on Lead in Household Plumbing

If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with service lines and home plumbing. Your local utility is responsible for providing high quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. If you are concerned about lead in your water, you may wish to have your water tested. Information on lead in drinking water, testing methods, and steps you can take to minimize exposure is available from the Safe Drinking Water Hotline or at http://www.epa.gov/safewater/lead.

Drinking Water Fluoridation

In 2007, Calleguas' wholesale water provider, the Metropolitan Water District of Southern California, joined a majority of the nation's public water suppliers in systematically adding fluoride to drinking water at each of five water treatment plants in order to help prevent tooth decay.

In line with recommendations from the California Department of Public Health, as well as the U.S. Centers for Disease Control and Prevention, Metropolitan adjusted the natural fluoride level in the water, which ranges from 0.1 to 0.4 parts per million, to the optimal range for dental health of 0.7 to 0.8 parts per million.

Fluoride levels in drinking water are limited under California state regulations at a maximum dosage of 2 parts per million.

Fluoride has been added to U.S. drinking water supplies since 1945. Of the 50 largest cities in the U.S, 43 fluoridate their drinking water.

For more information about the benefits of drinking water fluoridation, please visit the following web sites:

The American Dental Association
http://www.ada.org/fluoride.aspx

U.S. Centers for Disease Control and Prevention
http://www.cdc.gov/fluoridation/fact_sheets/cwf_qa.htm

Information on Radon

Water suppliers are required to provide information on the presence of radon in water sources. A known human carcinogen, radon is a radioactive gas that one cannot see, taste, or smell. Commonly found in soils throughout the United States, breathing air containing radon may lead to lung cancer. Drinking water containing radon may also cause increased risk of stomach cancer. Radon can seep up through the ground and into homes and other structures through cracks and holes in foundations. Over time, concentrations of the gas can increase to high levels potentially exposing inhabitants to greater health risks. It is possible that radon can also be released from tap water when used for showering, washing dishes, and other household activities. However, the concentration of radon released through tap water is in most cases assumed to be considerably lower than concentrations entering a home from underlying ground. If you are concerned about radon, you are advised to test the air in your home. Testing is inexpensive and easy. The EPA recommends taking measures to reduce radon levels in your home if concentrations are 4 PicoCuries per liter of air (pCi/L) or higher. For additional information, call your State radon program (1-800-745-7236), the EPA Safe Drinking Water Act Hotline at (1-800-426-4791), or call the National Safe Council Radon Hotline (1-800-SOS-RADON).

More Information on Water Quality

Calleguas Municipal Water District
2100 Olsen Road • Thousand Oaks, CA 91360-6800
(805) 526-9323
http://www.calleguas.com

Metropolitan Water District of Southern California
Public Affairs • P.O. Box 54153 • Los Angeles, CA 90054-0153
(800) CALL MWD
www.mwdh2o.com/

State of California Department of Public Health
Office of Drinking Water • 601 North 7th Street • Sacramento, CA 94234-7320
http://www.cdph.ca.gov/programs/Pages/DDWEM.aspx

U.S. Environmental Protection Agency (WH-550)
Office of Ground Water & Drinking Water
401 M. Street, S.W. • Washington, D.C. 20460
Safe Drinking Water Hotline (800) 426-4791
http://water.epa.gov/drink/index.cfm

The Calleguas Municipal Water District Board of Directors meets on the first and third Wednesday of each month at 5:00 pm at the District's administration building, 2100 Olsen Road in Thousand Oaks. The public is welcome to attend these meetings.

CALLEGUAS
MUNICIPAL WATER DISTRICT

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ORIGINAL PAPER

Wildfire promotes dominance of invasive giant reed (*Arundo donax*) in riparian ecosystems

Gretchen C. Coffman · Richard F. Ambrose · Philip W. Rundel

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Abstract Widespread invasion of riparian ecosystems by the large bamboo-like grass *Arundo donax* L. has altered community structure and ecological function of streams in California. This study evaluated the influence of wildfire on *A. donax* invasion by investigating its relative rate of reestablishment versus native riparian species after wildfire burned 300 ha of riparian woodlands along the Santa Clara River in southern California in October 2003. Post-fire *A. donax* growth rates and productivity were compared to those of native woody riparian species in plots established before and after the fire. *Arundo donax* resprouted within days after the fire and exhibited higher growth rates and productivity compared to native riparian plants. *Arundo donax* grew 3–4 times faster than native woody riparian plants—up to a mean of 2.62 cm day^{-1}—and reached up to 2.3 m in height less than 3 months after the fire. One year post-fire, *A. donax* density was nearly 20 times higher and productivity was 14–24 times higher than for native woody species. Three mechanisms—fire-adapted phenology, high growth rate, and growth response to nutrient enrichment—appear to promote the preemption of native woody riparian species by *A. donax* after fire. This greater dominance of *A. donax* after wildfire increased the susceptibility of riparian woodlands along the Santa Clara River to subsequent fire, potentially creating an invasive plant-fire regime cycle. Moreover, *A. donax* infestations appear to have allowed the wildfire to cross the broad bed of the Santa Clara River from the north, allowing thousands of acres of shrubland to the south to burn.

Keywords *Arundo donax* · Invasive plant-fire regime cycle · Invasive species · Mediterranean-type climate · Riparian · Wildfire

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Introduction

Wildfire is a natural process in terrestrial ecosystems worldwide. Many ecosystems are adapted to fire as a periodic and natural disturbance regime, including Mediterranean-type shrublands, temperate conifer forests, savannas, and grasslands (Ellis 2000; Bond and Keeley 2005). In semi-arid climates, fire has a particularly significant role in shaping vegetation due

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to weather conditions favorable for growth and short periods in which decomposition can occur. Historically, dense cover of shrub biomass accumulating for up to 50 years or more provided fuel for high-intensity wildfires in shrublands of southern California and other semi-arid climate regions (Keeley et al. 1999; Keeley and Fotheringham 2001, 2005). Lightning was the primary natural cause of wildfires, especially during the dry, low humidity conditions that occur in late summer and fall (Naveh 1975; Keeley 1982; Keeley et al. 1999). Currently, most wildfires in these areas are anthropogenic in origin and occur much more frequently than they did historically when human population density was lower (D'Antonio and Vitousek 1992; Keeley et al. 1999).

Invasion of annual grass species has been linked to altered fire regimes in rangelands, deserts, and wildlands in many parts of the world (Brooks and Pyke 2001; Brooks et al. 2004; Sugihara et al. 2006). Invasive grass-fire cycles, also called invasive plant-fire regime cycles, may ensue when alien grass species colonize an area and provide fuel for fire propagation, thereby increasing the frequency, extent, and intensity of fires (D'Antonio and Vitousek 1992; D'Antonio 2000; Brooks 2002; Brooks et al. 2004; Keeley 2004; Keeley and Fotheringham 2005). Rapid recovery of alien grass species after fire compared to native species after fire leads to increased susceptibility of that ecosystem to fire.

Large riparian corridors have historically acted as natural firebreaks in semi-arid Mediterranean-type climates (Dudley 1998; Dudley et al. 2000; Rundel 2000) because of their low-lying topography and relative absence of flammable fuels. However, invasive woody species have been shown to alter this situation. Thickets of saltcedar (*Tamarix ramosissima*), for example, have invaded riverine corridors throughout the Southwestern United States. Saltcedar burns more frequently and destructively than native riparian vegetation (Dudley et al. 2000) and resprouts rapidly from the rootcrown the year after it is burned (Duncan 1997).

In coastal shrubland watersheds of California, a large invasive grass species *Arundo donax* L. (often called giant reed and hereafter referred to as *Arundo*) poses multiple threats in riparian ecosystems, with many similarities to saltcedar, including high flammability. *Arundo* was introduced from southern Eurasia into California several hundred years ago for erosion control and building materials (Robbins et al. 1951; Perdue 1958). It now infests many stream and river systems throughout coastal California (Gaffney 2002) and other arid and Mediterranean-type climates worldwide, including South Africa, Australia, and the Mediterranean Basin. The natural flood disturbance regime in these climates successfully distributes vegetative culms and rhizomes of *Arundo* along streams, where it establishes readily on bare substrates (Else 1996). Studies indicate that increased water and nutrient delivery to these systems has increased its invasion success (Coffman 2007), yet the influence of fire on its invasion in river systems remains relatively unexplored. Several accounts suggest that infestations of *Arundo* have increased fuel load as well as fire frequency and intensity along riparian corridors (Robbins et al. 1951; Bell 1997; Scott 1994; D'Antonio 2000).

The Simi/Verdale wildfire of October 2003 (Keeley and Fotheringham 2005) provided the opportunity to study the role of fire in the invasion of riparian terrace ecosystems of the Santa Clara River by *Arundo* after hundreds of hectares of healthy riparian ecosystems containing a mixture of native riparian vegetation and *Arundo* burned. In this study, we compared growth and recolonization of *Arundo* to that of native plant species in this riparian ecosystem after the wildfire. We hypothesized that *Arundo*'s immediate post-fire resprouting, phenology, and higher growth rate compared to native plants and the high soil nutrient content after fire would promote the dominance of *Arundo*.

Methods

Study area

The Simi/Verdale fire burned more than 45,000 ha of shrublands, grasslands, and riparian ecosystems from 25 October to 1 November 2003 (Keeley and Fotheringham 2005; Coffman 2007; California Department of Forestry and Fire Protection unpublished data; G. Coffman unpublished data; Fig. 1). Fire severity was variable throughout the riparian areas burned, but was predominately high or deep burning in areas in which *Arundo* density was highest. Study sites were located along the Santa Clara River floodplain throughout approximately 300 ha of riparian ecosystems burned in this fire.

Percent canopy closure was variable throughout sites before the fire—from 10 to 45% cover of trees and shrubs. We observed deep burning (high fire severity) in study sites with a few patches of moderate fire severity on the edges of a couple of the sites according to field indicators described in Keeley (2009). Indicators observed throughout study sites included: native riparian trees in the canopy layer killed; all leaves consumed; shrubs burned to ground or only skeletons remaining; surface litter of all sizes consumed; and white ash deposition and charred organic matter between 1 and 30 cm thick. Most native trees and shrubs were top-killed with no green or singed leaves remaining. Some woody native plants resprouted from stumps and others did not. According to the County of Ventura, Fire Department records, no other recorded fires from 1918 to present (greater than 1 acre) were found to coincide with our 14 study sites within the 500-year floodplain of the Santa Clara River. Detailed descriptions of fire intensity and stand composition are available from the author.

Natural riparian vegetation along the river consisted of large black cottonwood (*Populus balsamifera* subsp. *trichocarpa*), Fremont cottonwood (*Populus fremontii*), and red willow (*Salix laevigata*) trees in the canopy layer. A mixture of smaller trees and shrubs comprised the understory layer, including arroyo willow (*Salix lasiolepis*), sandbar willow (*Salix exigua*), shining willow (*Salix lucida* subsp. *lasiandra*), mulefat (*Baccharis salicifolia*), and blue elderberry (*Sambucus mexicana*). Species names follow Hickman (1993). Currently, *Arundo* infests more than 2,000 ha of floodplain along the Santa Clara River (Stillwater Sciences, URS 2007).

Study species

Arundo is a robust, perennial, bamboo-like member of the Poaceae family that has become widely established throughout the floodplains and terraces of rivers and streams in California and other warm, temperate climates worldwide (Hickman 1993). *Arundo* reproduces vegetatively through a network of large rhizomes that grow horizontally just below the soil surface. Under some conditions it produces a large (3–6 dm), terminal, plume-like inflorescence (panicle) at the end of the growing season (Hickman 1993); however, seeds of the inflorescence are generally sterile in California (Johnson et al. 2006).

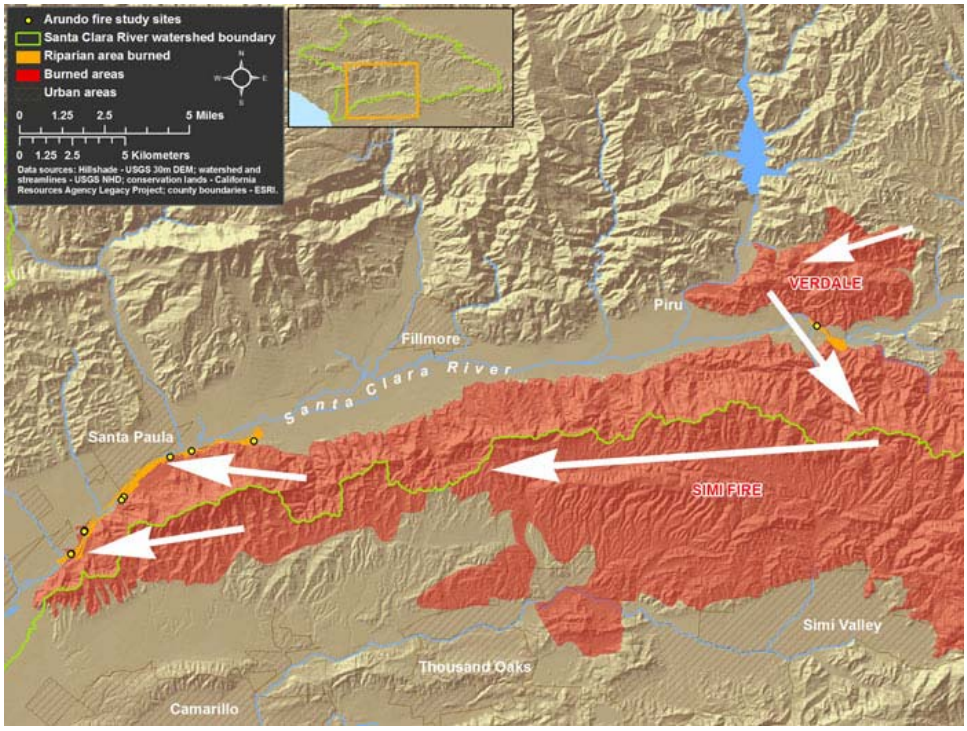

Fig. 1 Location of study sites within riparian ecosystems along the Santa Clara River, Ventura County, California. *Arrows* indicate progression of the Simi/Verdale wildfire

For comparison, we also studied several native woody riparian plant species commonly found on burned riparian terraces and along other rivers in southern California, including *Salix laevigata, S. lasiolepis*, *S. exigua*, *Populus balsamifera* subsp. *trichocarpa*, and *Baccharis salicifolia*.

Sampling design and methods

Six permanent study sites established in a previous study (Coffman 2007) along the Santa Clara River burned during the 2003 wildfire; all were located on riparian floodplain terraces adjacent to shrubland ecosystems (Fig. 1). We compared pre-fire plant composition and soil nutrient data collected in summer 2003 at these six permanent monitoring sites to data collected monthly during 2004, the year after the wildfire occurred. We established eight additional study sites along riparian terrace areas burned to the west of the permanent study sites to ensure that sites were well-distributed throughout the burned areas and represented the range of environmental conditions found in the study area. We monitored reestablishment of plant cover on the 14 sites from November 2003 to December 2004. Each study site was approximately 600 m^2 and 30 × 20 m in extent.

Precipitation and temperature data along the Santa Clara River were recorded at the Piru 2 ESE station (34.40°N 118.75°W, elevation 222 m). Although 24 mm of rain were recorded only 5 days after the fire, the 2003–2004 hydrologic year was relatively dry with a total of 256 mm compared to a long-term mean of about 435 mm (Fig. 2).

We determined change in plant abundance in burned areas by comparing pre- and post-fire (summer 2003 and July 2004) percent cover of *Arundo* and native woody plant species in the six permanent study sites. Plant composition before the fire was determined by ocular estimation of percent aerial cover within the entire study site area. Since all trees and shrubs were top-burned, we used visual estimates of percent aerial cover of new seedlings and stump resprouts by species within 1 m^2 quadrants placed randomly throughout all study sites during post-fire sampling periods and within six study sites during summer 2003. Post-fire mean shoot density (stems m^{-2}) of *Arundo* and all native species were sampled monthly (March to September 2004) within six 1 m^2 quadrants (placed randomly each sampling period) within all 14 study sites. We measured mean shoot length (cm) and basal diameter (mm) of 20 randomly selected individuals of

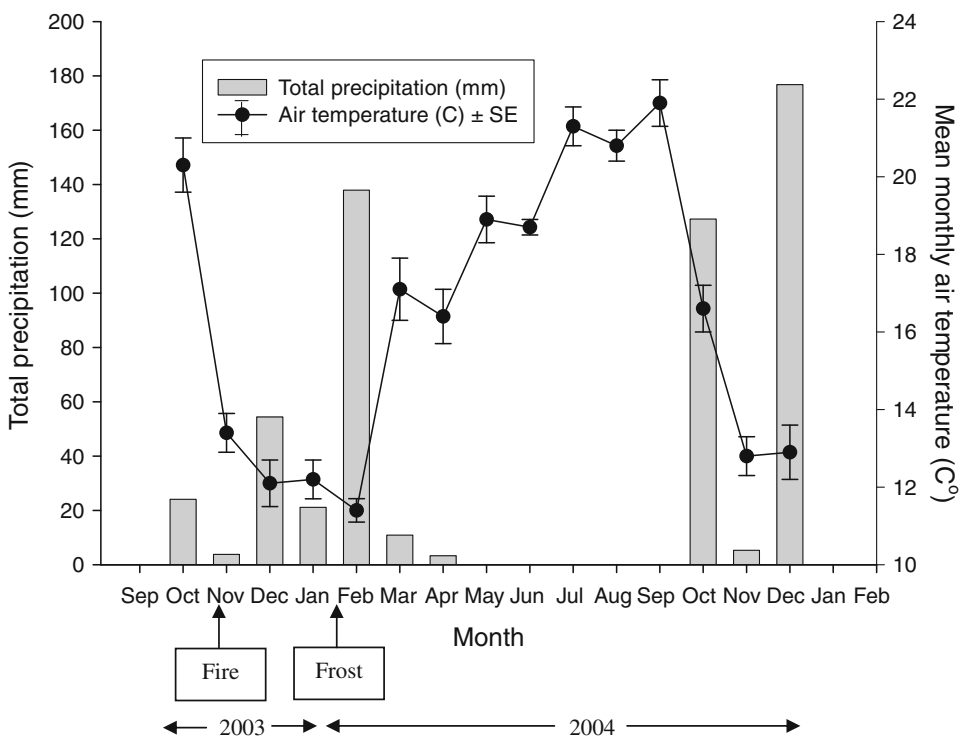

Fig. 2 Mean monthly precipitation and temperature within the Santa Clara River study area near Piru, CA for the study period (October 2003–December 2004). *Frost label* indicates freezing air temperatures (from 0 to −5°C) were experienced near the ground surface at several of the low-lying sites for several days

Arundo and each dominant native woody riparian species at all sites during each post-fire sampling period. In addition, we measured shoot height and basal diameter (10 cm above the soil surface) of three permanently marked *Arundo* and native plant shoots (three of each species) during each sampling period. We calculated mean shoot elongation rate (cm day^{-1}) for each species using data from permanently marked individuals.

We calculated the aboveground biomass, relative growth rates (RGRs), and productivity of plants within the study sites using plant dimension data collected during the study period. Non-destructive dimensional analyses were used to estimate aboveground biomass dry weight of plants in study sites with minimal plant growth interference (Whittaker 1965; Whittaker and Marks 1975; Sharifi et al. 1982; Spencer et al. 2006). We created regression models for each species using basal diameter, shoot length, and aboveground biomass of culm/branch samples measured in a nearby field experiment to predict biomass of each individual plant sampled in the study sites. Regression models were based on *Arundo* (resprouts) and native woody plants (resprouts) grown at an experimental field plot on a terrace of the Santa Clara River near the burned study sites. Regression models for aboveground biomass were very highly significant for all species ($r^2 = 0.971$–0.990, $P < 0.001$; Coffman, 2007). Biomass of *Arundo* and native species was estimated based on both basal diameter and shoot length measurements taken at all study sites. All data were log transformed in regression models to achieve normally distributed residuals.

We calculated RGRs for all permanently marked individuals using the following differential equation, where W is the total aboveground biomass dry weight (g) of each shoot, t is time (days post-fire), and ln is natural logarithm:

$$\mathrm{RGR} = \frac{\mathrm{d}W}{\mathrm{d}t}\frac{1}{W} = \frac{\mathrm{d}(\ln W)}{\mathrm{d}t}.$$

Mean productivity (kg m^{-2} $year^{-1}$) for each species was calculated at approximately 1 year post-fire. We estimated biomass (kg) for the 20 randomly sampled culms/stems for each species measured during September 2004. For each species, mean biomass per shoot (kg $shoot^{-1}$) was multiplied by mean density (shoots m^{-2}) at each study site and then divided by time (1 year). We averaged productivity calculations for each species across study sites.

Five soil sub-samples were collected at each study site adjacent to *Arundo* and each native woody plant species in summer 2003 (*Arundo* and *S. laevigata* only) and immediately after the fire. Samples were collected in the upper 20 cm of the soil where nutrient concentrations are greatest. For each species, five soil samples were combined into a composite sample by thorough mixing in a stainless steel bowl. Soil samples were air-dried and ground to a powder in preparation for nutrient content analyses at the DANR Analytical Laboratory in Davis, California using standard techniques for total nitrogen (total N- %), nitrate–N (NO_3-N—ppm), ammonia-N (NH_4-N—ppm), and orthophosphate (PO_4-P—ppm; http://danranlab.ucanr.org/). Soil grain size was analyzed at UCLA with a hydrometer to determine the particle size distribution of sand, silt, and clay in soil suspension (Sheldrick and Wang 1993).

Statistical analyses

One-way and two-way analysis of variance (ANOVA) tests were used to analyze effects of various combinations of factors (plant type and time) on plant performance and growth data (dependent or response variables; Systat Software, Inc 2000). We conducted a one-way ANOVA of productivity (kg m^{-2} $year^{-1}$) by species (*Arundo*, *B. salicifolia*, and *S. laevigata*). Two-way ANOVAs for plant performance metrics by factors of plant type (*Arundo* and native plant species) and time (pre-fire vs. post-fire or months post-fire) were conducted to determine differences in plant growth by species over time post-fire. Dependent variables included plant abundance (percent cover), density (stem m^{-2}), shoot length (cm), and soil nutrient concentrations (NH_4-N, NO_3-N, and PO_4-P in ppm). Soil grain size (% silt + clay) was used as a covariate in two-way ANOVAs for soil nutrients. Repeated measures ANOVA were used for shoot elongation rate (cm day^{-1}) and RGR (g $g^{-1}day^{-1}$) because data consisted of repeated samplings of the same individuals over time.

Tukey's post-hoc test was used for pairwise comparisons of means in one-way ANOVAs. We performed ANOVA F-tests to evaluate a priori contrasts between means of grouping variables and levels in two-way and repeated measures ANOVA

results. Probability plots were examined to test for normality of data and to identify any data that required transformation. All biomass, soil NH_4-N, and soil NO_3-N data were ln transformed. When means and standard errors are used to describe or present statistical differences, data were back-transformed and reported in original units.

Results

The pre-fire diameter of native woody riparian species varied by species as follows: *B. salicifolia* (1–4 cm), *Salix exigua* (2–5 cm), *S. lasiolepis* (9–22 cm), *S. laevigata* (62–75 cm), *P. balsamifera* subsp. *trichocarpa* (21–70), and *P. fremontii* (72–80 cm). Regeneration of native plant species observed in study sites was predominantly by new seedlings. Resprouting from the root crown was only observed at a few sites for the following species (range of diameters): *P. balsamifera* subsp. *trichocarpa* (1–2 cm, died by the end of summer 2003), *B. salicifolia* (1–2 cm), *S. lasiolepis* (3–14 cm), *S. exigua* (2–5 cm), and *S. laevigata* (7–12 cm).

Pre- versus post-fire plant abundance

Percent cover of *Arundo* was significantly greater than native woody riparian plant cover both before and after the study sites were burned (Table 1). Although both *Arundo* (65.0 ± 6.7% cover, mean ± SE) and the native woody plants (21.7 ± 6.0% cover) were more abundant before the fire than after, less than a year after the fire *Arundo* (42.8 ± 4.3% cover) was the overwhelmingly dominant plant species in these riparian ecosystems (native woody species = 0.4 ± 0.2% cover). Thus, native woody species comprised 25.0% relative cover of the total vegetation before the fire and less than 1% of the vegetation in burned riparian terraces 9 months after the fire.

Post-fire density

The two-way ANOVA (plant type x time period) of plant density revealed a significant two-way interaction (Table 1). The mean density of *Arundo* (stems m^{-2}) was significantly greater than that of native plant species for all months sampled (March–September 2004; Fig. 3a). Mean density of native plant species declined somewhat over time during the first year after the fire, although differences between sampling periods were not significant. However, mean density of *Arundo* shoots increased significantly over time. A year after the wildfire, *Arundo* density (26.3 ± 3.2 stems m^{-2}) was an order of magnitude greater than that of native species (1.4 ± 0.4 stems m^{-2}) within the burned riparian plots sampled.

Post-fire shoot growth

The post-fire phenology of resprouting timing and shoot growth differed significantly between *Arundo* and native plants (Fig. 3b). *Arundo* began growing within days after being burned to the ground, whereas resprouts of native woody plants did not appear until January, over 2 months post-fire. The two-way ANOVA of shoot length by plant type and time period revealed a highly significant two-way interaction as the shoot lengths diverged over time (Table 1). Shoot length was 1.7–5.2 times greater (over 2.5 times greater on average) for *Arundo* than for natives during all months sampled (Fig. 3b).

Arundo shoots grew at a much faster rate than native woody riparian plant species within the first year after fire (Fig. 4). The repeated measures

Table 1 Two-way ANOVA of plant abundance (% cover), density (stems m^{-2}), and shoot length (cm) by factors of plant type (*Arundo donax* and native plant species) and pre- and post-fire time periods

Factors and interactions	Plant abundance	Density	Shoot length
Plant type	$F_{(1,80)} = 59.123$; $P < 0.001$***	$F_{(1,852)} = 322.769$; $P < 0.001$***	$F_{(1,3231)} = 819.299$; $P < 0.001$***
Time period	$F_{(1,80)} = 15.166$; $P < 0.001$***	$F_{(5,852)} = 1.700$; $P = 0.132$	$F_{(8,3231)} = 442.074$; $P < 0.001$***
Plant type × time period	$F_{(1,80)} = 0.006$; $P = 0.937$	$F_{(5,852)} = 2.850$; $P = 0.015$*	$F_{(8,3231)} = 21.295$; $P < 0.001$***
r^2	0.626	0.287	0.591

* = $0.05 \geq P > 0.01$ = significant; ** = $0.01 \geq P > 0.001$ = highly significant; *** = $P \leq 0.001$ = very highly significant

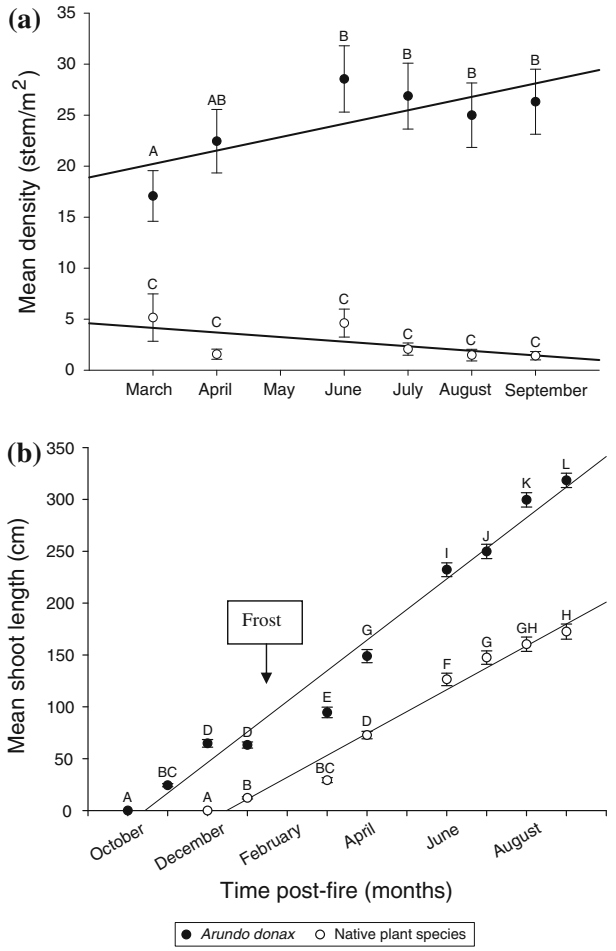

Fig. 3 Mean density (**a**) and shoot length (**b**) of *Arundo donax* versus native woody plants for 1 year after wildfire (October 2003–September 2004). *Regression lines* illustrate trends over time. *Letters* denote results of post-hoc hypothesis tests (comparison of means) with significance at $\alpha < 0.05$

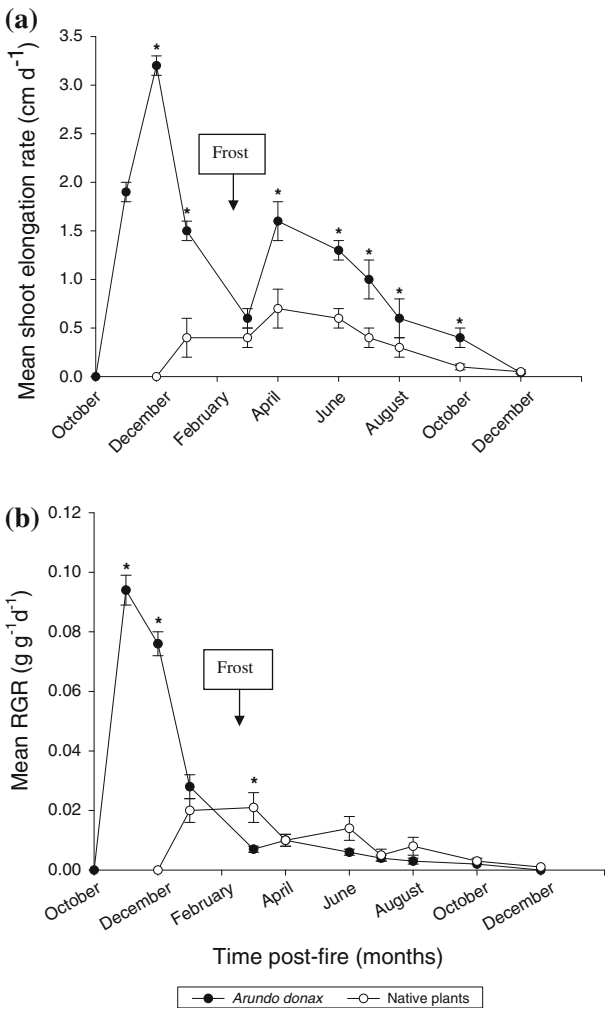

Fig. 4 Mean monthly shoot elongation rates (**a**) and relative growth rates (**b**) of *Arundo donax* compared to native woody plants for 1 year after wildfire (October 2003–September 2004). *Asterisks* denote significant differences in means between *Arundo donax* and native plants at each time period based on results of post-hoc hypothesis tests (comparison of means) with significance at $\alpha < 0.05$

ANOVA (time post-fire × plant type) for the shoot elongation rate revealed a significant main effect for time post-fire within subjects due to variation in rates for both *Arundo* and native plants (Table 2). *Arundo* emerged immediately after the fire, and the highest *Arundo* shoot elongation rates were observed in the first two months post-fire. Native woody species did not resprout until January 2004 and grew much more slowly than *Arundo*. Mean shoot elongation rates of *Arundo* were significantly higher than those of native woody species except in March and December. A series of heavy frosts occurred in late February 2004 (4 months post-fire) and appeared to have lowered *Arundo* shoot elongation rates substantially during the March sampling period. In April, shoot elongation rates for both *Arundo* and native woody species increased from winter levels, corresponding with warmer spring growing conditions. From April 2004 until the end of the year, elongation rates decreased for all plants, with *Arundo* maintaining higher rates (up to two times higher) than native species until December 2004.

In the repeated measures ANOVA (time post-fire × plant type), RGR varied significantly by plant type between subjects (individuals) and by time post-fire within subjects (Table 2). The mean RGR of *Arundo* was much greater initially than that of the native woody species (Fig. 4b). *Arundo*'s mean RGR was extremely high (0.094 ± 0.005 g $g^{-1}day^{-1}$)

Table 2 Repeated measures ANOVA with shoot elongation rate (cm day^{-1}) and relative growth rate (RGR; g g^{-1}day^{-1}) between time post-fire (months) as dependent variables and plant type (*Arundo donax* and native plant species) as the independent variable

Factors and interactions	Shoot elongation rate				RGR			
	df	MS	*F*	*P*	*df*	MS	*F*	*P*
Between subjects								
Plant type	1	0.228	0.614	0.440	1	0.001	16.026	<0.001***
Error	29	0.371			29	0.000		
Within subjects								
Time post-fire	6	4.559	17.071	<0.000***	6	0.001	5.983	0.001***
Time post-fire × plant type	6	0.128	0.480	0.728	6	0.000	1.796	0.158
Error	174	0.267			174	0.000		

immediately after the fire, whereas native plants did not emerge until the third month after the fire and then grew at a much more moderate rate. Mean RGR of native plants was higher than *Arundo* only during the spring, 5 months after the fire. While the heavy frosts in February 2004 appeared to curtail *Arundo* growth, they had little effect on the RGR of native plants. The mean RGR of both *Arundo* and native plants was very low at the end of the growing season from mid-summer (July) to winter (December).

Post-fire productivity

Approximately 1 year after the fire, *Arundo* productivity was significantly higher than that of any of the native species [$F_{(2,295)} = 43.291; P < 0.001$]. Productivity of *Arundo* (4.83 ± 0.34 kg m^{-2} year^{-1}) was 14 times higher than that of *B. salicifolia* (0.34 ± 0.06 kg m^{-2} year^{-1}) and 24 times higher than that of *S. laevigata* (0.20 ± 0.08 kg m^{-2} year^{-1}) in burned areas. Due to initial low abundance and significant mortality during the year, *S. exigua*, *S. lasiolepis*, and *P. balsamifera* subsp. *trichocarpa* were at such low densities in burned sites that their productivity was undetectable 1 year after the fire.

Soil nutrients

Mean pre- and post-fire soil nutrient levels surrounding *Arundo* differed significantly from levels found around native plants (Fig. 5; Table 3). Mean soil nutrient levels (NH_4-N, NO_3-N, and PO_4-P) adjacent to *Arundo* plants increased substantially after the study sites burned, but no significant differences in nutrient concentrations were observed between pre- and post-fire soil adjacent to native woody species. Concentrations of NH_4-N and PO_4-P in the soil next to *Arundo* versus native plant species were significantly higher post-fire.

Discussion

Several accounts have previously suggested that infestations of *Arundo* have increased fuel loads as well as fire frequency and intensity along riparian corridors (Robbins et al. 1951; Bell 1997; Scott 1994; D'Antonio 2000). Growing from 4 to 8 m in height and as fast as 10 cm day^{-1} (Perdue 1958; Hickman 1993), *Arundo* produces abundant flammable biomass that accumulates during the summer and fall months (Rundel 2000). Its ability to recover more rapidly than native plants after fire contributes to its invasion success, but no supporting quantitative evidence for this has been published to date. Several researchers have suggested that fire may increase the ability of *Arundo* to invade natural riparian systems (Rieger and Kreager 1989; Scott 1994; Bell 1997) and that it may be part of an invasive plant-fire regime cycle, changing riparian ecosystems from primarily flood-defined to fire-defined systems (Bell 1997).

Our study provides the first evidence that wildfire promotes invasion of riparian ecosystems by *Arundo*. Comparisons of post-fire *Arundo* and native plant performance demonstrated several physiological and morphological characteristics that give *Arundo* an advantage over native species after fire.

Three mechanisms—fire-adapted phenology, high growth rate, and growth response to nutrient enrichment—appear to promote the preemption of native

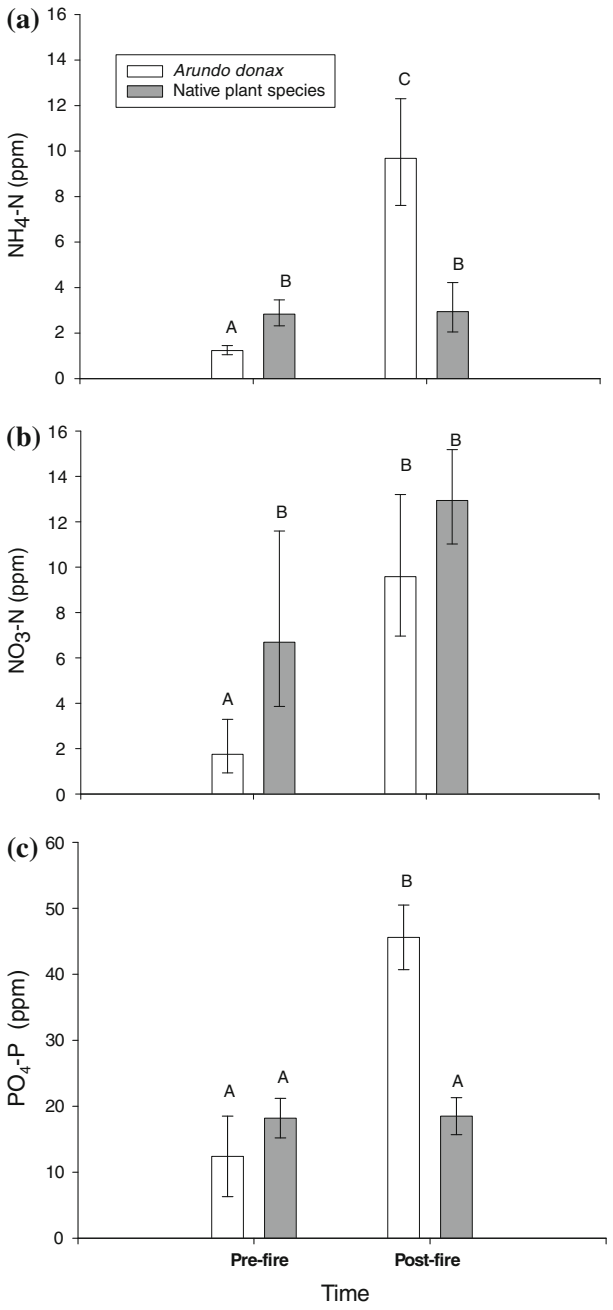

Fig. 5 Pre- and post-fire mean nutrient levels in soil adjacent to *Arundo donax* compared to soil next to native woody plants. *Letters* denote results of post-hoc hypothesis tests (comparison of means) with significance at $\alpha < 0.05$

woody riparian species by *Arundo* after fire. Fire stimulated *Arundo* regrowth almost immediately, as might be expected from a species with large below-ground carbohydrate reserves, whereas native woody riparian plant species recovered much more slowly after being burned. The evergreen phenology of *Arundo* clearly aids this invader in establishing resprouts following late fall or winter fires. Native riparian woody species measured in this study, *S. laevigata, S. lasiolepis*, *S. exigua*, *P. balsamifera* subsp. *trichocarpa*, and *B. salicifolia*, are all winter deciduous. Their growth and seedling establishment occur between late winter and early spring, corresponding with declining river flows (Stella et al. 2006) and increased temperatures. Decruyenaere and Holt (2005) found that *Arundo* exhibited no dormancy during the year in areas with high nitrogen levels, although recruitment of new shoots from rhizomes was higher in the summer than in winter months.

Arundo clearly expanded its dominance in our study area over the first year following the wildfire. It increased in relative abundance by almost 25% and comprised more than 99% of the vegetative cover in study sites only a year after fire. The large increase in relative biomass of *Arundo* 1 year after the fire compared to *Salix laevigata* and *Baccharis salicifolia* suggests that abundance of native riparian trees and shrubs might eventually be greatly reduced or excluded completely by *Arundo* in fire-prone riparian ecosystems. Observations of study sites taken in December 2009 indicate that native plant regeneration after the fire (less than 5% cover on average) has been greatly reduced due to *Arundo* dominance. Similar examples of post-fire competitive exclusion of native plant species by invasive grasses have been documented in many ecosystems in which fire is an unnatural or altered process (D'Antonio and Vitousek 1992; D'Antonio 2000; Brooks and Pyke 2001; Keeley 2006). The invasion of riparian forests by saltcedar has also exhibited a substantial effect on the composition and fire regime of riparian woodlands in the southwestern United States (Brothers 1984; Ellis 2000; Glenn and Nagler 2005; Nagler et al. 2005).

Large differences in pre- and post-fire soil nutrient levels post-fire may have stimulated and/or helped maintain high growth rates of *Arundo* following fire. Precipitation received within a few weeks of the fire mobilized nutrients, making them available for plant uptake. Both field and pot experiments have shown that *Arundo* responds positively to nutrient enrichment under non-burn conditions and may enhance competition with native plants under some conditions (Coffman 2007; Quinn et al. 2007). Levels of ammonia-N and orthophosphate in the soil surrounding *Arundo* were much higher in riparian study sites

Table 3 Two-way ANOVA of soil nutrients [ammonia-N (NH_4-N), nitrate–N (NO_3-N), and orthophosphate (PO_4-P)] by factors of plant type (*Arundo donax* and native plant species) and pre- and post-fire time periods

Factors and interactions	NH_4-N (ppm)[a]	NO_3-N (ppm)[a]	PO_4-P (ppm)
Plant type	$F_{(1,23)} = 1.120$; $P = 0.301$	$F_{(1,23)} = 2.160$; $P = 0.155$	$F_{(1,23)} = 4.511$; $P = 0.045$*
Time period	$F_{(1,23)} = 12.737$; $P = 0.002$**	$F_{(1,23)} = 5.037$; $P = 0.035$*	$F_{(1,23)} = 7.044$; $P = 0.014$*
Plant type × time period	$F_{(1,23)} = 12.753$; $P = 0.002$**	$F_{(1,23)} = 0.967$; $P = 0.336$	$F_{(1,23)} = 7.281$; $P = 0.013$*
Silt + clay[b]	$F_{(1,23)} = 5.245$; $P = 0.032$*	$F_{(1,23)} = 0.893$; $P = 0.354$	$F_{(1,23)} = 3.240$; $P = 0.085$
r^2	0.690	0.322	0.607

[a] Data ln transformed

[b] Soil grain size (% silt + clay) was used as a covariate

after the fire, whereas soil nutrient levels adjacent to native plants did not change. Higher post-fire soil nutrient levels found next to *Arundo* versus native plants were likely due to quality and quantity of fuel (vegetation) burned, fire intensity, and resulting ash deposited (Debano and Conrad 1978).

Riparian ecosystems invaded by *Arundo* adjacent to fire-prone shrublands in southern California appear to be on a trajectory toward a potential invasive plant-fire regime cycle (Brooks et al. 2004). Introduction of a tall clonal grass species such as *Arundo* into this riparian ecosystem has altered fuel types and loads (Scott 1994; Brooks et al. 2004). Decreased moisture content and increased surface-to-volume ratio of *Arundo* versus native vegetation may lead to altered or increased fire susceptibility or increased probability of ignition in these systems. Addition of this fuel to the riparian ecosystem has increased vertical continuity (i.e., the structure of fuel allows fire to spread from surface to crowns of shrubs and trees). Due to its tall growth form, infestations of *Arundo* mixed with native species may spread fire vertically into the canopy of riparian trees.

The October 2003 Simi/Verdale wildfire provides an excellent example of the invasive plant-fire regime cycle that *Arundo* invasion has created. The wildfire reached the Santa Clara River from the north, crossed the broad riverbed through large stands of *Arundo* (one of our permanent study sites), then burned through thousands of hectares of native shrublands and alien grasslands before again entering extensive riparian woodlands intermixed with *Arundo* to the west along the river (Fig. 1).

The results of this study have important implications for *Arundo* invasion in river systems in other regions of the world. Removal of *Arundo* from riparian ecosystems adjacent to fire-prone shrublands in arid climates should be a key management priority. Negative effects on other ecosystem functions, such as wildlife habitat reduction (Knick et al. 2005), generally follow fire regime changes (Brooks et al. 2004) and associated plant invasions (Herrera and Dudley 2003; Kisner 2004). The invasion of *Arundo* on riparian terraces adjacent to communities or agricultural fields and structures pose an increased risk of fire to people and property.

Post-fire removal of *Arundo* when aboveground biomass is still low helps to reduce future fire risk. However, time of year is critical to selection and success of appropriate removal techniques, and diligent maintenance is required to completely remove *Arundo* (Spencer et al. 2005; Coffman 2007). Active planting of removal areas with a diverse composition of native species may be required to prevent reinvasion by *Arundo* or other exotic species due to enhanced nutrient levels and openings in the canopy (Quinn and Holt 2008) in post-fire riparian ecosystems.

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UNIVERSITY OF CALIFORNIA

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Factors Influencing Invasion of Giant Reed (*Arundo donax*) in Riparian Ecosystems of Mediterranean-type Climate Regions

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Environmental Health Sciences

by

Gretchen Christina Coffman

2007

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The dissertation of Gretchen Christina Coffman is approved.

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DEDICATION

I dedicate this dissertation to my parents

Mary Lou Coffman

and

Glenn Norman Coffman

Without their constant love and support over the years

this dissertation would not have been possible.

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ABSTRACT OF THE DISSERTATION

Factors Influencing Invasion of Giant Reed (*Arundo donax*)

in Riparian Ecosystems of Mediterranean-type Climate Regions

by

Gretchen Christina Coffman

Doctor of Philosophy in Environmental Health Sciences

University of California, Los Angeles, 2007

Professor Richard F. Ambrose, Chair

Giant reed, *Arundo donax* L., is one of the greatest threats to riparian ecosystems of Mediterranean-type climate regions, including California. Forming extensive monotypic stands, *A. donax* increases the risks of flooding and fire, uses prodigious amounts of water, and reduces habitat value for wildlife. Urban and agricultural development adjacent to riparian ecosystems may contribute to its invasion success. The main hypothesis of my dissertation is that the current abundance of nutrients, water, light, and fire in riparian ecosystems of Mediterranean-type climate promotes *A. donax* invasion. A two-year field experiment in a riparian ecosystem on the Santa Clara River

in California showed that *A. donax* produced greater biomass than native species under high soil moisture, light, and nutrient levels, and its biomas-s in monoculture was much greater than most species and treatment levels. However, results suggest that high resource levels and this new plant functional group in these riparian ecosystems, rather than superior resource competition, promote *A. donax*'s competitive exclusion of native riparian species. Analysis of the influence of nutrient enrichment from residential and agricultural land use types on *A. donax* infestation throughout several coastal watersheds in Southern California revealed that floodplains with enriched soil NO_3-N supported *A. donax* infestations whereas sites with lower N levels did not. Unlike the native red willow (*Salix laevigata* Bebb.), *A. donax* may take advantage of anthropogenically enriched N (and K) levels in riparian ecosystems. Regarding fire, *A. donax* began regrowth from rhizomes immediately after being burned in October 2003 along the Santa Clara River whereas native riparian plants remained dormant for several months, and *A. donax* grew 3–4 times faster than native riparian plants. A year after the fire, *A. donax* dominated these burned areas (99% relative cover and a 24% increase in relative cover compared to pre-fire conditions). *Arundo donax* infestations appear to create an invasive plant-fire regime. These results help elucidate the optimal conditions for *A. donax* invasion of riparian ecosystems, which in turn can help prioritize control strategies and revegetation of riparian ecosystems.

CHAPTER 1 -

INTRODUCTION

Invasion of riparian ecosystems by the alien plant giant reed, *Arundo donax* L., is one of the most serious threats to rivers in Mediterranean-type climate regions worldwide. *Arundo donax* has successfully invaded many rivers in these regions, forming extensive monocultures and altering physical and biological processes. In California, infestations of *A. donax* are known to increase risks of flooding, create unnatural fire hazards, outcompeting indigenous riparian species for scarce water resources, and reduce the value of riparian habitat for most wildlife (Dudley and Collins 1995, Bell 1997, DiTomaso 1998, Dudley 2000). Although introduced several hundred years ago to southern California, rapid expansion of *A. donax* in natural riparian ecosystems appears to have occurred in the last 35 years (Bell 1997).

Researchers have suggested that natural and human disturbances, which are prevalent in Mediterranean-type climate regions such as California, are primary factors contributing to the extensive distribution of *A. donax* along rivers in these areas (Rieger and Kreager 1989, Bell 1997). Large winter floods occur naturally every few years and remove riparian plants from floodplains, thereby creating open substrates for recolonization. Pieces of *A. donax* (rhizomes and culms) are dispersed downstream during flooding and establish vegetatively wherever they are deposited (Else 1996, Else and Zedler 1996). However, natural disturbance along rivers is not a new phenomenon in Mediterranean-type climates; river systems have long been dynamic components of the

landscape in these regions (Mount 1995). Most physical human disturbance of rivers and their watersheds dates back to human settlement of these regions (Mount 1995, Rundel et al. 1998), which occurred much earlier than the onset of *A. donax* invasion. Therefore, other factors must contribute to the relatively recent success of this plant's invasion.

More recently, humans have altered riparian ecosystem processes by increasing nutrient delivery from adjacent land use practices, importing water for the ever-growing population, exporting water for agriculture, removing mature riparian vegetation for development, and increasing fire frequency in adjacent shrubland communities. I investigated the influence of these factors on invasion of rivers by *A. donax* in southern California. I hypothesized that increased nutrient, water, and light availability, as well as the introduction of fire into riparian ecosystems, has contributed to successful *A. donax* invasion in Mediterranean-type climate regions.

BACKGROUND

Throughout history, man has embraced the idea of cultivating exotic plants and animals worldwide for agricultural, aesthetic, and other purposes. However, moving biological organisms has created a human-induced breakdown of biogeographical barriers to species dispersal and many species that evolved separately are now living together (D'Antonio and Vitousek 1992, Richardson et al. 2000). As far back as 1958, Charles Elton wrote of the terrific dislocations in nature that mixing different organisms from various parts of the world would cause (Elton 1958). Despite his warning, consequences of these introductions of plants and animals had not been fully recognized until recently.

The problem of plant introductions[1] and resulting invasions[2] in Mediterranean-type climate regions has received considerable attention because these regions provide ideal climactic conditions for plant growth (Drake et al. 1989, D'Antonio and Dudley 1993). In California, plant invasions have occurred in many natural ecosystems, including grasslands, woodlands, wetlands, coastal dunes, salt marshes, and riparian areas (Kruger et al. 1989, Rejmanek 1989, Rejmanek et al. 1991). Aquatic ecosystems such as rivers and wetlands are among the world's most heavily invaded systems (Mooney et al. 1986, Kruger et al. 1989, Pysek and Prach 1994, Alpert et al. 2000, Rundel 2000). Natural and altered disturbance regimes and anthropogenic enhancement of nutrients are thought to contribute to success of plant invasion in rivers (Crawley 1986, Ashton and Mitchell 1989, Drake et al. 1989, Hobbs 1989, Hobbs and Huenneke 1992, Alpert et al. 2000).

Riparian ecosystems occupy a unique area in the landscape; as ecotones between aquatic and terrestrial ecosystems, they have naturally high species diversity, a diverse array of biological and physical processes, and a mosaic of vegetation types and structural components due to natural disturbance regimes (Gregory et al. 1991, Malanson 1993, Naiman and Decamps 1997). Natural dynamic disturbance regimes of river and stream systems in Mediterranean-type climates likely promote the spread of invasive plant species through these systems. For example, intense but infrequent winter flooding

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[1] Introduction implies human transport of a plant across a major geographic barrier.
[2] Invasion refers to an introduced plant that produces reproductive offspring in areas distant from the origin of its introduction (>100m in <50 years). Richardson et al. (2000) suggested several barriers to plant introduction, naturalization, and invasion by including geographic, environmental (local), reproductive, dispersal, environmental (disturbed habitats), and environmental (natural habitats).

scours stream corridors and exposes vast areas of sandy floodplain, channels, and terraces (Gasith and Resh 1999), rendering them vulnerable to disturbance colonizers, which are primarily invasive, weedy plants. Weedy plants are able to establish and grow quickly in these open disturbed areas, often out-competing the indigenous riparian plant species for light, water, and nutrients (Baker 1974).

Historically, riparian plant communities in Mediterranean-type climates have been particularly impacted by human perturbations due to the ephemeral and braided nature of the river systems in which they are found (Mount 1995). Since early human settlement of these areas, humans have dammed, channelized, mined, rerouted, diverted, and developed floodplains of rivers, resulting in great losses and degradation of associated riparian plant communities (Palmer 1993, Mount 1995). These alterations to river systems have left riparian plant communities susceptible to plant invasions by weedy species. Rapid expansion of urban and agricultural development into these regions in the last century has resulted in habitat fragmentation, reduction in biological diversity, and altered distribution of resources in these areas (i.e., water and nutrients) (Aschmann 1991, Palmer 1993). These anthropogenic land-use changes have created conditions that allow for large-scale plant invasion of remaining natural ecosystems (D'Antonio and Dudley 1993).

Arundo donax *Invasion*

Currently, one of the greatest invasive threats to the highly modified river ecosystems of Mediterranean-type climate regions is a tall bamboo-like member of the grass family (Poaceae), giant reed (*Arundo donax* L.). *Arundo donax* appears to be of a

broad southern Eurasian origin, extending from Southeast Asia to the Mediterranean Basin, although the precise extent of its native distribution is unclear (Perdue 1958, Zohary 1962, Hickman 1993). The relatively high diversity of herbivores associated with *A. donax* in the Mediterranean Basin compared to other areas where it grows suggests plant-animal co-evolution in that region (Kirk et al. 2003), but *A. donax* might have a broader indigenous range. Introduced to other areas primarily for building materials, erosion control, and windbreaks, it is now successfully established in freshwater systems in tropical to temperate climates worldwide (Polunin and Huxley 1987). In the U.S., *A. donax* has become especially widespread in riparian ecosystems in California's Mediterranean-type climate (Fischer et al. 1978). Although *A. donax* is thought to have been introduced to southern California for building materials and erosion control as early as the 1700s, and it was abundant along the Los Angeles River in the 1820s (Robbins et al. 1951), its widespread expansion in riparian ecosystems appears to be recent (Bell 1997). Currently, *A. donax* infests almost every stream and river system in coastal southern California (Gaffney 2002) (Figure 1). Based on spatial data analyses, researchers estimate more than 1,500 acres of *A. donax* infestations occur throughout rivers in southern California, although only approximately one-third of the riparian areas in coastal southern California have been surveyed (Casanova et al. unpublished data). A comprehensive survey is in progress to verify coverage of *A. donax* infestations in the field throughout all streams and rivers in southern California (Giessow pers. comm.).

Although *A. donax* produces a long plume-like inflorescence with no viable seeds in California (Johnson et al. 2006), *A. donax* spreads rapidly downstream when small

pieces of the plant break off, land on bare, moist substrates, and begin to grow (Else 1996, Else and Zedler 1996, Bell 1997, Boose and Holt 1999, Decruyenaere and Holt 2005). Growing at an extremely high rate (4–10 cm per day under optimal conditions) and during all times of the year, *A. donax* quickly establishes on unvegetated or sparsely vegetated soil and grows taller than 2-4 m after only a few months and may eventually reach up to 8 m (Perdue 1958). Singh et al. (1997) suggested that *A. donax* thrives in a variety of soil types in its indigenous range in India. Under greenhouse conditions, rhizomes of *A. donax* rooted successfully during all months of the year and both rhizomes and stem fragments established under various temperatures, moisture conditions, and soil types (Boose and Holt 1999, Decruyenaere and Holt 2001). It then expands outward in area via its large rhizome or via layering (adventitious sprouting of stem tips in contact with the ground), crowding and even displacing indigenous shrubs, herbs, grasses, and eventually even trees, under elevated light, soil moisture, and nutrient conditions, (Boland 2006, Decruyenaere pers. comm.). Wang (1998) suggested that nutrient loading contributes to *A. donax* invasion, and several authors have proposed that fire might promote *A. donax* invasion because this species can respond more quickly to fire than natives (Bell 1994, DiTomaso 1998). In this manner, *A. donax* forms extensive stands or monocultures in riparian ecosystems along the floodplains and terraces of southern California's river and stream systems.

Impacts of Invasion

Infestations of *A. donax* have created serious physical and biological problems along rivers in southern California. Where it grows extensively along floodplains, *A.*

donax acts as a transformer species; it causes physical obstructions to natural water flow, thereby increasing the risk of flooding to adjacent lands. During large floods *A. donax* increases stream roughness, creates debris dams at bridge crossings, and causes bank erosion and instability (DiTomaso 1998). As the aboveground biomass dries in the hot, dry summer months that characterize Mediterranean-type climates, *A. donax* creates an unnatural fire hazard where moisture-rich riparian corridors used to form natural barriers to fire (Scott 1994, Rundel and Gustafson 2005). Water loss due to high evapotranspiration (ET) of *A. donax* reduces already scarce water resources in Mediterranean-type climate regions. Based on transpiration rates of rice (another C3 species thought to have similar transpiration rates), Iverson (1994) estimated that *A. donax* uses three times more water than native riparian species. Studies using a variety of methods indicate that ET of *A. donax* (1.2–7.5 m/year) may be much higher than that of native riparian vegetation such as *Salix* spp., *Populus* spp. (1.0–3.3 m/year) and mixed riparian communities of arid and Mediterranean-type climates (0.11–1.6 m/year) (Zimmerman 1999, Hendrickson and McGaugh 2005, Shafroth et al. 2005, Abichandani 2007, Coffman in press). Abichandani (2007) showed that *A. donax* infestations may transpire 6 to 110 times more (up to 18,206 kg m^{-2} $year^{-1}$) than native vegetation.

Arundo donax has very little known value as a wildlife habitat in California (Bell 1997, Kisner 2004) compared to the dominant native vegetation (Bell 1994, Herrera and Dudley 2003). Its stems and leaves contain an array of inorganic noxious chemicals (Jackson and Nunez 1964) that reduce herbivory by most native insects and grazers. Due to its dense clonal growth form, it physically restricts indigenous wildlife passage, yet

many animals depend on the riparian corridor and river floodplain for foraging, nesting, and cover (Kisner 2004). Like other invasive plants, *A. donax* appears to have negative impacts on indigenous plant and animal biodiversity through the loss of suitable habitat and competition with indigenous species (Czech and Krausman 1997). In addition, *A. donax* threatens river ecosystem sustainability via its impacts on natural river processes, such as lowering of the groundwater table, decreased surface water levels in streams, creating the potential for unnatural and extremely hot fires, and loss of plant and animal biodiversity.

Control of* Arundo donax *in California

Because of the numerous impacts of *A. donax* infestations on rivers, streams, and adjacent property, large-scale *A. donax* control efforts have been initiated throughout California since 1990 by several multi-agency organizations. For example, Team Arundo, a forum of local, state, federal, and private organizations dedicated to the control of *A. donax*, was formed in 1992 and leads control efforts along the Santa Ana River in southern California, where invasion has been a problem since 1969 (SAWPA 2007). In 2001, the Santa Ana River contained approximately 10,000 acres of *A. donax*-infested riparian habitat; Team Arundo is currently removing *A. donax* along this river on a watershed-scale. Formed in 1996, the Team Arundo del Norte partnership was modeled after the original Team Arundo and leads control and eradication efforts in Central and Northern California, where *A. donax* has more recently invaded (Team Arundo del Norte 2007).

Many local organizations also work on *A. donax* control at the county and watershed levels. For example, the Ventura County Arundo Task Force, led by the Ventura County Resource Conservation District, conducted a pilot removal project on the Ventura River in 2003 and plans to continue long-term watershed-wide eradication of *A. donax* in all major watersheds in Ventura County starting with the Santa Clara River. In the Malibu Creek watershed, the Resource Conservation District of the Santa Monica Mountains and Mountain Conservation Trust conducted an *A. donax* eradication project on 5.2 miles of the stream. Also, *A. donax* eradication is being used for compensatory riparian and wetland mitigation in California (Stein 1998). However, controversy continues over *A. donax* removal and herbicide use associated with its removal in the Topanga Canyon watershed (Topanga Online 2007).

Eradication of *A. donax* from watersheds in Mediterranean-type climates is an important initial step in restoration and long-term sustainability of riparian ecosystems. Various mechanical and hand-clearing techniques have been successful in removing small areas of *A. donax* infestations throughout California. Several researchers are investigating the ecophysiology of *A. donax* (e.g., relative growth rates and critical nitrogen content) to determine the most effective time to apply glyphosate-containing herbicides to kill the rhizomes of these plants (Spencer et al. 2005, Wijte et al. 2005). Research on biocontrol agents is underway; however, the U.S. Food and Drug Administration (USFDA) has not approved any yet. Based on the mechanisms by which it spreads and colonizes, *A. donax* removal efforts are primarily concentrated along higher riparian terraces, locations where it is less likely to reinvade (Coffman et al. 2004).

Removal from floodplain locations requires development of watershed-scale removal plans and permits that specify removal from the upstream most infestation working downstream. However, Boland (2006) proposed an inside-out approach for *A. donax* removal (i.e., conduct treatments first inside and then outside the flood zone) due to his documentation of the importance of layering. Researchers believe that revegetation of riparian areas with native plant species after *A. donax* removal is essential in preventing infestations of other weedy species. However, long-term eradication of *A. donax* from rivers and streams in Mediterranean-type climate regions may not be completely successful without knowledge of understanding how to manage the factors that contribute to its invasion and proper management of those factors.

***Riparian Ecosystem Restoration and* Arundo donax**

Degradation of ecosystem processes and functions by man-made physical and biological alterations threatens river systems worldwide (Naiman and Decamps 1997). River restoration projects have increased exponentially since 1995 and are being conducted across the U.S. to improve water quality, enhance in-stream and riparian habitat quality, re-establish fish passage, and provide bank stabilization (Bernhardt et al. 2005). Current watershed-level river and stream restoration efforts in California include removal of dams for fish passage, elimination of levees to allow for more natural channel migrating and meandering, releases of water from dams to simulate natural flooding, implementation of policies to reduce pollutants, and revegetation of natural riparian ecosystems. However, regardless of the restoration goal or activity, restoration success will depend on control of *A. donax* in the streams that it infests. For example, removing a

dam with upstream *A. donax* infestations without implementing control programs first would result in widespread dispersal of this species. Understanding the relationship between nutrient levels found in rivers, the sources of these nutrients, and *A. donax* versus native riparian species growth will help watershed managers formulate more realistic nutrient reduction policies and implementation plans. Understanding water use by *A. donax* compared to native riparian plants is critical to justifying funding of removal efforts due to its presumed high use of water in arid regions where water is limited (Abichandani 2007).

Watershed managers, restoration planners, *A. donax* eradication groups, conservation organizations, and many others require scientifically based management recommendations to control expansion of and remove *A. donax* effectively. Knowledge of how factors such as nutrient levels, water, light, and fire contribute to growth and invasion of *A. donax* is essential to long-term, large-scale control. However, little is know about the *A. donax* invasion process related to the factors. In this dissertation, I address the influence of water, nutrients, light, and fire on the *A. donax* invasion process. My aim was to provide valuable information about *A. donax* invasion and long-term restoration of riparian ecosystems in California and other Mediterranean-type climate regions.

***Influence of Water, Nutrients, Light, and Fire on Invasion by* Arundo donax**

Water Availability

Mediterranean-type climate regions are characterized by wet winters and warm, dry summers that regulate natural ecosystems processes. Many rivers and streams in

these regions are intermittent (i.e., with loosing and gaining reaches) or ephemeral because of wetting and drying periods (Gasith and Resh 1999) and underlying geology (Malanson 1993). Ever-increasing population pressure in these regions has created intense competition for water, resulting in serious alterations to water quantity and quality in rivers and streams (Gasith and Resh 1999). The city of Los Angeles, for example, imports 88% of its water to supply water for drinking, agricultural irrigation, and industrial uses (Hazy 2006). This imported water is discharged into natural water bodies after use, in many cases with degraded water quality, thereby increasing flow in many streams and creating perennial systems. Groundwater abstracted for agricultural irrigation and rural residential uses adjacent to rivers may decrease flow.

Increased water quantity in stream systems of Mediterranean-type climates may promote growth of invasive species such as *A. donax*. Although *A. donax* reportedly can tolerate a wide variety of ecological conditions, it thrives in areas with high soil moisture such as along canals, ditches, and stream banks (Perdue 1958, Rezk and Edany 1979). Much higher transpiration of *A. donax* compared to native riparian plants such as *Salix* spp. and *Populus* spp. and mixed riparian communities typical of arid and Mediterranean-type climates may give it an advantage where water is abundant (Zimmerman 1999, Hendrickson and McGaugh 2005, Shafroth et al. 2005, Abichandani 2007). I hypothesized that *A. donax* would have a competitive advantage over those native species found to uptake water at a lower rates in river floodplains and terraces that receive increased water inputs from anthropogenic sources.

In riparian ecosystems in which water tables are lowered due to groundwater extraction or along naturally loosing reaches (i.e., river reaches that contribute water to the groundwater supply), the scenario is more complicated. The presence of sustained high soil moisture or near-surface shallow groundwater during the growing season is important for establishment of most species, although both *A. donax* (Perdue 1958) and *Bacharris salicifolia* are known to establish under very low soil moisture conditions. Once established, rooting depth, distribution, and structure relative to soil moisture and groundwater likely play a large role in growth and competition between *A. donax* and native species. *Salix* spp., *Populus* spp., *B. salicifolia*, and other woody riparian species are phreatophytes with adaptations to low soil moisture conditions; their roots follow the receding soil moisture and can use water from depths of up to 30 m (Robinson 1958). *Arundo donax* is a perennial grass with roots that can only reach ~3 m below the soil surface.

Nutrient Loading

During the twentieth century, nutrient inputs to river systems worldwide increased dramatically due primarily to expanding agricultural practices and municipal sewage discharge (Rundel et al. 1983, Tilman et al. 2000, Nicola 2003, FAOUN 2004). Follett and Hatfield (2001) reported groundwater nitrate concentrations under agricultural systems in the U.S. to be as high as 30mg/L in 2001, which is much higher than the EPA drinking water standards [less than 10ppm (mg/L)]. Southern California is no exception; agricultural activities and their associated nutrient inputs are widespread along river systems of southern California (Mount 1995, Pedersen 2001). Other important

anthropogenic and natural sources of N and P that likely contribute to nutrient loading in river systems include: atmospheric N; manure from animal feedlots and corrals; fertilizer applied to lawns; leaky septic tanks; oxidation of organic materials; and the increased abundance of symbiotic N-fixing plants (Verhoeven et al. 1996, USEPA 1999).

Composition and increase in use of fertilizer has led to extensive nutrient loading of river systems, with mainly nitrogen (N) and phosphorus (P) (Nicola 2003). Global fertilizer use has increased more than fourfold, from 31.2 million tons in 1961 to 137.7 million tons in 2001 (FAO 2004). Total global nitrogen fertilization is expected to increase by 12.9% during the next 15 years and 23.7% in the next thirty years (FAOUN 2004). By 2050, Tilman et al. (2000) predicted that the global rates of nitrogen and phosphorus fertilization will be 2.5 times and 2.4 times, respectively, that of current levels. In the U.S., annual fertilizer use in agricultural areas has increased from 24.9 in 1959 to 53 million tons in 2001 and continues to increase (FAOUN 2004). Currently, nitrogen fertilizers represent about 55% of all fertilizer uses, followed by phosphate at 26%. In the U.S., the average percent of nitrogen, the main constituent in commercial fertilizers, has risen from 11% in 1959 to 22.7% in 2001 (FAOUN 2004).

Anthropogenic nutrient enrichment of natural ecosystems has been linked to plant invasions worldwide (Mooney et al. 1986, Drake et al. 1989, D'Antonio and Vitousek 1992, Hobbs and Huenneke 1992, Vitousek et al. 1996, Brooks 2003). Excess N and P from fertilizers used in agriculture, golf courses, and residential lawns, as well as treated wastewater effluent, have contributed to nutrient loading in rivers across the U.S. (USEPA 1999). Nutrient enrichment and the dynamics of riparian ecosystems in

agricultural landscapes in the eastern U.S. and Western Europe have been well studied (Peterjohn and Correll 1984, Gilliam 1994, Hill 1996, Bennett et al. 2005). However, limited information exists about these processes in Mediterranean-type climates such as southern California (Kim 2003, Robinson et al. 2005).

The effects of increased nutrient levels on plant composition and invasion may be even more profound in streams of Mediterranean-type climate regions compared to other regions of the world because they have naturally low levels of nitrogen and phosphorous (Day 1983, diCastri 1991, Dallman 1998). Plant species that are restricted to non-fertile sites generally respond less to nutrient addition or nutrient supply than do the same species from more fertile soils (Chapin et al. 1986). Hellmers et al. (1955) reported that the nitrogen-limiting conditions found in chaparral communities in southern California also exist in riparian ecosystems; thus, excess nitrogen from adjacent land use practices might promote *A. donax* growth and invasion in riparian ecosystems of southern California and other Mediterranean-type climate regions (Wang 1998). A demographic study of *A. donax* in southern California indicated that *A. donax* tends to spread radially or invade under nutrient-rich conditions, and it ceases spreading and establishes relatively dense clumps under nutrient-poor conditions (Decruyenaere and Holt 2001, Decruyenaere pers. comm. October 5, 2001). Preliminary results of another study indicate that *A. donax* biomass is greater than that of *Salix laevigata* under conditions of no nitrogen (0 g/m^2 N) and high levels of nitrogen addition (12–14 g/m^2 N) (Dudley unpublished data), whereas *S. laevigata* grows larger than *A. donax* at nutrient addition levels of $4g/m^2$. Seasonal drought conditions confine nutrient availability to wetter times

of the year and to areas with perennially high soil moisture retention regardless of nutrient inputs, potentially influencing invasion dynamics.

Excess nitrogen and phosphorus contained in surface and shallow groundwater are transported from land use activities to adjacent river ecosystems (Schlosser and Karr 1981, Correll 1984, Correll et al. 1992, Triska et al. 1994, Rodda 1995, Basnyat et al. 1999). Although the quantity of N and P in the shallow groundwater and soil is important to plant productivity, only certain constituents of N and P are readily available to plants. Plants absorb and assimilate both NO_3^- and NH_4^+ most readily. Nitrogen found in the form of NO_3^- and NH_4^+ in fertilizer and wastewater is water-soluble and moves quickly through soils in the shallow groundwater between agricultural practices, wastewater treatment plants, and adjacent river systems. Widely known as the primary productivity-enhancing nutrient, N assimilation and metabolism is complex and under genetic control (Duncan 1994). Although not addressed in this study, atmospheric N in the form of air pollution is a growing source of this nutrient for plants (Verhoeven et al. 1996). Because plant species vary in their ability to uptake atmospheric N through their stomata (Stark 1994), this anthropogenic source should be examined further.

Phosphorus is an insoluble mineral that readily adsorbs to soil particles, which are then transported to river systems through overland runoff and soil erosion. Required for many metabolic processes, P is absorbed rapidly into plant roots but requires active uptake due to steep concentration gradients between the soil solution and plant roots (Shuman 1994). Plants can uptake P only when dissolved in water as ortho-phosphates

or poly-phosphates, and the rate of uptake is highly pH-dependent (optimal uptake at pH 6.5) (Shuman 1994).

The majority of water and minerals absorbed by plants enters through the root system. The ability of plants to assimilate nutrients available in the surrounding soil and groundwater depends on the development of an extensive root system and on rooting structure (Kozlowski et al. 1991). Root morphology and architecture differ between monocots, such as *A. donax,* and dicots like *Salix laevigata* (Taiz and Zeiger 1991). The physiological strategies of both plants differ greatly due to their inherent structure. *A. donax* roots are fibrous and tend to be shallower than those of *S. laevigata*, which has a taproot that can extend 30 m or more to groundwater. Thus, *A. donax* may utilize nutrients in the upper soil profile and shallower groundwater compared to phreatophytes like *S. laevigata* from loosing stream reaches in which groundwater is deep.

The supply of N and P in the soil and the availability of these nutrients to plants in the soil medium can vary greatly based on soil grain size and pH (Metz et al. 1966). Variability in soil grain size leads to variability in soil moisture content, which in turn affects rates of both nutrient diffusion transport and biological activity. Soil grain size has a strong influence on water and nutrient retention in soils: Coarser soil grain sizes retain less water than finer particle soils, such as clay and silt, and have a lower cation exchange capacity due to lower surface area (Kozlowski et al. 1991; Taiz and Zeiger 1991). Soils with higher cation exchange capacity supply more minerals to roots. Mineral ions are either adsorbed onto the surface of soil particles or exist in soil solution. The cation NH_4^+ may be found dissolved in water or associated with aerobic soils in

which it oxidizes quickly into NO_2^- and NO_3^- (nitrification) or reacts with other components in the soil to form ammonium salts. Because NO_2^- and NO_3^- are highly soluble in water due to their negative charge, concentrations of these nutrients in the soil water solution tend to be lower in well-drained coarser grained soils. Conversely, negative charges on the soil particle surface promote adsorption of mineral cations such as phosphate, which bind readily to clay particles (containing aluminum or iron) and are not easily lost to groundwater or available to plants.

Light Availability

Light availability influences plant invasion in many ecosystems, due to both vegetation removal and direct effects of shading by invasive species (Crawley 1987, D'Antonio and Vitousek 1992, Yamashita et al. 2000, Meekins and McCarthy 2001, Fargione and Tilman 2002). Reduction in light availability may act as a barrier to invasion in both disturbed and natural habitats (Richardson et al. 2000). Plant species vary greatly in the amount of light they require for colonization and optimal growth (Treshow 1970, Menges and Waller 1983). Although the specific light requirements of *A. donax* and the dominant riparian plant species in California are not well known (Braatne et al. 1996), D'Antonio and Vitousek (1992) reported that invasive grass species prevent establishment and growth of woody species by shading them. Dudley (1998) suggested that monocultures (large infestations) of *A. donax* limit native riparian plant recruitment through light reduction, but the mechanisms behind this phenomenon are still unknown (Dudley 1998). Furthermore, light limitations can promote strong belowground competition between species (Schenk 2006).

Occurrence of Fire

Wildfires ignited by man at unnatural and dangerous times of the year burn rapidly through riparian corridors infested with *A. donax* and may help spread fires across watersheds and along riparian corridors. Historically, dense biomass that accumulated over a period of 30–50 years or more in chaparral communities of California and shrublands in other Mediterranean-type climate regions caused fires to ignite (Minnich 1983, Keeley et al. 1999, Keeley and Fotheringham 2001, 2005). Although fire was once a natural part of shrubland ecosystems in many Mediterranean-type climate regions, large riparian ecosystems provided natural firebreaks because native vegetation retained foliar water that resisted ignition (Bell 1994). Lightning was the primary cause of wildfires, especially during the summer and fall under dry, low humidity conditions (Naveh 1975, Keeley 1982, Keeley et al. 1999). Currently, however, most wildfires in these areas are anthropogenic in origin (Rugen 1987, D'Antonio and Vitousek 1992, Keeley et al. 1999). For example, all 14 concurrent fires in southern California in October 2003 (739,597 acres burned) resulted from human activities (Keeley and Fotheringham 2005).

Fire suppression and, more recently, controlled burning of wildland vegetation are techniques used in the twentieth century to manage vegetation and to avoid wildfires (Kozlowski et al. 1991). However, when enough fuel accumulates due to changes in vegetation type (i.e., native shrublands and perennial grasslands in California have changed to Mediterranean annual grasslands) or a decrease in fire frequency in a region, fires are easily started.

Invasion of annual grass species has been linked to altered fire regimes in rangelands, deserts, and wildlands of California and the Western U.S. (D'Antonio and Vitousek 1992, D'Antonio 2000, Brooks 2002, Brooks et al. 2004, Keeley 2004, Keeley and Fotheringham 2005). *Arundo donax* may pose a more extensive problem in riparian ecosystems due to its perennial growth form (the large volume of biomass produced) and its rapid recovery after fire. Several accounts suggest that infestations of giant reed have increased fuel load as well as fire frequency and intensity along riparian corridors (Rieger and Kreager 1989, Bell 1994, Scott 1994, Dukes and Mooney 2004).

Natural, healthy riparian areas historically have acted as firebreaks primarily because native vegetation has high leaf moisture content (i.e., contains enough water to have low flammability) when fires typically occur in summer and fall. However, the October 2003 wildfire along the Santa Clara River clearly has shown that when natural riparian habitats are infested with *A. donax*, fires spread readily through this historically fire-hardy habitat (Coffman in press). For example, during the Simi/Verdale fire, the fire jumped across Highway 126 and the Santa Clara River through a section of the river densely invaded by *A. donax*, and from there made its way rapidly up and down the riparian corridor on either side of the river (estimated 5 miles per hour) (see Chapter 4). The fire then spread from the riparian corridor to the shrublands on the other side of the river and burned the Santa Suzanna Mountains, including the Simi Hills in the Calleguas Creek watershed to the south. This process was observed in several other locations along the Santa Clara River where shrublands were located close to the river floodplains and terraces (observation by G. Coffman and S. Hedrick 2003). In this way, fire spread

rapidly up and down river corridors through large patches of *A. donax*, especially along terraces where *A. donax* was very dry and provided more fuel than natural vegetation.

Although no scientific evidence exists, a few authors have suggested that fire in riparian ecosystems may increase the ability of *A. donax* to invade natural riparian systems (Rieger and Kreager 1989, Bell 1994, Scott 1994). The large quantity of highly flammable biomass produced by *A. donax*, and its rhizomes immediate growth response compared to native riparian species following fire contributes to its invasion success. Bell (1994) suggested that invasion of riparian ecosystems by *A. donax* is changing these systems from primarily flood-defined to fire-defined systems. Riparian ecosystems infested by *A. donax* that are adjacent to fire-prone shrublands in southern California appear to be on a trajectory towards an invasive plant-fire regime (Brooks et al. 2004).

ORGANIZATION OF DISSERTATION

My dissertation research focused on investigating the influence of nutrients, water, light, and fire on *A. donax* invasion of riparian ecosystems in Mediterranean-type climate regions. My main hypothesis is that increased nutrient, water, and light availability caused by anthropogenic sources in river systems throughout southern California have promoted invasion by *A. donax*. To test this hypothesis, I conducted three main studies employing two study approaches. First, I conducted a large-scale field experiment, located along a riparian terrace of the Santa Clara River in southern California, to test competition between *A. donax* and three native plant species for water, nutrient, and light availability. In a second watershed-scale observational field study, I investigated the influence of nutrients from various land use types and fluvial geomorphic

locations on *A. donax* invasion of riparian ecosystems along several coastal rivers in southern California. In my third study, I examined the role of fire in promoting *A. donax* invasion of riparian terraces of the Santa Clara River. Following this Introduction chapter, each of these three studies will be described in chapters 1–3. The final chapter (Conclusions Chapter) of the dissertation presents conclusions and management implications based on these studies.

FIGURES

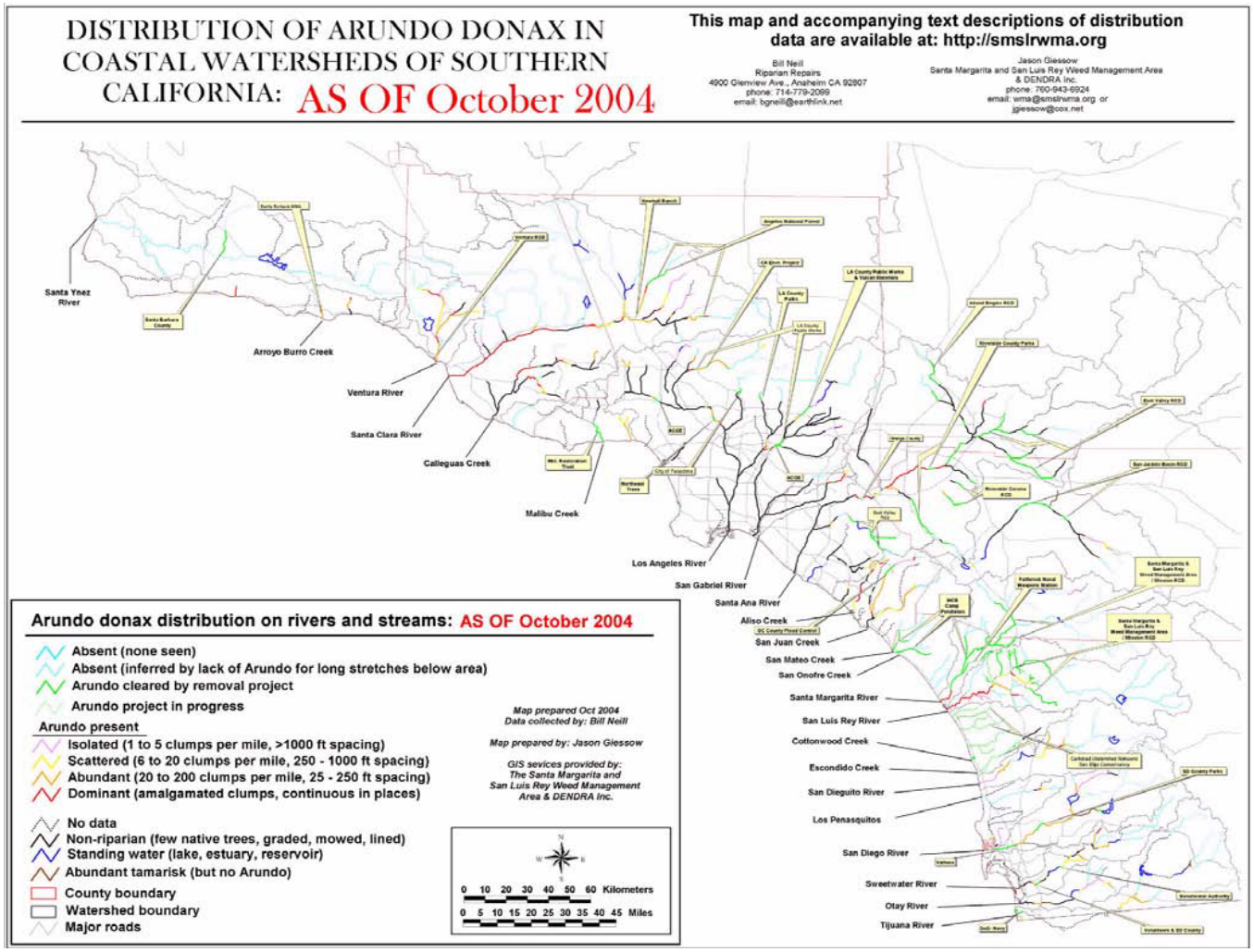

Figure 1. Distribution of *A. donax* throughout streams and rivers of Southern California (Used by the permission of Jason Giessow and Bill Neill, http://smslrwma.org/invasives/Arundo/ADRegionalMap.html).

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CHAPTER 2 -

EFFECTS OF WATER, NUTRIENT, AND LIGHT AVAILABILITY ON COMPETITION BETWEEN *ARUNDO DONAX*, A LARGE INVASIVE GRASS, AND NATIVE RIPARIAN SPECIES

Abstract: Invasion by alien plant species is currently one of the greatest threats to biodiversity and natural functioning of many ecosystems worldwide. Superior resource competition by alien grass species has been shown as the fundamental mechanism for invasion in many ecosystems. In this study, I tested the hypothesis that superior competition for soil moisture, light, and nutrient availability promotes invasion of a large bamboo-like grass, *Arundo donax* L., in riparian ecosystems. I established a large-scale field experiment with several competition plant groupings (mixed and single-species groupings), soil moisture, light, and nutrient treatments in a riparian ecosystem in southern California. I planted 168 four-plant groupings in 12 blocks perpendicular to shallow groundwater flow in a full factorial randomized block design. Effects of treatments on survivorship and aboveground biomass of *A. donax* were compared to native *Baccharis salicifolia*, *Salix laevigata*, and *Populus balsamifera* ssp. *trichocarpa*. Percent survivorship was high for all species (97.8% overall) and did not differ significantly for *A. donax* between treatments. Results show *A. donax* only suppressed one native species (*P. balsamifera* ssp. *trichocarpa*) under the most stressful environmental conditions. Competition from *B. salicifolia* and *S. laevigata* had a strong negative effect on *A. donax* biomass under high soil moisture, light, and nutrients.

Furthermore, *B. salicifolia* was facilitated by *A. donax* in half of the conditions tested. Despite negative effects of competition, *A. donax* produced a much higher biomass than native species under high soil moisture, light, and nutrient levels, and *A. donax* biomass in monoculture was much higher than all species within all treatment levels. Results suggest that high resource levels and the clonal growth form, not superior resource competition by the invasive *A. donax*, promote observed preemptive competitive exclusion of native riparian species. Its unique morphology and physiology, absent in this system before its introduction, allows *A. donax* to readily displace natives in many resource levels. *Arundo donax* appears to be a super invader, able to outperform native woody riparian species in almost every resource scenario tested.

Key Words: *Arundo donax, Salix laevigata*, *Populus balsamifera* ssp. *trichocarpa*, *Baccharis salicifolia*, giant reed, invasive species, alien, competition, nutrients, nitrogen, light, soil moisture, riparian, rivers, Mediterranean-type climate

INTRODUCTION

Invasion of natural ecosystems by alien plant species is a widespread phenomenon known to result in significant losses to biodiversity and impacts to ecosystem functioning (Elton 1958, Mooney and Drake 1986, Ramakrishnan and Vitousek 1989, D'Antonio and Vitousek 1992, Vitousek et al. 1996). Aquatic ecosystems such as rivers and wetlands are among the world's most heavily invaded systems (Mooney et al. 1986, Kruger et al. 1989, Pysek and Prach 1994, Alpert et al. 2000, Rundel 2000). Altered disturbance regimes, low stress environmental conditions, and anthropogenic enhancement of nutrients are thought to contribute to success of plant invasion in rivers and wetlands (Ashton and Mitchell 1989, Hobbs 1989, Hobbs and Huenneke 1992, Alpert et al. 2000). However, mechanisms by which invasive plant species exclude native plant species and dominate natural vegetation in these ecosystems are not well understood, yet are essential for developing effective control and restoration plans (Dudley 1998, Minchinton et al. 2006).

Superior interspecific competition between native and introduced species for water, light, and nutrient resources plays a critical role in plant invasion in many terrestrial ecosystems (D'Antonio and Vitousek 1992, Gordon and Rice 2000, Booth et al. 2003, Suding et al. 2004, White and Holt 2005, Richardson 2006). In the California grassland ecosystem, superior resource competition by Mediterranean annual grasses for water (Hamilton et al. 1999, Coleman and Levine 2007) and nutrients (Kolb et al. 2002) has been found to contribute to the almost total exclusion of native perennial bunchgrasses (D'Antonio and Vitousek 1992). Recent work by a number of authors has

revealed the relative importance of various resources and levels of each resource in this invasion process (Kolb and Alpert 2003, Corbin and D'Antonio 2004b, Thomsen et al. 2006). A few experimental studies in river and wetland ecosystems have demonstrated superior resource competition by invasive plants for either nutrients (Green and Galatowitsch 2002, Minchinton and Bertness 2003) or water (Sher and Marshall 2003), but no studies have examined effects of multiple resources simultaneously (i.e., various levels of water, light, and nutrients). Furthermore, controversy exists over the relative importance of competition in stressful, infertile versus productive ecosystems (Grime 1979, Tilman 1988, Goldberg and Novoplansky 1997, Alpert et al. 2000). Experimental studies addressing competitive interactions between invasive and native plants under multiple resources conditions (water, light, and nutrients) are needed to help elucidate the invasion process and aid in restoration of invaded ecosystems.

In the last half of the twentieth century, a tall bamboo-like member of the grass family (Poaceae), giant reed (*Arundo donax* L.), has become one of the most successful weedy riparian invaders in arid and Mediterranean-type climates worldwide (Bell 1997, Dudley 1998, Boose and Holt 1999). *Arundo donax* appears to be of a broad southern Eurasian origin, extending from Southeast Asia to the Mediterranean Basin, although the precise extent of its native distribution is unclear (Perdue 1958, Zohary 1962, Hickman 1993). Introduced extensively to other areas primarily for building materials, erosion control, and windbreaks, it is now successfully established in freshwater systems in tropical to temperate climates worldwide (Perdue 1958, Crampton 1974, Polunin and Huxley 1987, Hickman 1993, Sharma et al. 1998). Although the seeds are usually sterile

(Johnson et al. 2006), *A. donax* is dispersed downstream when pieces of culm or rhizome break off during flooding and land on bare, moist substrates (Else 1996, Else and Zedler 1996, Bell 1997, Boose and Holt 1999, Wijte et al. 2005). From these pieces, the plant grows at an extremely fast rate (up to 10 cm per day under optimal conditions), quickly establishing on exposed or sparsely vegetated soil and growing to more than 8 m in height after only a few months (Perdue 1958, Rieger and Kreager 1989, Bell 1994). Once established, *A. donax* expands outward in area by clonal propagation, displacing indigenous shrubs, herbs and grasses, and eventually even trees (Decruyenaere and Holt 2001). In this manner, *A. donax* forms extensive stands or monocultures in riparian ecosystems.

In Mediterranean-type climates, *A. donax* infestations have become especially devastating to riparian ecosystems, creating significant physical and biological impacts on natural river functioning and sustainability (Rieger and Kreager 1989, Bell 1997, DiTomaso 1998, Rundel 2003). High magnitude winter floods characteristic of many arid climates help distribute *A. donax* downstream, where it successfully establishes on a diverse array of substrates (Rieger and Kreager 1989, Else 1996, Else and Zedler 1996) much like the native riparian species in these systems. However, mechanisms of *A. donax* invasion in natural riparian ecosystems have been largely unexplored. Researchers have suggested that high resource levels and superior resource competition with native riparian plants (i.e., for elevated water, nutrients, and light availability) may promote invasion of *A. donax* in riparian ecosystems of southern California (Bell 1997, Wang 1998, Rundel 2003, Coffman et al. 2004), yet no experimental evidence of resource

competition by *A. donax* exists to support this hypothesis. Mechanisms that promote invasion of *A. donax* under various resource conditions in riparian ecosystems are essential to its control and restoration of these systems.

In this study, I examined the role of competition between *A. donax* and native species under varying resource scenarios found in riparian ecosystems in the plant invasion process. I predicted that aboveground biomass of native riparian plant species would be suppressed by high productivity of *A. donax* in high soil moisture, light and nutrient treatments, while under more stressful (and lower) resource conditions competitive interactions would favor native species which have evolved under these conditions (Alpert et al. 2000, Daehler 2003). Where *A. donax* establishes with native riparian plants in high resource conditions, growth rate will be high but competition from native plants for soil moisture and nutrients will be high as well. Differing habit, phenology, and rooting depth of *A. donax* (clonal) and native riparian species (phreatophytes) play a key role under these conditions (Fargione and Tilman 2005).

Physiological integration among culms and their spatial arrangement may provide *A. donax* with a competitive advantage over native woody riparian trees and shrubs (Gough et al. 2002). The clonal growth form of *A. donax* enables it to grow horizontally, preemptively acquiring space from competitors and to average out surrounding heterogeneity in soil resources (Decruyenaere and Holt 2005). Although *A. donax* has a much shallower rooting depth than native riparian phreatophytes, *S. laevigata* and *P. balsamifera* spp. *trichocarpa*, root depth of these plants should remain relatively shallow and density low when resources are abundant (Schade and Lewis 2006, Schenk 2006)

(See Chapter 3; Figure 9). Thus, substantial overlap in the density of root mass between species may result in stronger competition under these conditions. Depending on density (Gough et al. 2002) and native species competing, these conditions may lead to either successful competitive exclusion of all or some native species by *A. donax*. In high stress and low resource conditions, naturally found along rivers in Mediterranean-type climates, *A. donax* may avoid competition with native plants due to differential rooting depths; native phreatophytes will develop deeper roots than *A. donax* when soil moisture and nutrients are scarce.

I hypothesized that superior resource competition in high soil moisture, light, and nutrient regimes has promoted invasion of *A. donax* throughout rivers in Mediterranean-type climates. I investigated *A. donax* competition with several common native woody riparian plant species under various soil moisture, nutrient, and light levels in a large-scale field experiment in southern California. Plant survivorship and aboveground biomass of each species in intraspecific compared to interspecific competition groupings were analyzed. This experimental design allowed me to investigate the role of varying resource conditions thought to be most fundamental to competitive exclusion of indigenous riparian plants by *A. donax* using a natural, controlled approach.

METHODS

Study Site

The field experiment site was located on a private ranch on the south side of the Santa Clara River between Santa Paula and Fillmore, Ventura County, California (34.36° N, 118.99° W) (Figure 2). The 187 km long Santa Clara River and its tributaries drain a

4,185 square km watershed, the second largest coastal watershed in southern California. Prior to its clearing for agriculture, the riparian terrace in which the field experiment was established was once dominated by large riparian trees such as black cottonwood (*Populus* (L.) *balsamifera* ssp. *trichocarpa* Torrey & A. Gray) and red willow (*Salix laevigata* Bebb). A mixture of smaller trees and shrubs likely comprised the understory layer, including arroyo willow (*Salix lasiolepis* Benth.), mulefat [*Baccharis salicifolia* (Ruiz Lopez & Pavon) Pers.], and blue elderberry (*Sambucus mexicana* C. Presl.).

The experiment ran for two growing seasons, from December 2002 to December 2004. In October 2002, I began construction of the 0.5-hectare field experiment on a riparian terrace between agricultural fields and the river. Based on measurements of groundwater depth taken from a grid of borings throughout the experimental area, I found that shallow groundwater flowed in a southeast to northwest direction from the agricultural fields through the field experiment toward the river. Rows (or blocks) of plant groupings within the field experiment were located perpendicular to the direction of shallow groundwater flow to accommodate variance due to differing hydrology (Figure 3).

Baseline soil grain size (soil texture) and nutrient status were determined in Summer 2002, before construction of the experiment began to help in final placement of experimental groupings and treatments. The western side of the experimental area was primarily composed of a shallow horizon (soil surface to 26–66 cm) of sandy loam, silt loam, and loam with a deep horizon of fine sand and coarser sand below (to 171–199 cm and deeper). The eastern side of the experiment contained mostly loam (and silt loam) in

the top horizon (soil surface to 44–102 cm), loam and silt loam in a middle horizon, and sand in the lowest horizon (below 138–216 cm). Soil moisture was consistently higher on the eastern side of the experiment than the western side due to soil grain size composition and topography.

I conducted baseline soil nutrient analyses on 18 soil samples collected from 0–30 cm depth systematically throughout the experiment. In spring 2003, pre-fertilization soil nutrient levels in the experimental study area mean soil nitrate (5.2 ± 1.7 ppm) and phosphate (11.1 ± 1.1 ppm) levels were comparable to concentrations found in soil along similar riparian terraces along the Santa Clara River (see Chapter 3). Average soil pH (7.69 ± 0.02) did not differ markedly throughout the experimental site.

Study Species

Arundo donax is a robust, perennial, bamboo-like member of the Poaceae (grass) family that was introduced and is now widespread throughout the floodplains and terraces of rivers in California and other warm, temperate climates worldwide (Perdue 1958, Crampton 1974). It has erect stout (yet hollow) culms that are 1–4 cm thick and 2–8 m in height. Culms branch to form ramets, typically at the end of the first year of growth or after a culm is damaged. Leaf blades are broad (2–6 cm wide), less than 1 m long, flat, clasping at the base, strongly scabrous along their margins, and evenly spaced along the culm (Crampton 1974, Hickman 1993). *Arundo donax* reproduces vegetatively through a network of large, thick rhizomes that grow horizontally just below the ground surface. Under some conditions it produces a large (3–6 dm) terminal plume-like inflorescence (panicles) at the end of the growing season (Faber and Holland 1992, Hickman 1993).

I selected three native riparian plant species commonly found on terraces of rivers in southern California to use in the experiment: *Salix laevigata* (red willow) *Populus balsamifera* (black cottonwood) ssp. *trichocarpa*, and *Baccharis salicifolia* (mulefat). *Salix laevigata* is a riparian tree that can grow as tall as 15 m and is a member of the Salicaceae. Dominant in both floodplains and terraces along rivers in southern California, *S. laevigata* can be identified by its dark, deeply furrowed bark on mature trees and lanceolate leaves, which are shiny on the top and glaucous beneath. Also a member of Salicaceae, *P. balsamifera* ssp. *trichocarpa* grows to a height of 30 m in alluvial plains along rivers in southern California. *Populus balsamifera* ssp. *trichocarpa* trees can be identified by their broad crown and bicolored ovate leaves with acute tips, which are dark green on the top and glaucous underneath (Faber and Holland 1992, Hickman 1993). *Baccharis salicifolia* is the dominant shrub found throughout floodplains and terraces of streams and rivers in southern California. A member of the Asteraceae, *B. salicifolia* usually grows to a height of less than 4 m. Its long linear to lanceolate leaves resemble willow leaves, but they typically have three principal veins that extend the entire length of the leaf and are coarsely serrated (Faber and Holland 1992, Hickman 1993). In addition, *B. salicifolia* shrubs produce a rounded panicle of white simple compound dioecious flowers.

Experimental Design

This field experiment was organized as a full factorial randomized block design to minimize variation due to heterogeneous soil and shallow groundwater conditions found within the site. A total of 288 plant groupings (four plants per grouping) were organized

in 12 blocks (rows) of 24 groups each perpendicular to the general flow of shallow groundwater hydrology (Figure 3). Blocks of plant groupings were placed 4 m apart and plant groupings within blocks were placed 3 m apart. 756 cuttings of riparian trees (1 m long by approximately 2–3 cm in diameter) and 396 rhizomes of *A. donax* (200–400 g) were planted approximately 0.75 m apart in square configurations. Native riparian species cuttings were planted in December 2002, and *A. donax* rhizomes were planted in March 2003. Multiple levels of three resource treatments and competition treatment were applied randomly to plant groupings along rows before planting, including soil moisture (high and low), light (high and low), and nutrient additions (high and none). To simplify the interpretation and presentation of results, the 96 low-nutrient treatment plant groupings in the experiment are not included in the analyses.

I used two competition groupings (two-species and one-species groupings) in the experiment to compare interspecific versus intraspecific competitive interactions (Table 1). The two-species groupings, referred to as 'mixed species grouping' consisted of two *A. donax* plants and two plants of a single native species. Like species were planted diagonally across from each other in the mixed species groupings. One species-groupings, or monocultures, contained four plants of only one species per grouping. (The 36 four-species groupings in the experiment were not included in this study.) In this experiment, the criterion for existence of an interspecific competitive interaction was evidence of significantly different biomass in mixed plant groupings compared to monocultures. If mean biomass of a species was lower when grown with another species compared to in monoculture, an interspecific competitive interaction was present. An

interspecific interaction was deemed positive (facilitation) when the mean biomass of a species was higher in mixed species groupings compared to its biomass when grown in monoculture.

Two soil moisture treatments occurred naturally; the western half of the experiment contained soils that were better drained (referred to as low soil moisture), whereas the eastern half of the experiment retained higher soil moisture throughout the year (high soil moisture). To simulate natural establishment conditions, I did not apply artificial irrigation.

In Spring 2003, I built shade structures over half of the experiment to simulate shading by a mature riparian canopy and test the effects of light availability. The two light treatments consisted of full sun (referred to as high light) and 80% shade (low light). I used 80% black shade cloth on six shade structures (total dimensions were 200 feet x 10 feet x 15 feet high) that were erected along rows in two large blocks of the experiment to minimize the shade effect onto non-shaded rows. One block (three rows) was placed over the high soil moisture portion (northeast) and one block (three rows) was placed over the low soil moisture portion (southwest) (Figure 3). I applied nutrient treatments to designated plant groupings twice a year: a fertilized "high N" treatment and "no N" treatment control in which only water was added. Granular ammonium-nitrate fertilizer (N-P-K, 34-0-0) was used as the source of added nitrogen and was mixed with 2 gallons of water before application. High nitrogen treatments (100 g N/m^2/year or 56 g N/plant/year) were added to one-half of the plant groupings to simulate row crop fertilization levels adjacent to riparian areas. I applied half of the nutrient treatments at

the beginning of the growing season and the remainder at the peak of the growing season; this timing of fertilization application is similar to that used in agricultural practices in the area. Each plant in the no fertilizer treatment received 2 gallons of water at each of the two application periods.

Sampling Methods

I monitored soil moisture to characterize the soil water content throughout the experimental site using 14 soil moisture probes (20 cm ECH_2O Dielectric Aquameter sensors by Decagon Devices, Inc.), which I installed systematically throughout the experiment in the summer of 2004 (Figure 3). I placed 10 soil moisture probes in a soil horizon (between 60–80 cm from the soil surface) located roughly in the middle of the root system for most plants. The other four probes were placed in a shallower soil horizon (from 30–50 cm) to measure soil moisture in the area in which the cuttings were initially planted. I measured soil moisture content of these probes weekly from July 2004 to September 2005.

Annual mean soil moisture content (60–80 cm below ground surface) on the eastern side (Mean ± SE = 38.5% ± 0.5) of the experiment was significantly higher than on the western side (33.2% ± 1.0) during the 2004–2005 water year (one-way analysis of variance results: $F_{(1,383)} = 23.583$; $P < 0.001$). The shallower soil horizon (30–50 cm below the ground surface) in which cuttings were established exhibited a similar trend; soil moisture was 42.1% ± 0.4 on the eastern side and 37.8% ± 0.5 on the western side (one-way analysis of variance results: $F_{(1,166)} = 47.686$; $P < 0.001$). Mean soil moisture content fluctuated throughout the year but was consistently higher on the eastern side

than the western side (Figure 4). Although soil moisture probes were not installed until the end of the second growing season (Summer 2004), trends observed during 2004-2005 were likely similar or more pronounced in 2003-2004 due to lower annual precipitation. Thus, the eastern side was designated as the high soil moisture treatment and the western side as the low soil moisture treatment.

I measured plant survivorship at three time periods: 1) survivorship of planted cuttings in spring 2003, 2) plant survivorship at the end of 2003, and 3) plant survivorship at the end of 2004. A few cuttings and rhizomes that did not grow initially were replanted in spring 2003 and the replacement plant establishment success was included in the 2003 and 2004 percent survivorship results.

Biomass Estimation

The aboveground biomass of all plants in the field experiment was estimated over the two-year study period (2003 to 2004). I used non-destructive dimensional analyses to estimate aboveground biomass dry weight of plants in the experiment so that I would interfere as little as possible with plant growth and other measurements taken throughout the course of the study period (Whittaker 1961, 1965, Whittaker and Marks 1975, Sharifi et al. 1982, Spencer et al. 2006). Compartments of aboveground biomass measured included: branches, main trunk (cutting), leaves, flowers, and seeds of native species, and culms, leaves, and ramets of *A. donax*. Regression models were created using the basal diameter measurements to predict biomass of all compartments (except main trunks) of each plant. All data were natural log transformed in the regression models. Trunk biomass (the aboveground portion of the original cutting) of native species was estimated

by dividing the trunk volume (cm^3) by the density (cm^3/g) of a sample of wood of that particular species. Trunk volume was calculated using average diameter and length of the cutting in the equation for cylinder volume ($V = \pi r^2 h$).

At the end of each growing season (2003 and 2004), branches/culms were cut, basal diameter measured, biomass oven-dried, leaves separated from branches/culms, and biomass weighed separately. I collected a total of 320 branch/culm aboveground biomass samples in 2003 and 400 samples in 2004 for the dimensional analysis biomass estimation. In 2003, 20 branches/culms from the range of branch diameters present for each of the four species were harvested from monoculture competition groupings in each of the experimental quadrants (SE, NE, NW, SW – two soil moisture and two light levels) (20 x 4 x 4 = 320) (Figure 3). In addition, 20 second-year *A. donax* culms were collected in each experimental quadrant in 2004 (total of 80 culms). Only fully mature *A. donax* culms were sampled.

Regression equations for branch/culm basal diameter versus corresponding dry aboveground biomass samples were calculated for each species in each of the four soil moisture-light treatment combinations (16 for 2003 and 20 for 2004). Regression models for aboveground biomass were very highly significant for all species under various combinations of soil moisture and light treatments in 2003 and 2004 ($r^2 = 0.770–0.996$, $P < 0.001$) (see Appendix 2-1 for model equations). Therefore, I used these equations to estimate aboveground biomass for all plants within the field experiment.

At the end of the 2003 and 2004 growing seasons, I measured basal diameters (10 cm from the trunk of riparian plants or 10 cm above the ground surface for *A. donax*) of

each branch or culm growing from the original cutting. Only culms that were > 60% of mature height were measured. To calculate total biomass of each plant at the end of each growing season, I used the basal diameter of each branch/culm of an individual plant in the corresponding regression equation for that species and treatment and totaled the resulting biomass for all branches/culms. Trunk biomass estimates were added to total biomass for each native riparian plant.

Statistical Analyses

Descriptive statistics were performed on soil moisture and plant survivorship measurements. I conducted one-way ANOVAs on soil moisture content to validate high and low soil moisture treatments and establishment of plant species between the first and second growing season, with Tukey's post-hoc test for pair-wise comparisons of means.

The competition experiment was organized in a full multifactorial design in which combinations of four fixed factors (Model 1) were crossed with each other. Four-way analysis of variance (ANOVA) tests were used to analyze effects of various combinations of four factors (independent variables) on total aboveground biomass data (standing stock) collected at the end of the second growing season (dependent or response variables) (Systat Statistical Program [Version 10]). The four independent variables were competition plant groupings, soil moisture, light, and nutrient addition treatments. Data were analyzed for main effects of individual factors and interactions between factors. ANOVA F-tests were performed to evaluate a priori contrasts between means of grouping variables and levels in multifactor ANOVA results. Probability plots were examined to test for normality of data and to identify any data that required

transformation. Because soil moisture and percent survivorship data were normally distributed, data transformation was unnecessary. All biomass data were ln transformed. When means and standard errors were used to describe or present statistical differences, data were back-transformed and reported in original units.

RESULTS

Establishment

Plant establishment success between installation in winter 2002–2003 and the end of the growing season in 2004 was very high for all species. Cutting survivorship in spring 2003 was 97.7% for all plants. Total plant survivorship at the end of 2003 and 2004 was 98.4% and 97.8%, respectively, and slightly higher than cutting survivorship due to replanting of unsuccessful cuttings. Soil moisture, nutrient, and light treatments had no effect on *A. donax*, *S. laevigata*, or *B. salicifolia* survivorship (See Appendix 2-2 for analyses of species and resource treatment effects). However, establishment success of *P. balsamifera* ssp. *trichocarpa* at the end of the first growing season (2003) was significantly lower within the high soil moisture treatment than in any other species and soil moisture treatment combination. Percent survivorship did not decrease significantly during the two-year establishment period ($F_{(1,158)} = 0.485$; $P = 0.487$). Therefore, I considered plants fully established by the end of the first growing season (2003) and evaluated competitive interactions at the end of the second growing season (2004).

Biomass Production

Arundo donax biomass was higher than native plant species biomass under nearly all soil moisture, light, and nutrient conditions at the end of the second growing season. In fact, the mean biomass of *A. donax* in monoculture under high soil moisture, light and nutrient conditions was 2–34 times that of all native species under all conditions tested [range = 0.46 kg (SE 0.30–0.68) to 7.03 kg (SE 6.41–7.72)] (Figure 5). In high soil moisture, light, and nutrient conditions, monocultures of *A. donax* exhibited a significantly higher mean biomass [17.05 kg (SE 15.98–18.20)] than any native plant species under these conditions [2.63 kg (SE 2.24–3.10) to 4.21 kg (SE 3.69–4.80)] (Figure 6). Despite negative competitive interactions with *B. salicifolia* and *S. laevigata* under high resource conditions (high soil moisture, light, and nutrients), mean biomass of *A. donax* was nearly double that of *S. laevigata* and 20 percent higher than *B. salicifolia* in mixed groupings (Figure 5). Biomass of *A. donax* grown in monoculture was almost six times that of *P. balsamifera* spp. *trichocarpa* in high resource conditions. Facilitation by *P. balsamifera* spp. *trichocarpa* contributed to an even higher mean biomass of *A. donax* in the 2-species mixed grouping compared to monoculture in similar experimental conditions. *Arundo donax* biomass was consistently higher than that of most native species in other soil moisture, light, and nutrient treatments, however differences between biomass of *A. donax* and native species were not as great.

Biomass of *A. donax* grown under high soil moisture, light, and nutrient conditions was much higher than when grown under any other experimental condition (Figure 5 and Figure 6). Although native plant species show similar trends, differences in

mean biomass between these treatment conditions were much less than for *A. donax*. Under high resource conditions, mean biomass of *A. donax* was highest in monoculture [17.05 kg (SE 15.98–18.20)] and lowest in the low soil moisture-high light and high soil moisture-low light treatments (Figure 6). Of the native species grown in monoculture, *B. salicifolia* yielded the highest mean biomass [4.20 kg (SE 3.69–4.80)] in the high soil moisture, light, and nutrient treatment, but this was only one-quarter of the maximum biomass produced by *A. donax*. The lowest native species biomass in monoculture was produced by *P. balsamifera* spp. *trichocarpa* in the low soil moisture, light, and nutrient treatment [0.53 kg (SE 0.46–0.60)], more than 30 times lower than *A. donax* biomass in high resource conditions.

The 4-way ANOVA for aboveground biomass of all species by factors of plant grouping, soil moisture, light, and nutrients resulted in two 3-way interactions (Table 2). The plant grouping x soil moisture x light interaction was difficult to interpret but significance was mainly due to lower *S. laevigata* biomass than other species in low soil moisture-high light treatments as well as numerous significant competition interactions mentioned below. The significant soil moisture x light x nutrients interaction was explained by higher biomass in high soil moisture-high light than any other combination of these factors and levels.

Resource Competition

When I compared mean aboveground biomass by species in mixed groupings versus monocultures, effects of competition between *A. donax* and native plants varied significantly by species and resource treatment levels. *Arundo donax* was a superior

resource competitor to only one native plant, *P. balsamifera* spp. *trichocarpa*, under only one of the conditions tested. Under the most stressful experimental conditions of low soil moisture, full sun, and no nutrient additions, *A. donax* competition had a negative effect on *P. balsamifera* spp. *trichocarpa* biomass (Table 3). Under these conditions, *P. balsamifera* spp. *trichocarpa* obtained the lowest biomass of all native species [0.46 kg (SE 0.30–0.68)] (Figure 5). The 4-way ANOVA of *P. balsamifera* spp. *trichocarpa* biomass resulted in a significant 3-way interaction (plant grouping x light x nutrients) due to this competitive interaction (Table 3). In high resource conditions (high soil moisture, light, and nutrients), there was a suggestion of *A. donax* facilitation by *P. balsamifera* spp. *trichocarpa*, with *A. donax* biomass being 30% greater in the mixed species grouping with *P. balsamifera* spp. *trichocarpa* [22.95 kg (SE 20.13–26.16)] than in monoculture [17.05 kg (SE 15.98–18.20)], but this difference was not statistically significant. A significant negative effect of competition with *P. balsamifera* spp. *trichocarpa* was detected under high soil moisture, low light, and high nutrient levels, conditions in which *A. donax* was least productive [1.38 kg (SE 1.03–1.85)]. Significant 3-way interactions (plant grouping x light x nutrients and soil moisture x light x nutrients) in the 4-way ANOVA of *A. donax* biomass were found (Table 3). The plant grouping x light x nutrients interaction was due to facilitation of *A. donax* by *P. balsamifera* spp. *trichocarpa* under high soil moisture, light, and nutrients. Much higher biomass in high soil moisture-high light treatments than in all other treatments was the primary cause of the significant soil moisture x light x nutrients interaction.

When grown with *A. donax* in the mixed species grouping compared to in monoculture, *S. laevigata* exhibited no significant competitive interactions with *A. donax* regardless of resource levels. Although competitive effects were not significant, the trend throughout various combinations of treatments, especially under low soil moisture conditions, indicated slight facilitation of *S. laevigata* by *A. donax* (Figure 5). Two-way interactions (soil moisture x light and soil moisture x nutrients) were significant for *S. laevigata* biomass in the 4-way ANOVA (Table 4) due to differing trends among levels in these factors. The soil moisture x light interaction was significant due to lower biomass in high light-low soil moisture compared to the low light-low soil moisture treatments, and the significant soil moisture x nutrient interaction was caused primarily by higher biomass in high nutrient-high soil moisture treatments compared to low nutrient-high soil moisture treatments. *Arundo donax* aboveground biomass was significantly higher (roughly twice as high) in monoculture compared to in the 2-species grouping when grown with *S. laevigata* in the high soil moisture, light, and nutrient treatment (Figure 5). Results of the 4-way ANOVA indicate significant 2-way interactions between soil moisture and light as well as between light and nutrients. The soil moisture x light interaction was significant because in the shade biomass was similar with regard to soil moisture; however, biomass was significantly higher in full sun-high soil moisture compared to full sun-low soil moisture (Table 4). The significant light x nutrient interaction resulted from higher biomass in full sun-high nutrient treatment compared to full sun-no nutrient treatment.

When grown in the mixed species grouping compared to in monoculture, *A. donax* facilitated growth of *B. salicifolia* in half of the treatment combinations (Figure 5). When *B. salicifolia* was grown with *A. donax*, its mean aboveground biomass was almost two-fold higher on average than when grow in monoculture. In the 4-way ANOVA of *B. salicifolia* aboveground biomass, the 4-way interaction was significant (Table 5) due to the presence of strong facilitation effects on half of the treatment combinations and no significant effects on the other half. In contrast, *A. donax* biomass was suppressed by competition with *B. salicifolia* under high soil moisture, light, and nutrient conditions; its biomass was two times higher in monoculture [17.05 kg (SE 15.98–18.20)] than in the mixed grouping containing *A. donax* and *B. salicifolia* [8.74 kg (SE 6.55–1.17)]. Higher mean aboveground biomass of *A. donax* monocultures in high soil moisture-full sun treatments than in any other combination of treatments as well as the competitive suppression of *A. donax* by *B. salicifolia* (Figure 5) yielded a significant 3-way interaction between plant grouping, soil moisture, and light in the 4-way ANOVA (Table 5).

DISCUSSION

In this study, I experimentally investigated competition between a particularly invasive bamboo-like grass species and three native woody riparian species under varying multiple-resource conditions that are found in natural riparian ecosystems. Superior interspecific competitive interactions between native and introduced species for water, light, and nutrient resources are critical in the plant invasion process in many ecosystems (D'Antonio and Vitousek 1992, Hamilton et al. 1999, Gordon and Rice 2000,

Green and Galatowitsch 2002, Booth et al. 2003, Kolb and Alpert 2003, Sher and Marshall 2003, Suding et al. 2004, White and Holt 2005, Minchinton et al. 2006, Richardson 2006, Coleman and Levine 2007). Preemptive as well as interspecific competition for resources between plant species has been well documented in many ecosystems (Connell 1983, Schoener 1983, Tilman 1987, Goldberg and Barton 1992, Daehler 2003). Evidence of several positive, negative, and non-significant competitive interactions between species was observed in the experiment, but interactions were different than predicted. Surprisingly, results indicated only one negative competitive interaction of *A. donax* on a native riparian plant, although its biomass was higher than almost all native plants in almost every experimental condition tested during the length of this study. Competitive interactions between these species may change over time and should be studied over a longer time span.

Competition

The only instance in which *A. donax* outcompeted a native plant species for resources was under the most stressful experimental conditions tested (low soil moisture, high light, and no nutrient addition levels). Under these conditions, competition with *A. donax* resulted in lower *P. balsamifera* ssp. *trichocarpa* biomass than found in monoculture. In fact, the mean aboveground biomass of *P. balsamifera* ssp. *trichocarpa* under these conditions was lower than in any other combination of resource levels. It seems likely that exploitative competition (competition for limiting resources) for soil moisture and available nutrients accounts for this negative effect of competition, since *A. donax* did not grow large enough to shade out *P. balsamifera* ssp. *trichocarpa* by

preemptive (competition for space) or overgrowth (one species grows over another, blocking light or depriving other species of a limiting resource) competition (Schoener 1983). This finding does not concur with Grime's hypothesis that resource competition is relatively unimportant for plants in unproductive or stressful environments due to the low biomass produced and corresponding low resource depletion (Grime 1977, 1979). According to Tilman (1988) however, competition occurs across productivity gradients and plants compete strongly under low resource conditions for belowground resources, mainly nutrients and water. Alpert et al. (2000) asserted that environmental stress may shift the competitive balance between invasive and native plants; mainly invasive plants take advantage of high resource availability compared to natives and low resource availability tends to cause low invasibility. However, I found that *A. donax* grew much more rapidly than all three native species under nearly all treatment conditions and suppressed one native species under low resource conditions.

Despite these hypotheses and predictions, invasive-native competitive interactions in conditions of high environmental stress are not well understood and experimental results vary by species and ecosystem. In grasslands of the western U.S., low nitrogen levels were found to have no effect on competitive ability of invasive annual grasses (Kolb and Alpert 2003, Lowe et al. 2003, Thomsen et al. 2006) or an invasive herb (*Centaurea diffusa*) on native grassland species. An invasive perennial grass (*Phalaris arundinacea*) suppressed native aboveground and belowground biomass in a wetland sedge meadow at low nitrate levels (Green and Galatowitsch 2002), yet lower phosphorus levels decreased *C. diffusa* competitive advantage over native species (Suding et al.

2004). Lowered water availability had no effect on competitive interactions between an invasive grass compared to a native grass in a Canadian mixed-grass prairie; however, low water availability was found to favor a small invasive tree, *Tamarix ramosissima*, in a floodplain of the Mojave Desert (Cleverly et al. 1997). Only one published experiment has examined competitive interactions under stressful conditions similar to my study with low soil moisture, high light, and low soil nutrients. The non-native annual grass (*Lolium multiflorum*) outcompeted a native perennial grass (*Hordeum brachyantherum*) at all resource levels when germinated simultaneously (Kolb et al. 2002). No studies showed increase in (or higher) competitive ability of invasive species relative to native species in stressful conditions of low nutrients, low water, and/or high light availability (Alpert et al. 2000). My experiment demonstrates that resource competition between invasive and native species may be highly species-specific under stressful environmental conditions. Differences in physiology of competing species, including variation in soil moisture and associated nutrient use, phenology, and differing rooting depth, may be important in mediating competitive interactions between *A. donax* and native woody riparian species (Reynolds and Pacala 1993, Fargione and Tilman 2005, Schenk 2006).

Although specific light requirements of *A. donax* and dominant riparian plant species in California are not well known (Braatne et al. 1996), invasive grass species are known to prevent woody species establishment and growth by shading them (D'Antonio and Vitousek 1992). Under conditions of high soil moisture and nutrient levels but low light, such as those found in mature riparian forests along streams in California, *A. donax* biomass was lower when grown with *P. balsamifera* spp. *trichocarpa* compared to in

monoculture. Light limitations can promote strong belowground competition between species (Schenk 2006). Although not measured in this study, similarities in rooting depth and higher growth rate of roots versus shoots of *P. balsamifera* spp. *trichocarpa* (Braatne et al. 1996, Pregitzer and Friend 1996) compared to *A. donax* in these conditions may help explain suppression of *A. donax*. *Populus balsamifera* spp. *trichocarpa* develops a shallow, lateral root system primarily with occasional sinker roots (similar to a taproot) (Pregitzer and Friend 1996). Nonetheless, this finding was surprising given the documented shade-intolerance of riparian *Populus* spp. (Walters and Reich 2000, Portsmuth and Niinemets 2007), but competitive effects might differ if grown from seed due to high light germination requirements (Braatne et al. 1996). Conservation and restoration of structurally diverse mature riparian forest, including *P. balsamifera* spp. *trichocarpa*, may help suppress *A. donax* invasion where high water and nutrient conditions prevail.

Competition with both *S. laevigata* and *B. salicifolia* reduced *A. donax* biomass by half when grown together in mixed groupings in high soil moisture, light and nutrient conditions. Suppression of *A. donax* biomass by native trees in these high resource conditions was an unexpected result. I predicted *A. donax* would competitively suppress and exclude natives under high resource availability following Goldberg and Novoplanksy's (1997) two-phase resource dynamics hypothesis and Tilman's resource competition hypothesis (Tilman 1982, 1988). Native plant preemptive competition may be responsible for negative effects on *A. donax* biomass, since water, light, and nutrient resources were abundant. Although biomass of these two natives was much lower than

the *A. donax* they suppressed, their woody phenology (upward, wide branching growth habit) may have restricted *A. donax* from expanding horizontally in all directions as it does naturally when grown alone or with other *A. donax* individuals. After the first year of growth upward, *A. donax* adds biomass by growing outward in a clonal manner. It appears that *S. laevigata* and *B. salicifolia* were able to limit its growth outward toward them somewhat (although not totally). Close observation of *A. donax* removed after the experiment indicated that individual clones planted in monoculture (four individuals) grow laterally in all directions intertwining with other *A. donax* individuals.

Facilitation

The role of positive interspecific competition for multiple resources in the invasion process has been relatively unexplored, but potentially of considerable importance in explaining mechanisms of riparian ecosystems invasion. Most examples of invasive plant species exerting competitive exclusion on native species have focused on and demonstrated negative competitive effects varying only one resource condition. However, the importance of facilitation in plant community organization and structure and its role in ameliorating harsh physical environments have been elucidated recently (Bertness and Callaway 1994, Bruno et al. 2003). Several examples of positive competitive interactions, or facilitation, between invasive and native plant species have been documented (Maron and Connors 1996, Green and Galatowitsch 2001, Rodriguez 2006).

Direct positive interactions, including facilitation, between native and invasive species has been overlooked until recently (Bertness and Callaway 1994, Rodriguez

2006). In California coastal prairie, Maron and Connors (1996) demonstrated that the native bush lupine shrub (*Lupinus arboreus*) facilitates an invasive annual grass (*Bromus diandrus*) invasion through fertilizing of the surrounding soil by nitrogen fixing and deposition of nitrogen-rich litter. I found only one study exhibiting facilitation of a native plant species by an invasive plant species; evidence of weak facilitative effects of an invasive wetland monocot (*Typha* x *glauca*) on native sedge meadow community were documented under the highest nitrate levels applied (Green and Galatowitsch 2001). However, the authors admit that *T*. x *glauca* did not appear to be well established during the short duration (4-months) of the experiment and this likely effected results. I discovered that the invasive *A. donax* facilitated the native *B. salicifolia* under half of the conditions tested; *B. salicifolia* exhibited much higher biomass when grown with *A. donax* than when grown in monoculture. In three out of four treatments tested, facilitation of the native *B. salicifolia* was detected under high soil moisture, high light, or low nutrient conditions. Similar but weaker trends in facilitation of *S. laevigata* by *A. donax* were observed.

Plant facilitation may be a particularly common characteristic in harsh physical environments in which primary space-holders buffer neighbors from potentially limiting stresses (Bertness and Callaway 1994, Bruno et al. 2003, Rodriguez 2006). Introduction of novel habitats or physical structure provided by an invasive species can alter abiotic conditions that enable native species to survive (Rodriguez 2006). Although both plants occupy roughly the same rooting zone especially in the first few years under high soil moisture conditions, *A. donax* may ameliorate stressful conditions for *B. salicifolia*. For

example, *A. donax* may draw down high soil water content in the surrounding rooting zone in very high soil moisture levels or decrease high salinity levels, conditions that have been shown to limit *B. salicifolia* growth otherwise (Vandersande et al. 2001). Since *A. donax* is functionally unique compared to the native phreatophyte *S. laevigata* and slight facilitation was detected under almost all growing conditions, novel facilitation by *A. donax* could provide a new habitat structure for *S. laevigata* as well. Mechanisms responsible for this type of facilitative interaction should be addressed in future research. Finally, facilitation of *B. salicifolia* and *S. laevigata* by *A. donax* may be only present in paired species groupings or when surrounded by *A. donax* and absent or not as important in naturally diverse riparian communities due to more complex interspecific relationships with other species.

High Resource Levels and Competitive Exclusion

Contrary to my prediction, I found that *A. donax* did not exhibit superior resource competition or competitive exclusion of natives under high resource levels during the time period of my experiment. *Arundo donax* exhibits competitive exclusion of native species in riparian ecosystems in Mediterranean-type climates under most resource conditions, especially in high water, light, and nutrient levels. Although most competition experiments are 2 years or less in duration (Goldberg and Barton 1992), exclusion of native plant species by *A. donax* by resource competition was not observed due likely to the short duration of this study.

Arundo donax demonstrated inferior resource competition ability in almost all conditions, was suppressed by both a native tree and shrub in high resource conditions,

and even facilitated the native shrub *B. salicifolia* in half of the treatments. Despite these disadvantages, *A. donax* was still much more productive in high soil moisture, light, and nutrients compared to the native plants and under other experimental conditions. *Arundo donax* appears to be on a trajectory to competitive exclusion of natives when resource availability is high (high soil moisture, light, and nutrient levels) regardless of its inferior resource competitive ability.

Results of resource competition experiments between invaders and native species vary considerably by resource level (Alpert et al. 2000), but most invaders benefited from elevated nutrient and water conditions. In a review of invader versus native plant species performance, invaders exhibited either universal superior competitive performance or superior performance in high nutrient conditions in two-thirds of the studies examined, but under low resource conditions native species usually outperformed invaders (Daehler 2003). Daehler (2003) concluded from his evaluation that relative performance of invasive compared to native species may shift in high resource conditions; increased resource availability combined with altered disturbance regimes, not universal performance advantages, often increase performance of invasive relative to native species. High biomass production of *A. donax* compared to native species in high resource conditions revealed in this study supports Daehler's hypothesis.

Invasion Mechanisms in Varying Resource Conditions

Results of this study suggest that mechanisms of *A. donax* invasion in riparian ecosystems may vary depending on availability for multiple resources and competition from native species. When resources are abundant (high soil moisture, light, and

nutrients) and no competition from native species exists, high allocation to photosynthetic tissue, high growth rate, and phenology of *A. donax* allow it to accumulate biomass faster than natives and eventually competitively exclude natives in these areas. In this study, *A. donax* monocultures grew exceptionally well under high soil moisture, nutrient, and light conditions, producing between four to six times more biomass than other native species under these optimal conditions. Several other invasive versus native plant comparative studies in wetlands have reported similar trends in clonal plant performance under conditions of high resource availability (Green and Galatowitsch 2001, Svengsouk and Mitsch 2001, Green and Galatowitsch 2002).

When resources are abundant, Tilman (1988) suggested differences in growth rates between species are due to a greater allocation of growth to photosynthetic tissues compared to non-photosynthetic roots, seeds, and branches/trunk. In contrast, plants that allocate to more non-photosynthetic tissues are favored in resource limiting environments (Tilman 1988). All *A. donax* biomass produced in the first year of growth, both leaves and culms, contains photosynthetic tissue (Sharma et al. 1998, Decruyenaere and Holt 2001), whereas *B. salicifolia*, *S. laevigata*, and *P. balsamifera* ssp. *trichocarpa* allocate a significant percentage of their biomass to non-photosynthetic trunks, branches, roots, and reproductive parts. *Arundo donax* has an extremely high growth rate, with shoot elongation of up to 10 cm per day and a relative growth rate of 0.13 g $g^{-1}day^{-1}$ under optimal conditions (Perdue 1958, Else 1996, Bell 1997, DiTomaso 1998, Spencer et al. 2005). At the end of two growing seasons, the mean height of *A. donax* throughout the experiment was 4.01 m (SE ± 0.04) and ranged from 0.64–7.84m. On average native

riparian species grown from cuttings attained much lower heights than *A. donax* after two years growth [*P. balsamifera* ssp. *trichocarpa* = 2.71 m (SE ± 0.03); *S. laevigata* = 2.75 m (SE ± 0.05); *B. salicifolia* = 2.94 m (SE ± 0.03)] or when grown from seedlings. Seedlings of native species such as *P. balsamifera* ssp. *trichocarpa* are known to reach only 5–60 cm after two years (Braatne et al. 1996). Furthermore, Decruyenaere and Holt (2005) documented year-round growth of *A. donax* and recruitment of new culms in sites with high nitrogen levels in southern California.

High resource conditions appear optimal for competitive exclusion of natives by *A. donax*. However, *A. donax* exhibited higher biomass production than either *S. laevigata* or *P. balsamifera* ssp. *trichocarpa* in most other treatments and greatest differences between *A. donax* and native species were seen in low soil moisture treatments. This evidence of plant plasticity (ability of a plant to thrive under all resource availability levels) may contribute to *A. donax* invasibility (Rezk and Edany 1979, Claridge and Franklin 2002) in other resource conditions, as is often the case with other invaders (Daehler 2003). When resource levels are lower, soil resource availability for *A. donax* versus riparian species is likely more distinctly partitioned (niche differences greater) and interspecific competition is avoided. Fargione and Tilman (2005) attributed coexistence of two prairie bunchgrasses to niche differences of phenology and rooting depth. Phreatophyte adaptations to resource limitation, such as greater root:shoot allocation (Vandersande et al. 2001, Schade and Lewis 2006) and deep tap roots (Tilman 1988) provide *A. donax* almost exclusive use of soil moisture and nutrients in shallow soil horizons. Interspecific competition between *A. donax* and native phreatophytes may

only be important when native aboveground biomass is extremely low and thus rooting depths are similar. For example, evidence of negative competitive effects of *A. donax* on native plants was only found in the most stressful environmental conditions (low soil moisture, light, and nutrients); competition from *A. donax* reduced *P. balsamifera* spp. *trichocarpa* biomass to the lowest values found in the experiment. Native woody riparian plants were not found to have a competitive advantage in low resource conditions as predicted (Tilman 1988) or shown in other studies (Alpert et al. 2000, Daehler 2003).

Arundo donax appears to be a "super invader", outperforming three common native species under high as well as low resource conditions (Daehler 2003) due to its unique morphology and physiology in riparian ecosystems of Mediterranean-type climates. However, the competitive ability of *A. donax* is strongest under high resource conditions. Strong novel facilitation of *B. salicifolia* (and week facilitation of *S. laevigata*) by *A. donax* in several resource conditions and competition from *P. balsamifera* spp. *trichocarpa* in high soil moisture-low light-high nutrient conditions may partially combat this invasion, but further study is required. Community-level competition experiments are needed to identify any indirect competitive interactions and verify the magnitude of pairwise or individual-level competitive interactions found in this study. Also, competitive interactions and productivity are likely to change over time and should be studied over a longer-time frame to validate invasion predictions.

CONCLUSIONS

This experiment demonstrated the absence of competitive advantages for resource use by a highly invasive grass, *A. donax*. Under high resource levels, *A. donax* is

extremely productive, but is slightly suppressed by two native species. Nonetheless, it still obtains a higher biomass than all native plant species under these conditions. Relatively high plant plasticity allows *A. donax* to obtain a higher biomass than natives under lower resource level conditions as well. The unique morphology and physiology of *A. donax* compared to native woody riparian species enable *A. donax* to dominate the aboveground biomass under most environmental conditions. Under high resource levels, *A. donax* appears to be on a trajectory of competitive exclusion despite little observed resource competition with two common native species.

The results of this study have broad application to managing *A. donax* in rivers and wetlands worldwide, especially in areas where high soil moisture, elevated nutrients, and disturbance (high light availability) all exist. In arid and Mediterranean-type climates with naturally low soil nutrients (Pettijohn 1975, Day 1983, diCastri 1991, Dallman 1998) and groundwater levels, dense urbanization and intense agricultural practices have elevated both nutrient and water levels in streams (Hazy 2006). Both the natural dynamic flood regime characteristic of these climates and anthropogenic enhancement of water, nutrients, and light levels have created the ideal conditions for invasion of river and stream systems by *A. donax* (see Chapter 3).

If we continue to create or promote high resource conditions in riparian ecosystems, invasion of *A. donax* will continue and may eventually lead to its expanded dominance in riparian ecosystems. Displacement of native riparian species by *A. donax* will only continue to lead to decreased biodiversity, altered ecosystem functioning, loss

of wildlife habitat, and changes in natural flood and fire (Bell 1997, DiTomaso 1998, Dudley 2000).

My findings will help organizations working on riparian habitat conservation and restoration predict locations where it is most invasive and least invasive, contributing to successful control of this invasive species. Large-scale restoration projects (levee and dam removal) need to consider the effects of these restoration actions on the potential spread of fast growing invasive plants like *A. donax*. *Arundo donax* will be most invasive in high soil moisture, nutrient and light levels and most difficult to manage or remove. These conditions are commonly found along urbanized or agricultural river floodplains after large storms and along interfaces between high nutrient land use practices (agricultural fields) and riparian ecosystems (see Chapter 3). Areas exhibiting the most stressful environmental conditions (low soil moisture, low nutrients, high light, and competition from native species) will have the lowest risk of *A. donax* invasion. *Arundo donax* control efforts should focus in these stressful environments, such as dry reaches of rivers or ephemeral streams where *B. salicifolia* and other native species are established along with *A. donax*.

Knowledge of the effects of environmental conditions on *A. donax* growth provides valuable insight into the timing and selection of management techniques in *A. donax* control projects. Active revegetation with natives after *A. donax* removal is recommended in areas with high soil moisture and nutrients. However, *B. salicifolia* planting may be lower priority because it naturally colonizes riparian ecosystems. Active revegetation may also be effective in the low soil moisture, low nutrients, and full sun

conditions found in many arid stream systems; under such condition in this study, *B. salicifolia* had a higher biomass and was facilitated by *A. donax*.. Because plants are more susceptible to herbicide treatments when carbohydrates are translocated from aboveground to belowground organs, *A. donax* in low soil moisture and full sun conditions may require treatment earlier in the growing season than those growing along streams with high water availability (Spencer et al. 2005).

Long-term control of invasive species such as *A. donax* in natural ecosystems may require management of resource levels that promote invasion to reduce growth and competition. Manipulation of resource availability in favor of a given native (desired) species may create a competitive advantage and a barrier to reinvasion (Blumenthal et al. 2003, Corbin and D'Antonio 2004a, Suding et al. 2004, Prober et al. 2005, Perry and Galatowitsch 2006). Watershed management organizations should consider reducing nutrient levels from urban runoff and excess treated wastewater released into rivers to reduce growth and invasion by *A. donax*. Suppression of *A. donax* via competition from several native species under high soil moisture and low light conditions has implications for riparian forest conservation and restoration efforts aimed at controlling *A. donax*, but further research is needed to verify these finding over a longer time frame. Conservation and restoration of structurally and species diverse riparian forests may help to suppress and reduce *A. donax* invasion in areas of high soil moisture.

TABLES

Table 1. Plant distribution in competition plant groupings (four plants per grouping) used in the field experiment.

Competition grouping treatment	**Plant species (number of species per grouping)**			
	Arundo donax	***Baccharis salicifolia***	***Salix laevigata***	***Populus balsamifera* ssp. *trichocarpa***
2-species grouping	2	2		
	2		2	
	2			2
1-species grouping (monoculture)	4			
		4		
			4	
				4

Table 2. Four-way ANOVA significance table for aboveground biomass (total biomass at end of 2004 growing season) by factors of competition groupings [2-species mixed grouping of *A. donax* and one native riparian species (*S. laevigata*, *P. balsamifera* ssp. *trichocarpa*, and *B. salicifolia)* and monocultures groupings)], soil moisture (high and low), and light (high and low), and nutrients (high and none). Significant results are reported in bold.

Factors and interactions	Mean aboveground biomass
Plant grouping	**$F_{(9,560)}$ = 33.384, P < 0.001*** **
Soil moisture	**$F_{(1,560)}$ = 145.772, P < 0.001*** **
Light	**$F_{(1,560)}$ = 26.615, P < 0.001*** **
Nutrients	**$F_{(1,560)}$ = 16.339, P < 0.001*** **
Plant grouping x soil moisture	**$F_{(9,560)}$ = 1.917, P = 0.047***
Plant grouping x light	**$F_{(9,560)}$ = 3.633, P < 0.001*** **
Plant grouping x nutrients	$F_{(9,560)}$ = 1.100, P = 0.361
Soil moisture x light	**$F_{(1,560)}$ = 81.422, P < 0.001*** **
Soil moisture x nutrients	$F_{(1,560)}$ = 3.365, P = 0.067
Light x nutrients	**$F_{(1,560)}$ = 5.593, P = 0.018***
Plant grouping x soil moisture x light	**$F_{(9,560)}$ = 2.974, P = 0.002** **
Plant grouping x soil moisture x nutrients	$F_{(9,560)}$ = 1.124, P = 0.343
Plant grouping x light x nutrients	$F_{(9,560)}$ = 1.789, P = 0.067
Soil moisture x light x nutrients	**$F_{(1,560)}$ = 4.689, P = 0.031***
Plant grouping x soil moisture x light x nutrients	$F_{(9,560)}$ = 0.694, P = 0.715
r^2	0.581

Legend: * = 0.05 ≥ P > 0.01 = significant, ** = 0.01 ≥ P > 0.001 = highly significant, *** = P ≤ 0.001 = very highly significant

Table 3. Four-way ANOVA significance table for mean aboveground biomass (total biomass at end of 2004 growing season) of *A. donax* and *P. balsamifera* ssp. *trichocarpa* by factors of plant groupings (2-species mixed grouping and monocultures), soil moisture (high and low), light (high and low), and nutrients (high and none). Significant results are reported in bold.

Factors and interactions	*A. donax*	*P. balsamifera* ssp. *trichocarpa*
Plant grouping	$F_{(1,122)} = 1.789$, $P = 0.184$	$F_{(1,115)} = 0.053$, $P = 0.819$
Soil moisture	**$F_{(1,122)} = 35.445$, $P < 0.001$*** **	**$F_{(1,115)} = 63.190$, $P < 0.001$*** **
Light	**$F_{(1,122)} = 36.561$, $P < 0.001$*** **	**$F_{(1,115)} = 4.094$, $P = 0.045$* **
Nutrients	**$F_{(1,122)} = 7.682$, $P = 0.006$** **	**$F_{(1,115)} = 6.966$, $P = 0.009$** **
Plant grouping x soil moisture	$F_{(1,122)} = 1.027$, $P = 0.313$	$F_{(1,115)} = 0.900$, $P = 0.345$
Plant grouping x light	$F_{(1,122)} = 2.118$, $P = 0.148$	$F_{(1,115)} = 2.340$, $P = 0.129$
Plant grouping x nutrients	$F_{(1,122)} = 0.881$, $P = 0.350$	$F_{(1,115)} = 1.017$, $P = 0.315$
Soil moisture x light	**$F_{(1,122)} = 87.616$, $P < 0.001$*** **	**$F_{(1,115)} = 5.376$, $P = 0.022$* **
Soil moisture x nutrients	$F_{(1,122)} = 1.838$, $P = 0.178$	$F_{(1,115)} = 0.068$, $P = 0.795$
Light x nutrients	**$F_{(1,122)} = 12.246$, $P = 0.001$*** **	$F_{(1,115)} = 0.061$, $P = 0.805$
Plant grouping x soil moisture x light	$F_{(1,122)} = 1.024$, $P = 0.314$	$F_{(1,115)} = 0.241$, $P = 0.624$
Plant grouping x soil moisture x nutrients	$F_{(1,122)} = 0.706$, $P = 0.402$	$F_{(1,115)} = 0.165$, $P = 0.686$
Plant grouping x light x nutrients	**$F_{(1,122)} = 4.564$, $P = 0.035$* **	**$F_{(1,115)} = 5.022$, $P = 0.027$* **
Soil moisture x light x nutrients	**$F_{(1,122)} = 8.449$, $P = 0.004$** **	$F_{(1,115)} = 0.369$, $P = 0.545$
Plant grouping x soil moisture x light x nutrients	$F_{(1,122)} = 0.242$, $P = 0.623$	$F_{(1,115)} = 0.265$, $P = 0.608$
r^2	0.646	0.457

Table 4. Four-way ANOVA significance table for mean aboveground biomass (total biomass at end of 2004 growing season) of *A. donax* and *S. laevigata* by factors of plant groupings (2-species mixed grouping and monocultures), soil moisture (high and low), light (high and low), and nutrients (high and none). Significant results are reported in bold.

Factors and interactions	***A. donax***	***S. laevigata***
Plant grouping	$F_{(1,122)} = 0.034$, $P = 0.854$	$\mathbf{F_{(1,120)} = 5.348, P = 0.022^{*}}$
Soil moisture	$\mathbf{F_{(1,122)} = 52.395, P < 0.001^{***}}$	$\mathbf{F_{(1,120)} = 21.523, P < 0.001^{***}}$
Light	$\mathbf{F_{(1,122)} = 23.905, P < 0.001^{***}}$	$F_{(1,120)} = 1.303$, $P = 0.256$
Nutrients	$F_{(1,122)} = 0.873$, $P = 0.352$	$F_{(1,120)} = 0.636$, $P = 0.427$
Plant grouping x soil moisture	$F_{(1,122)} = 1.364$, $P = 0.245$	$F_{(1,120)} = 0.076$, $P = 0.783$
Plant grouping x light	$F_{(1,122)} = 0.423$, $P = 0.516$	$F_{(1,120)} = 0.084$, $P = 0.772$
Plant grouping x nutrients	$F_{(1,122)} = 1.631$, $P = 0.204$	$F_{(1,120)} = 1.076$, $P = 0.302$
Soil moisture x light	$\mathbf{F_{(1,122)} = 73.333, P < 0.001^{***}}$	$\mathbf{F_{(1,120)} = 5.427, P = 0.022^{*}}$
Soil moisture x nutrients	$F_{(1,122)} = 0.477$, $P = 0.491$	$\mathbf{F_{(1,120)} = 4.416, P = 0.038^{*}}$
Light x nutrients	$\mathbf{F_{(1,122)} = 4.349, P = 0.039^{*}}$	$F_{(1,120)} = 0.904$, $P = 0.344$
Plant grouping x soil moisture x light	$F_{(1,122)} = 2.279$, $P = 0.134$	$F_{(1,120)} = 0.918$, $P = 0.340$
Plant grouping x soil moisture x nutrients	$F_{(1,122)} = 3.837$, $P = 0.052$	$F_{(1,120)} = 0.514$, $P = 0.475$
Plant grouping x light x nutrients	$F_{(1,122)} = 0.194$, $P = 0.660$	$F_{(1,120)} = 0.407$, $P = 0.525$
Soil moisture x light x nutrients	$F_{(1,122)} = 3.866$, $P = 0.052$	$F_{(1,120)} = 0.060$, $P = 0.808$
Plant grouping x soil moisture x light x nutrients	$F_{(1,122)} = 0.897$, $P = 0.345$	$F_{(1,120)} = 0.013$, $P = 0.908$
$\mathbf{r^2}$	0.652	0.310

Table 5. Four-way ANOVA significance table for mean aboveground biomass (total biomass at end of 2004 growing season) of *A. donax* and *B. salicifolia* by factors of plant groupings (2-species mixed grouping and monocultures), soil moisture (high and low), light (high and low), and nutrients (high and none). Significant results are reported in bold.

Factors and interactions	***A. donax***	***B. salicifolia***
Plant grouping	**$F_{(1,125)} = 4.715$, $P = 0.032$***	**$F_{(1,128)} = 21.950$, $P < 0.001$*****
Soil moisture	**$F_{(1,125)} = 56.410$, $P < 0.001$*****	**$F_{(1,128)} = 27.082$, $P < 0.001$*****
Light	**$F_{(1,125)} = 18.760$, $P < 0.001$*****	**$F_{(1,128)} = 32.204$, $P < 0.001$*****
Nutrients	**$F_{(1,125)} = 14.659$, $P < 0.001$*****	$F_{(1,128)} = 3.708$, $P = 0.056$
Plant grouping x soil moisture	$F_{(1,125)} = 0.483$, $P = 0.488$	$F_{(1,128)} = 1.033$, $P = 0.311$
Plant grouping x light	$F_{(1,125)} = 1.159$, $P = 0.284$	$F_{(1,128)} = 3.079$, $P = 0.082$
Plant grouping x nutrients	$F_{(1,125)} = 2.789$, $P = 0.097$	**$F_{(1,128)} = 5.154$, $P = 0.025$***
Soil moisture x light	**$F_{(1,125)} = 55.937$, $P < 0.001$*****	**$F_{(1,128)} = 16.483$, $P < 0.001$*****
Soil moisture x nutrients	$F_{(1,125)} = 2.668$, $P = 0.105$	$F_{(1,128)} = 0.009$, $P = 0.925$
Light x nutrients	$F_{(1,125)} = 0.801$, $P = 0.373$	$F_{(1,128)} = 0.093$, $P = 0.761$
Plant grouping x soil moisture x light	**$F_{(1,125)} = 5.539$, $P = 0.020$***	$F_{(1,128)} = 0.488$, $P = 0.486$
Plant grouping x soil moisture x nutrients	$F_{(1,125)} = 0.908$, $P = 0.342$	**$F_{(1,128)} = 5.346$, $P = 0.022$***
Plant grouping x light x nutrients	$F_{(1,125)} = 0.505$, $P = 0.479$	$F_{(1,128)} = 0.548$, $P = 0.460$
Soil moisture x light x nutrients	$F_{(1,125)} = 2.519$, $P = 0.115$	$F_{(1,128)} = 2.638$, $P = 0.107$
Plant grouping x soil moisture x light x nutrients	$F_{(1,125)} = 1.579$, $P = 0.211$	**$F_{(1,128)} = 6.267$, $P = 0.014$***
r^2	0.633	0.496

FIGURES

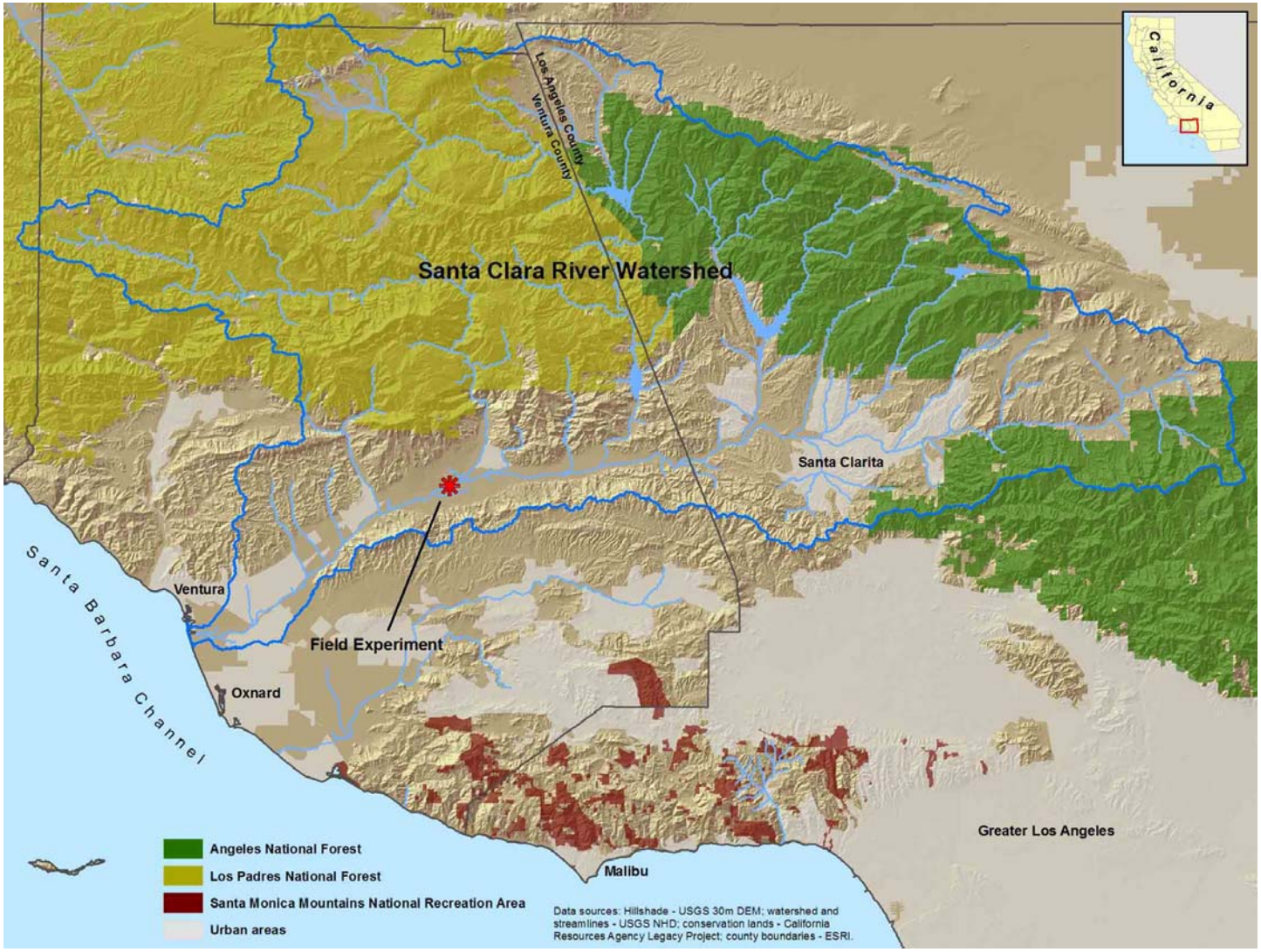
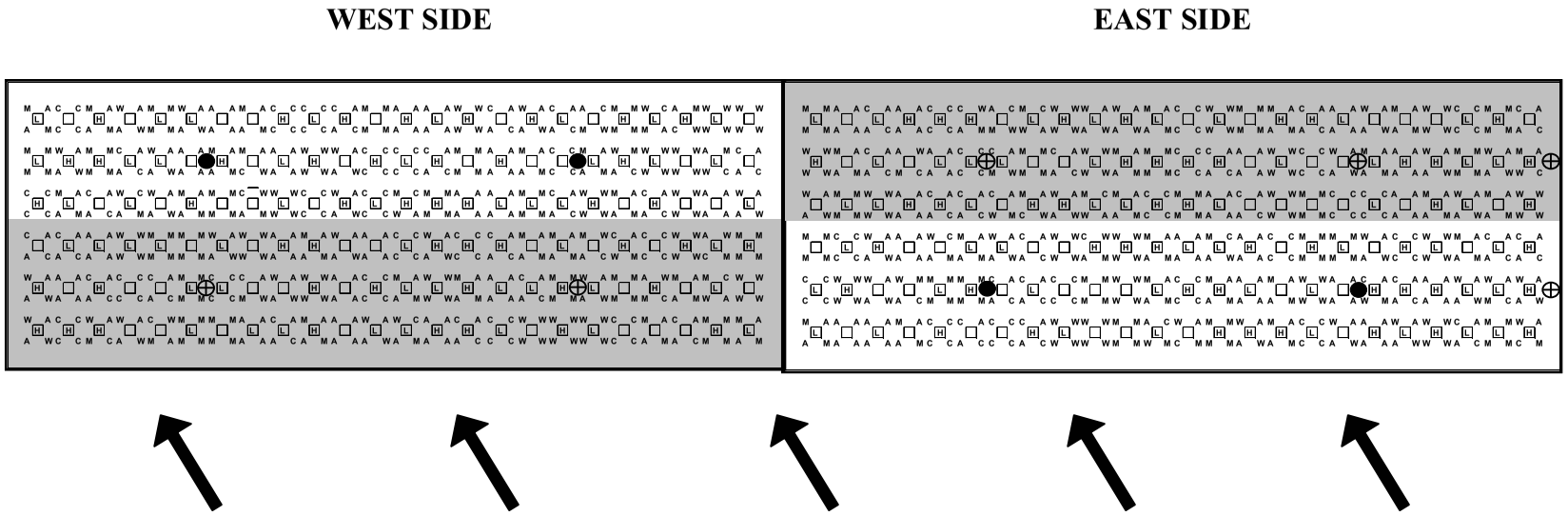


Figure 2. Location of field experiment study site, Santa Clara River Watershed, Ventura County, California.



Shallow Groundwater Hydrology

Legend:

- **A** = **Arundo (*Arundo donax*)**
- **C** = **Black cottonwood (*Populus balsamifera ssp. trichocarpa*)**
- **M** = **Mulefat (*Baccharis salicifolia*)**
- **W** = **Red willow (*Salix laevigata*)**
- **H** = **High N fertilizer treatment**
- **L** = **Low N fertilizer treatment**
- **N** = **No N fertilizer treatment**
- ▢ = **80% shade treatment and plant grouping**
- ● = **Soil moisture monitoring stations (deep only)**
- ⊕ = **Soil moisture monitoring stations (shallow and deep)**

Figure 3. Field experiment planting and sampling layout.

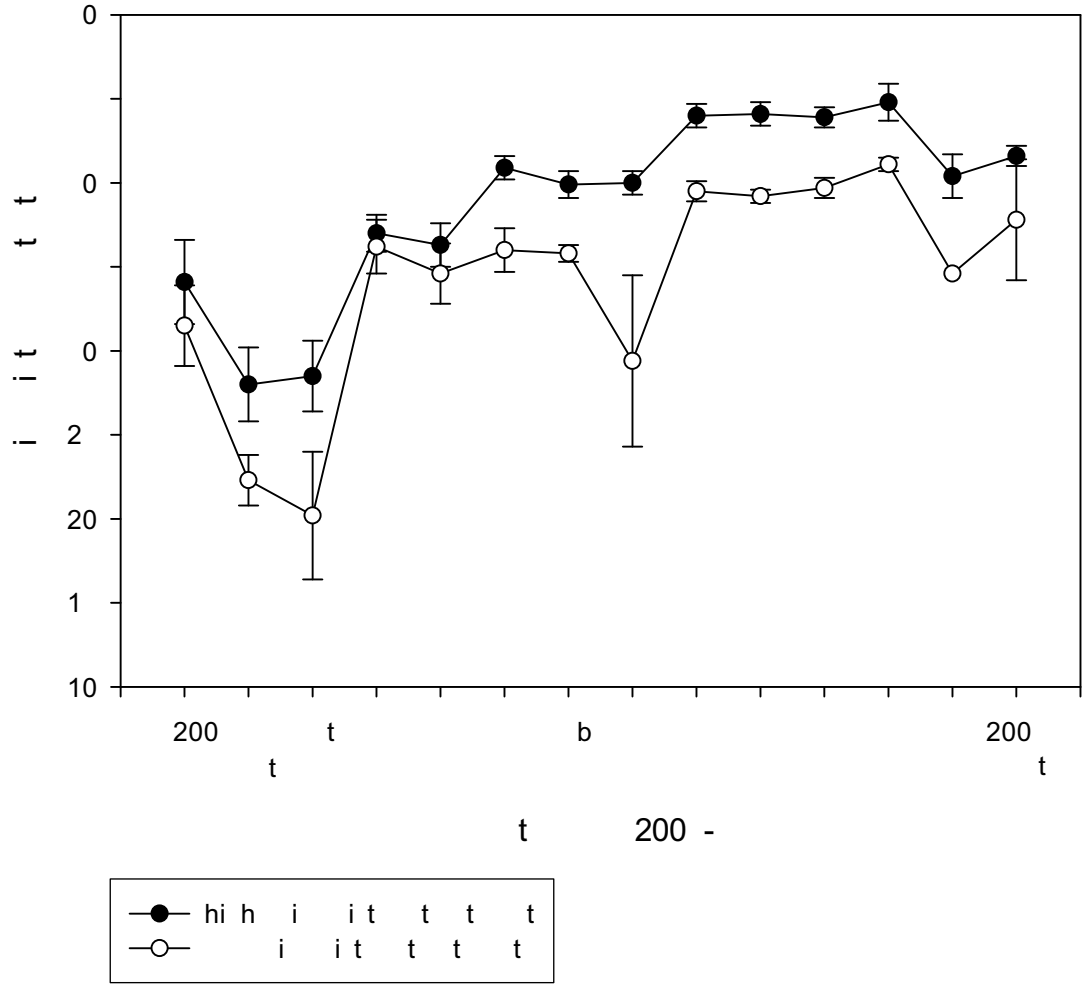


Figure 4. Mean monthly soil moisture content (percent) at 60–80 cm depth in the east and west sides of the experiment (high and low soil moisture treatments).

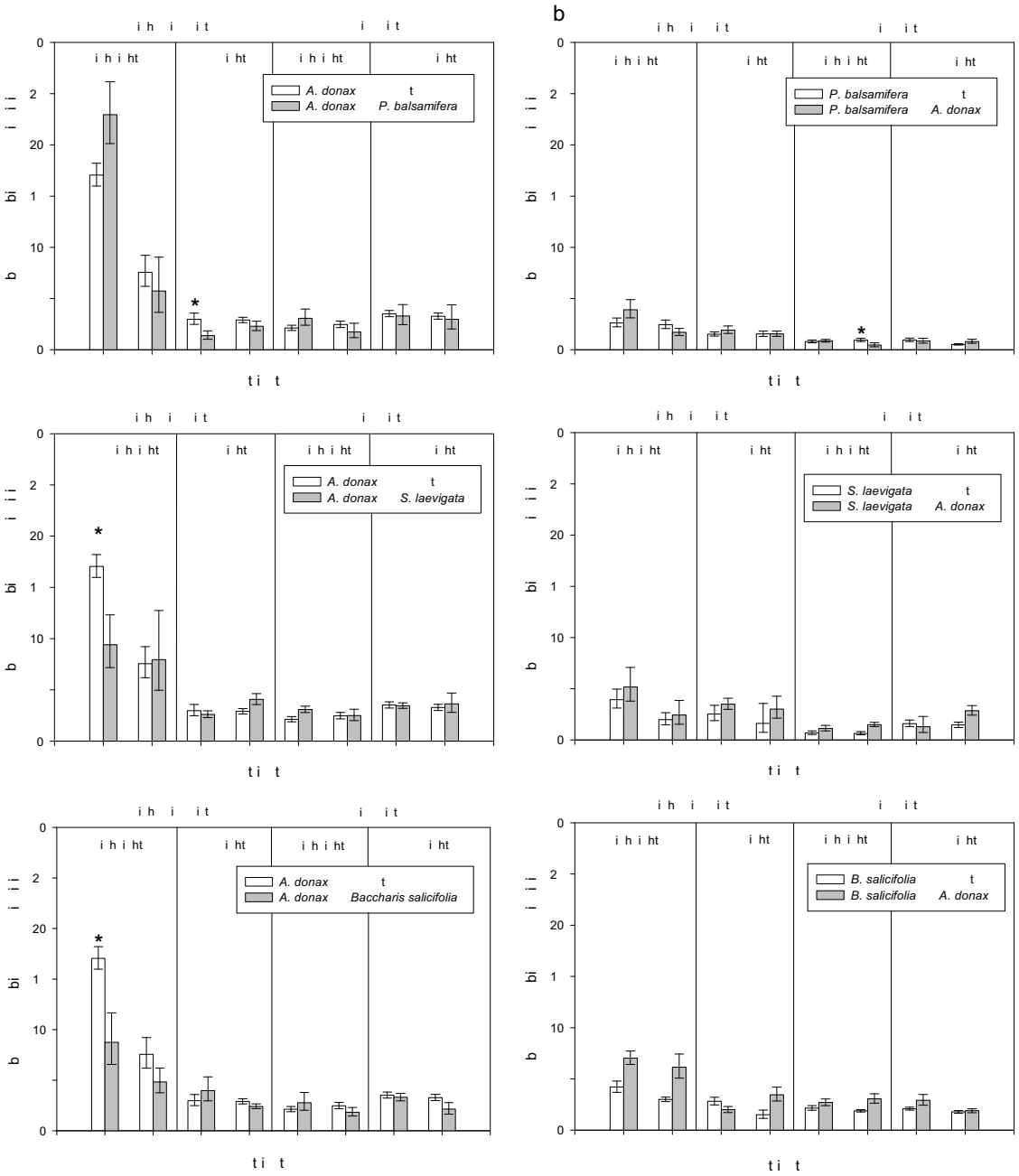


Figure 5. Mean aboveground biomass (± SE represented by error bars) of plants grown in monoculture compared to with a single competitor in the field experiment at the end of the 2004 growing season. Graphs show competitive effects by species pairings: a) *A. donax* by *P. balsamifera* spp. *trichocarpa*, b) *P. balsamifera* spp. *trichocarpa* by *A. donax*, c) *A. donax* by *S. laevigata*, d) *S. laevigata* by *A. donax*, e) *A. donax* by *B. salicifolia*, and f) *B. salicifolia* by *A. donax*. Asterisks denote results of post-hoc hypothesis tests (comparison of means) between plant groupings within similar treatments, with significance recognized at $\alpha < 0.05$.

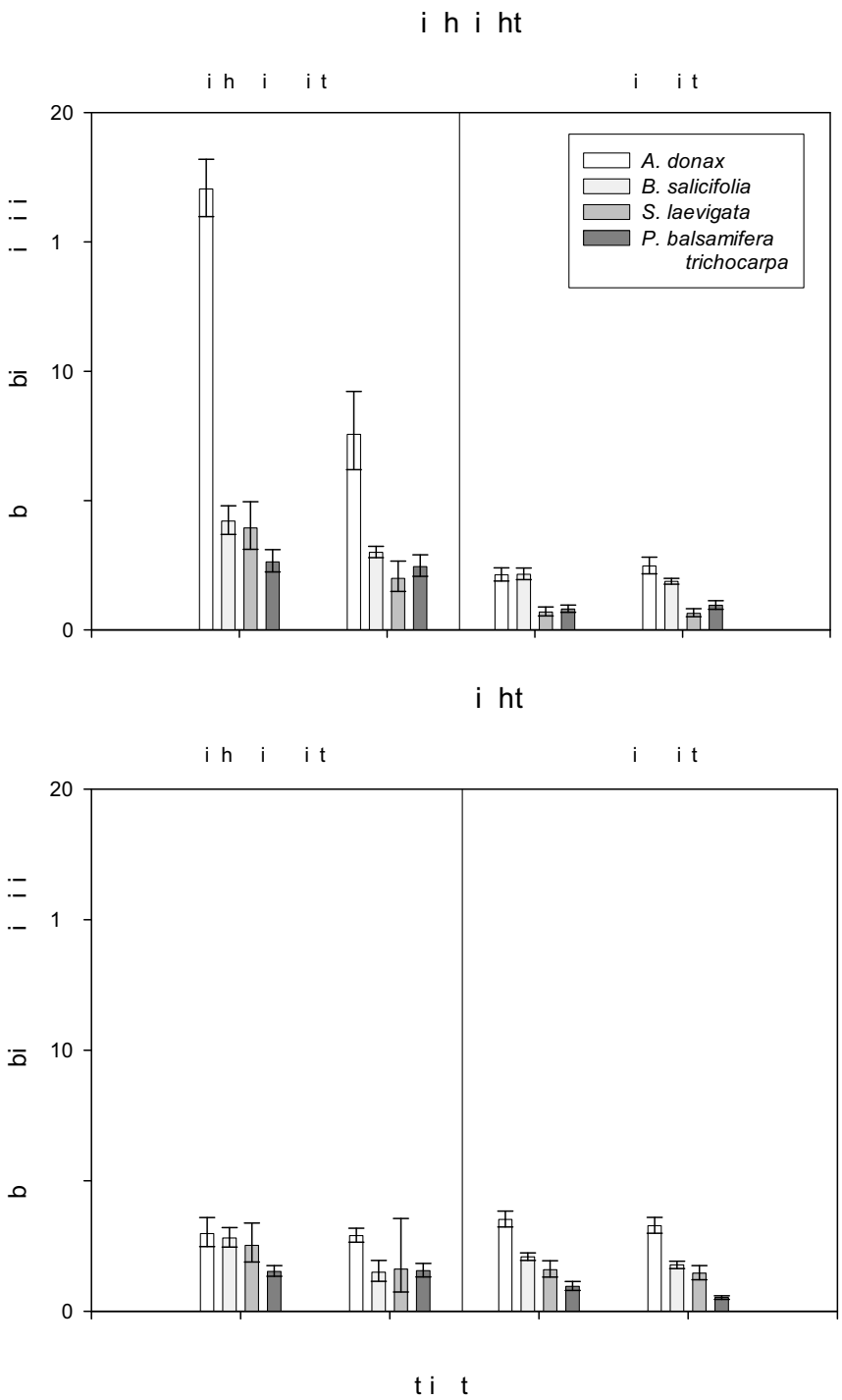


Figure 6. Mean aboveground biomass (± SE represented by error bars) of all plants grown in monoculture in the field experiment at the end of the 2004 growing season by species, soil moisture, nutrient, and light factors. Graphs are grouped by high light (a) and low light growing conditions (b).

APPENDICES

APPENDIX 2-1

BIOMASS REGRESSION EQUATIONS

Figure 1. Regression equations for *A. donax*, *Baccharis salicifolia*, *Salix laevigata*, and *Populus balsamifera* ssp. *trichocarpa* used to predict aboveground biomass of all plants under various soil moisture and light treatments in the field experiment in 2003. Equations ($y = b_1x_1 + c$) were based on aboveground biomass (g) of sample culms/branches (dependent variable or y), a

	High soil moisture						**Low soil moisture**					
	Full sun			**80% shade**			**Full sun**			**80% shade**		
Plant species	**b**	**c**	**r^2**	**b**	**c**	**r^2**	**b**	**c**	**r^2**	**b**	**c**	**r^2**
A. donax *(< 1 year)*	1.878	-0.197	0.906	3.097	-3.192	0.936	1.142	0.794	0.425	2.086	-0.760	0.923
B. salicifolia	2.287	-1.502	0.969	2.503	-2.110	0.995	2.455	-2.101	0.989	2.402	-1.905	0.969
S. laevigata	2.172	-1.023	0.989	2.173	-1.042	0.985	2.130	-1.248	0.979	2.335	-1.421	0.992
P. balsamifera* ssp. *trichocarpa	2.273	-1.037	0.993	2.256	-1.150	0.993	2.092	-1.266	0.982	2.210	-1.127	0.933

regression coefficient (b_1), basal diameter (mm) of sample culms/branches (independent variable or x_1), and a constant (y-intercept or c). All data were ln transformed. All regressions were significant.

Table 2. Regression equations for *A. donax*, *Baccharis salicifolia*, *Salix laevigata*, and *Populus balsamifera* ssp. *trichocarpa* used to predict aboveground biomass of all plants under various soil moisture and light treatments in the field experiment in 2004. Equations ($y = b_1x_1 + c$) were based on aboveground biomass (g) of sample culms/branches (dependent variable or y), a

	High soil moisture						**Low soil moisture**					
	Full sun			**80% shade**			**Full sun**			**80% shade**		
Plant species	**b**	**c**	**r^2**	**b**	**c**	**r^2**	**b**	**c**	**r^2**	**b**	**c**	**r^2**
A. donax *(< 1 year)*	2.516	-1.744	0.980	1.609	0.770	0.908	1.864	-0.020	0.956	1.634	0.686	0.891
A. *donax* (> 1 year)	2.636	-1.910	0.971	2.301	-0.918	0.895	2.316	-1.290	0.936	2.856	-2.336	0.947
B. salicifolia	2.625	-2.132	0.995	2.511	-1.869	0.994	2.657	-2.314	0.993	2.658	-2.302	0.994
S. laevigata	2.195	-0.983	0.993	2.305	-1.228	0.990	2.295	-1.358	0.988	2.321	-1.337	0.995
P. balsamifera* ssp. *trichocarpa	2.408	-1.352	0.993	2.413	-1.498	0.996	2.306	-1.285	0.992	2.353	-1.445	0.993

regression coefficient (b_1), basal diameter (mm) of sample culms/branches (independent variable or x_1), and a constant (y-intercept or c). All data were ln transformed.

APPENDIX 2-2

PLANT SURVIVORSHIP IN FIELD EXPERIMENT

METHODS

Sampling Methods

I measured plant survivorship at three time periods: 1) survivorship of planted cuttings in March 2003, 2) plant survivorship at the end of 2003, and 3) plant survivorship at the end of 2004. A few cuttings (14) and rhizomes (9) that did not grow initially were replanted in spring 2003. 2003 and 2004 percent survivorship results represented the establishment success for all initial and replacement cuttings.

Statistical Analyses

Descriptive statistics were performed on plant survivorship measurements. Four-way ANOVAs (all combinations of competition groupings, soil moisture, light, and nutrient factors and levels) were performed on percent survivorship data for three time periods (cuttings and at the end of the two growing seasons) to determine treatment effects during the plant establishment period. Percent plant survivorship measured at the end of 2003 and 2004 was compared in the two-way ANOVA (year x competition grouping). The 36 four-species groupings and 96 low nutrient treatments plant groupings in the experiment were not included in these statistical analyses.

RESULTS

The four-way ANOVA (species x soil moisture x nutrients x light) for percent survivorship yielded no significant main effects or interactions for cuttings and plants at

the end of the 2004 growing season (Table 1), yet resulted in one two-way interaction between species and soil moisture for plant survivorship at the end of 2003 growing season (Table 1). Only five plants (0.8% of plants in groupings analyzed) did not survive the second growing season. First year plant survivorship of *P. balsamifera* ssp. *trichocarpa* was significantly lower within the high soil moisture treatment than in any other species and soil moisture treatment combination (Figure 1).

Table 1. Four-way ANOVA significance table for percent plant survivorship during establishment by factors of species from one-species and two-species groupings combined (*Arundo donax* and three native riparian species, *Salix laevigata*, *Populus balsamifera* ssp. *trichocarpa*, and *Baccharis salicifolia*), soil moisture (high and low), nutrient additions (high and none), and light (high and low). Results are for three time periods: 1) cutting survivorship (March 2003), 2) plant survivorship at end of 2003, and 3) plant survivorship at end of 2004. Significant results are in bold.

Factors and interactions	Cuttings	2003	2004
Species	$F_{(3,48)} = 1.821$, $P = 0.156$	$F_{(3,48)} = 2.352$, $P = 0.084$	$F_{(3,48)} = 2.523$, $P = 0.069$
Soil moisture	$F_{(1,48)} = 1.346$, $P = 0.252$	$F_{(1,48)} = 4.029$, $P = 0.050$	$F_{(1,48)} = 1.858$, $P = 0.179$
Nutrients	$F_{(1,48)} = 0.050$, $P = 0.824$	$F_{(1,48)} = 0.042$, $P = 0.839$	$F_{(1,48)} = 0.046$, $P = 0.831$
Light	$F_{(1,48)} = 1.625$, $P = 0.208$	$F_{(1,48)} = 0.855$, $P = 0.360$	$F_{(1,48)} = 0.170$, $P = 0.682$
Species x soil moisture	$F_{(3,48)} = 1.456$, $P = 0.238$	**$F_{(3,48)} = 3.628$, $P = 0.019$***	$F_{(3,48)} = 2.100$, $P = 0.113$
Species x nutrients	$F_{(3,48)} = 0.398$, $P = 0.755$	$F_{(3,48)} = 0.513$, $P = 0.675$	$F_{(3,48)} = 0.723$, $P = 0.543$
Species x light	$F_{(3,48)} = 0.400$, $P = 0.754$	$F_{(3,48)} = 1.197$, $P = 0.321$	$F_{(3,48)} = 0.412$, $P = 0.745$
Soil moisture x nutrients	$F_{(1,48)} = 0.361$, $P = 0.551$	$F_{(1,48)} = 0.490$, $P = 0.487$	$F_{(1,48)} = 1.018$, $P = 0.318$
Soil moisture x light	$F_{(1,48)} = 0.022$, $P = 0.884$	$F_{(1,48)} = 0.000$, $P = 0.984$	$F_{(1,48)} = 1.455$, $P = 0.234$
Nutrients x light	$F_{(1,48)} = 0.624$, $P = 0.434$	$F_{(1,48)} = 0.001$, $P = 0.980$	$F_{(1,48)} = 0.138$, $P = 0.712$
Species x soil moisture x nutrients	$F_{(3,48)} = 0.124$, $P = 0.946$	$F_{(3,48)} = 0.265$, $P = 0.850$	$F_{(3,48)} = 1.266$, $P = 0.296$
Species x soil moisture x light	$F_{(3,48)} = 2.431$, $P = 0.077$	$F_{(3,48)} = 1.253$, $P = 0.301$	$F_{(3,48)} = 1.543$, $P = 0.215$
Species x nutrients x light	$F_{(3,48)} = 1.193$, $P = 0.322$	$F_{(3,48)} = 2.046$, $P = 0.120$	$F_{(3,48)} = 0.921$, $P = 0.438$
Soil moisture x nutrients x light	$F_{(1,48)} = 0.111$, $P = 0.740$	$F_{(1,48)} = 0.772$, $P = 0.384$	$F_{(1,48)} = 1.359$, $P = 0.249$
Species x soil moisture x nutrients x light	$F_{(3,48)} = 2.212$, $P = 0.099$	$F_{(3,48)} = 2.104$, $P = 0.112$	$F_{(3,48)} = 2.431$, $P = 0.077$
r^2	0.428	0.490	0.457

* = $0.05 \geq P > 0.01$ = significant; ** = $0.01 \geq P > 0.001$ = highly significant; *** = $P \leq 0.001$ = very highly significant.

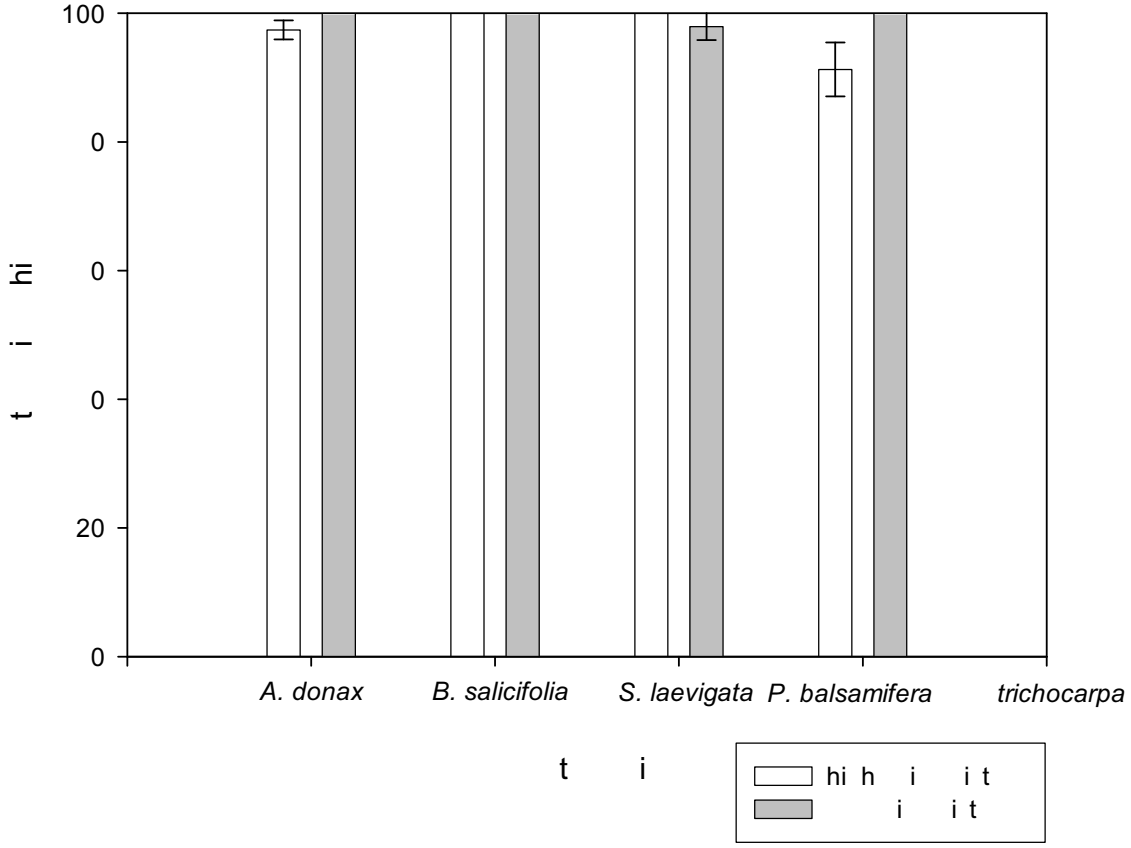


Figure 1. Effects of soil moisture availability on percent plant survivorship of *A. donax* compared to three native riparian plant species at the end of the first growing season (fall 2003) based on the four-way ANOVA (competition x soil moisture x nutrients x light). Letters denote results of post-hoc hypothesis tests (comparison of means) between individual treatments within each graph only, with significance recognized at $\alpha < 0.05$.

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CHAPTER 3 -

INFLUENCE OF ANTHROPOGENIC NUTRIENT ENRICHMENT ON INVASION OF RIPARIAN ECOSYSTEMS BY *ARUNDO DONAX* IN SOUTHERN CALIFORNIA

Abstract: One of the greatest threats to riparian ecosystems of Mediterranean-type climate regions, including California, is a member of the grass family (Poaceae), giant reed (*Arundo donax* L.). I tested the hypothesis that anthropogenic nutrient enrichment is one of the most significant factors contributing to the recent invasion of riparian ecosystems by *A. donax* in southern California. I examined the influence of nutrient enrichment of shallow groundwater and soil from various land use practices on the degree of infestation of *A. donax* throughout several coastal watersheds. Elevated levels of N (nitrogen) found in shallow groundwater and soils of floodplains were associated with adjacent land use and watersheds with higher anthropogenic nutrient inputs. Both large and small *A. donax* infestations on floodplains contained higher soil NO_3-N concentrations than did non-infested areas. Higher N and K (potassium) leaf tissue content of *A. donax* in large and small infestations compared to native red willow (*Salix laevigata* Bebb.) in non-infested and reference sites suggests that these nutrients may be more available to *A. donax*. Unlike *S. laevigata*, *A. donax* may take advantage of anthropogenically enriched N levels in riparian ecosystems, as illustrated by its positive response to all forms of shallow groundwater N in floodplains and soil N on riparian terraces. Results of this study suggest that N limiting conditions may naturally occur in

riparian ecosystems in this geologically young landscape, but anthropogenic nutrient inputs have elevated groundwater N:P ratios in study watersheds. Results of this study can help predict optimal nutrient conditions for *A. donax* invasion. Reducing excess N supply to riparian ecosystems associated with agricultural and residential land use activities may aid in the long-term control of *A. donax*.

Key Words: Arundo donax, giant reed, invasive species, alien species, nutrients, nutrient loading, nitrogen, phosphorus, land use, riparian, Mediterranean-type climate, watershed, rivers

INTRODUCTION

Both natural and anthropogenic disturbances along rivers in Mediterranean-type climate regions are thought to promote the spread of invasive plant species (Drake et al. 1989, Gregory et al. 1991, Pysek and Prach 1994, Else 1996, Else and Zedler 1996, Dudley 1998). Several experimental studies in wetland ecosystems have demonstrated higher response to nitrogen by clonal, invasive plants than natives (Green and Galatowitsch 2002, Maurer and Zedler 2002, Minchinton and Bertness 2003). Elevated nutrient levels have been linked to plant invasion in many ecosystems (Kolb et al. 2002, Booth et al. 2003, Brooks 2003, Kolb and Alpert 2003, Suding et al. 2004), however little is known about the role of nutrients in promoting invasion in riparian ecosystems (Wang 1998). In this paper, I explore the influence of anthropogenic nutrient enrichment on the invasion of riparian ecosystems by the clonal grass species *Arundo donax* in southern California.

Due to the intense but infrequent winter storm patterns characteristic of Mediterranean-type climates, rivers are heavily scoured every few years. Strong floods remove and disperse riparian vegetation downstream, creating open floodplains for colonization. Weedy plant species are able to establish and grow quickly in disturbed areas such as these (Elton 1958, Tilman 1988, Drake et al. 1989, Richardson et al. 2000), the most invasive of which often physically compete with native species for light, nutrients, and water. Historically, riparian ecosystems in Mediterranean-type climates have been severely altered by human perturbation. Since early human settlement of these areas, rivers have been dammed, channelized, mined, diverted, and subjected to

residential and commercial development in Mediterranean-type climates (Palmer 1993, Mount 1995). These alterations have magnified their susceptibility to plant invasions by weedy plant species (Randall et al. 1998, Rundel 1998). Currently, one of the greatest invasive threats to riparian ecosystems in Mediterranean-type climates is a tall, perennial bamboo-like member of the grass family (Poaceae) called giant reed (*Arundo donax* L.).

Indigenous to southern Eurasia, *A. donax* was introduced extensively to other locales and now thrives in many warm climates worldwide (Perdue 1958, Crampton 1974, Polunin and Huxley 1987, Hickman 1993, Sharma et al. 1998). In the United States, *A. donax* has become especially devastating to riparian habitats in California's Mediterranean-type climate region, creating significant impacts to natural-river functioning and sustainability (Rundel 2000). *Arundo donax* was introduced to agricultural landscapes in the Los Angeles area for building materials and erosion control along irrigation canals. Carried by floodwaters, *A. donax* eventually made its way to adjacent streams and rivers and by the 1820s patches were commonly found along floodplains of many streams (Robbins et al. 1951). However, it appears that *A. donax* has only recently succeeded in invading (i.e., expanding its distribution and displacing native vegetation) riparian ecosystems along floodplains and terraces in southern California after large floods in 1969 (Sanger Hedrick pers. comm.) (Bell 1997).

Arundo donax is one of the most successful weedy invaders in the disturbance-defined riparian ecosystems of Mediterranean-type climates (Bell 1997, Boose and Holt 1999). Although inflorescences (0.5 m long terminal panicles) are not known to produce seed in California (Johnson et al. 2006), *A. donax* reproduces readily by vegetative

propagation; it is dispersed downstream when small pieces of rhizomes or culms break off during flooding and land on bare, moist substrates (Else 1996, Else and Zedler 1996, Bell 1997, Boose and Holt 1999, Wijte et al. 2005). Growing at an extremely fast rate (up to 10 cm per day under optimal conditions), *A. donax* quickly establishes on exposed or sparsely vegetated soil and grows to more than 4 m in height after only a few months (Rieger and Kreager 1989) and may attain heights of up to 8 m a few years after establishment (Perdue 1958). Once established, *A. donax* then expands outward in area by clonal propagation (Decruyenaere and Holt 2001), crowding and displacing indigenous shrubs, herbs and grasses, and trees under elevated soil moisture, nutrient, and light conditions (Rieger and Kreager 1989). In this manner, *A. donax* forms extensive stands, or monocultures, along floodplains and terraces of California's river and stream systems.

Infestations of *A. donax* have created serious physical and biological problems along rivers in Mediterranean-type climate regions (Dudley and Collins 1995, DiTomaso 1998, Dudley 2000, Rundel 2003). Where it grows extensively along floodplains, *A. donax* physically obstructs natural water flow, thereby increasing the risk of flooding. As the aboveground biomass dries in the hot, dry summer months, *A. donax* creates a fire hazard where moisture-rich riparian corridors would normally form natural barriers to fire (Scott 1994, Rundel and Gustafson 2005). Furthermore, *A. donax* may outcompete native riparian species for scarce water resources (Iverson 1994, Coffman in press), thereby decreasing biodiversity and reducing the value of riparian habitats for wildlife (Kisner 2004).

Millions of dollars have been spent in efforts to remove *A. donax* from riparian ecosystems in southern California. Although these attempts have been successful in removing small infestations of *A. donax* on riparian terraces, it continues to thrive in floodplains. An understanding of the ecological conditions that promote continued growth and invasion of *A. donax* is needed for its effective control. Ever expanding residential and agricultural development in coastal southern California and other Mediterranean-type climates has led to increased water import and discharge into rivers, declining water quality, and removal of the once vast low-lying areas of riparian forest. The result – increased nutrient, water, and light availability – may promote invasion of riparian ecosystems by *A. donax* (Bell 1997, Wang 1998, Rundel 2003, Coffman et al. 2004). This study investigated one of the most important factors influencing *A. donax* invasion: elevated nutrient levels in riparian ecosystems caused by anthropogenic inputs.

Soils in Mediterranean-type climates commonly contain low levels of nitrogen (N) and phosphorus (P) (Day 1983, diCastri 1991, Dallman 1998). In southern California, the young sedimentary geology is naturally high in P, but has N-limiting conditions (Pettijohn 1975). Nutrient enrichment of riparian ecosystems (especially by N) from adjacent land use practices may promote *A. donax* growth and invasion in river systems of southern California. Excess N, P, and potassium (K) are transported in surface and shallow groundwater from various land use activities to adjacent riparian ecosystems (Schlosser and Karr 1981, Correll 1984, Correll et al. 1992, Triska et al. 1994, Rodda 1995, Basnyat et al. 1999). Weedy and invasive plant species often differ in their nutrient requirements and uptake efficiency compared to native plants, resulting in a

competitive advantage for the former in nutrient rich environments (Claridge and Franklin 2002). Thus, elevated nutrient levels in riparian ecosystems are thought to promote invasion of plants such as *A. donax*.

This study investigated the influence of anthropogenic nutrient enrichment on invasion of *A. donax* in three river systems of southern California. I hypothesized that nutrient enrichment of riparian ecosystems from anthropogenic sources has contributed significantly to invasion of river systems by *A. donax* in southern California. To test this hypothesis, I examined relationships between the degree of *A. donax* infestation and nutrient levels in the associated shallow groundwater, soil, and leaf tissue using a correlational approach.

METHODS

Study Area

The study area lies northwest of Los Angeles in Ventura and Los Angeles Counties, California. Three river systems (Calleguas Creek, the Santa Clara River, and Topanga Canyon) located in watersheds with varying compositions of land use were studied (Figure 7). Ten reference subwatersheds from within this region where *A. donax* is absent were used as indicators of natural conditions.

The Calleguas Creek watershed drains an area of approximately 888 km^2, predominantly in southern Ventura County. It contains a roughly equal mix of three main land use categories: ~30% residential development, ~32% agricultural areas (both row crops and orchards mostly in the western and lower watershed), and ~38% open

space (mainly in the mountains of the upper watershed) (Figure 8). This watershed was chosen for its relatively high level of anthropogenic nutrient input.

The Santa Clara River is one of southern California's last remaining large, unregulated river systems. The river and its tributaries drain a watershed of approximately 4,185 km^2, the second largest coastal watershed in southern California. The 187-km long river flows in a westerly direction from its headwaters on the northern slopes of the San Gabriel Mountains in Los Angeles County to the Oxnard Plain in Ventura County, emptying into the Pacific Ocean near the City of Ventura. The Santa Clara River contains a mix of land use types representing moderate anthropogenic nutrient input, although over 80% of the watershed (mainly upper and higher elevation portions) remains as open space (Figure 8). The floodplain of the lower watershed is dominated by agricultural land use (orchards and row crops), and urban and residential development is rapidly expanding in the mid to upper watershed.

The Topanga Canyon Watershed, approximately 91 km^2, is located in the heart of the Santa Monica Mountains in western Los Angeles County. Topanga Canyon is a low anthropogenic nutrient input system. The watershed is composed primarily of low-density rural residential development (6%) and open space (93%) in the upper parts of the watershed, with almost no agricultural land use (Figure 8).

To fully test my hypothesis that riparian ecosystems in developed watersheds were invaded due to increased nutrient supply from anthropogenic inputs, I documented reference conditions in undeveloped watersheds throughout the study area to compare to developed watersheds. In this coastal geographic region, none of the undeveloped

watersheds contained *A. donax*, so they were not true controls for testing my hypothesis. However to establish reference conditions, I sampled shallow groundwater, soil, and leaf tissue nutrients within ten undeveloped watersheds (reference sites) in the region: three subwatersheds (tributaries) of the Santa Clara River Watershed and seven smaller undeveloped watersheds in the Santa Monica Mountains. Reference sites were located in open space areas containing no upstream anthropogenic nutrient inputs and were dominated by red willow, *Salix laevigata* (no *A. donax* was present). I could not control for N inputs from atmospheric deposition, but based on model results for dry atmospheric N deposition for watersheds in the Los Angeles Region, I assumed similar levels of atmospheric N dry deposition among watersheds (Lu et al. unpublished data).

Study Design and Sampling Locations

I established stratified sampling locations along the main stem of each of the three river systems based on three factors and different levels within each factor: adjacent land use type (agricultural, residential development, and open space); fluvial geomorphic landform (floodplains and terraces); and degree of *A. donax* infestation (none, small, and large) (Table 6; Figure 8). Effects of nutrient inputs from land use activities on *A. donax* invasion were thought to be more directly related to adjacent land use type in higher riparian terraces (called terraces), whereas the watershed factor was used to address cumulative effects of upstream land use activities on floodplain sampling locations (lower terraces immediately adjacent to main channels with baseflow).

Each sampling location was approximately 600 m^2. Floodplain sampling sites were roughly 30 m in length (parallel and immediately adjacent to the main stream

channel, containing baseflow) by 20 m in width (perpendicular to the channel). Terrace sampling sites had similar dimensions but were located immediately adjacent to upland land use areas. I also selected locations where *A. donax* was: (1) completely absent and native riparian vegetation (*Salix laevigata*) dominated, (2) only present as small infestations (between 1–9 m^2), and (3) the dominant component of the vegetation (> 100 m^2), representing heavily invaded river reaches. *Salix laevigata* Bebb. (Salicaceae family) was selected because it is the most common woody plant consistently found throughout riparian ecosystems in the study area. Roots of the phreatophyte *S. laevigata* can reach up to 30 m when the groundwater table is deep, whereas *A. donax* roots have been observed to grow to only 8 feet in depth (Figure 9) (See Appendix 3-1 for site locations).

Sampling Methods

Samples of *A. donax* or *S. laevigata* leaf tissue and associated shallow groundwater and soils were taken once at each sampling location from July to September 2003. Ten *A. donax* or *S. laevigata* leaves from at least three plants were collected at each sampling location for leaf tissue nutrient analyses. *Arundo donax* leaves were collected at large and small infestation sampling sites. *Salix laevigata* leaves were collected from riparian ecosystem sampling sites with no *A. donax* and at reference sites where *A. donax* was absent. Only newly mature, healthy, full sun leaves were collected from the top of *A. donax* culms and the middle of *S. laevigata* canopies. Leaf tissue was analyzed for relative nutrient content to evaluate nutrient use and availability to plants (Taiz and Zeiger 1991).

Shallow groundwater samples were collected in the center of each sampling location next to the target plant (either *A. donax* or *S. laevigata*). An 8-cm diameter bucket auger was used to create sampling holes, and a temporary stainless steel piezometer connected to a bailer was used to collect the groundwater samples. After purging the bailer several times, a groundwater sample was collected. Each day, these samples were kept on ice until delivered to a local laboratory for immediate analysis. Because groundwater was too deep to sample at terrace study sites, only soil and leaf tissue nutrient contents were collected in these areas. Five subsamples of soil were collected adjacent to target plants and combined into a composite sample by mixing together thoroughly in a stainless steel bowl. Each soil subsample was collected with an 8-cm diameter bucket auger from the upper 30 cm of the soil surface, where nutrient concentrations are expected to be greatest (Day 1983).

Leaf tissue and soil samples were air-dried and ground to a powder in preparation for nutrient content analyses at the DANR Analytical Laboratory in Davis, California. Leaf tissue was analyzed for total percent N, P, and K. Total N content of leaf tissue was determined using a Nitrogen Gas Analyzer combustion method (LECO FP-528) (AOAC International 1997a), total P content by microwave acid digestion/dissolution of leaf tissue samples and quantitative determination by AAS and ICP-AES (Meyer and Keliher 1992, Sah and Miller 1992), and total K content by the 2% acetic acid extraction method and a quantitative determination using atomic emission spectrometry (Johnson and Ulrich 1959).

Soil samples were analyzed for total N (%), nitrate-N (NO_3-N/ppm), ammonia-N (NH_4-N/ppm), orthophosphate (PO_4-P/ppm), and pH. Total N in the soil was determined by the combustion gas analyzer method (Method 972.43) (AOAC International 1997b). Concentrations of NO_3-N and NH_4-N in the soil were determined by equilibrium extraction of soil with potassium chloride and a flow-injection analyzer (Hofer 2003, Knepel 2003). Because the soils studied were neutral to alkaline, the Olsen-P method was used to estimate the relative availability of inorganic PO_4-P in soils (Olsen and Sommers 1982, Prokopy 1995). Soil pH was determined using a saturated paste prepared from the soil and a pH meter (USDA 1954). Soil grain size was analyzed using a hydrometer to determine the particle size distribution of sand, silt, and clay in soil suspension (Sheldrick and Wang 1993).

Shallow groundwater samples were analyzed for NH_4-N, NO_3-N + NO_2-N, PO_4-P, total Kjeldahl nitrogen (TKN), total N (total N = TKN + NO_3-N + NO_2-N), and pH by Fruit Growers Environmental Laboratories in Santa Paula, California. NH_4-N (4500NH3H), NO_3-N + NO_2-N (SM4500-NO3 F/EPA 300.0), and pH (Method 4500-H B) were analyzed according to the *Standard Methods for the Examination of Water and Wastewater* (Franson et al. 1998). TKN (EPA Method 351.1) and PO_4-P (Olsen P Methods 300.0 and 4500) were analyzed per *Methods for Chemical Analysis of Water and Wastes* (USEPA 1983).

Statistical Analyses

In this study, I used a multifactorial design in which combinations of four fixed factors (Model 1) were crossed with each other. The factors and associated levels were:

watersheds (Santa Clara River, Calleguas Creek, Topanga Canyon, and reference watersheds), land use types (agricultural, residential, and open space), fluvial geomorphic location (floodplain and terrace), and degree of *A. donax* infestation (none, small, and large). Sampling sites with small *A. donax* infestations represented areas where *A. donax* presence may indicate different invasion trajectories (i.e., depending on site conditions *A. donax* will either invade the area or persist as a small patch). ANOVA tests were used to analyze effects of various combinations of the four factors (independent variables) on nutrient concentrations in shallow groundwater, soil, and leaf tissue, soil grain size, pH, and leaf tissue and shallow groundwater N:P (dependent or response variables) (Systat Statistical Program [Version 10]).

Since data for terrace locations were only collected within the Santa Clara River Watershed, four-way ANOVAs could not be conducted. Instead, two three-way ANOVAs (watershed x land use x degree of infestation and land use x fluvial geomorphic location x degree of infestation) were performed on a combination of the fixed factors and response variables. To further investigate differences between invaded and non-invaded sites, small *A. donax* infestation data were removed and three-way ANOVAs repeated. Because soil nutrients can be strongly influenced by soil grain size, three-way ANOVAs for soil nutrients were conducted using soil grain size (percent silt + clay) as a covariate. This parameter covaried significantly with all soil nutrient analytes. Since *A. donax* and *S. laevigata* leaves were not collected from the same sample locations to test species specific variation in leaf tissue nutrients, one-way ANOVAs were performed by the species factor (*A. donax* and *S. laevigata*, data from all infestation types

combined) using groundwater nutrient analytes as covariates. *Arundo donax* leaf tissue nutrient content was significantly greater than *S. laevigata* in all cases. Therefore, *A. donax* and *S. laevigata* leaf tissue nutrient results were compared separately in ANOVAs because variation in species nutrient uptake and use efficiency could potentially confound results (Chapin et al. 1986). F tests were performed to evaluate contrasts between means of grouping variables and levels in three-way ANOVA results.

I conducted one-way ANOVAs for watershed identity using all response variables to analyze the main effects of three study watersheds compared to reference watersheds. Nutrient content of leaf tissue was analyzed and reported separately by species in this one-way ANOVA. In addition, one-way ANOVAs by degree of infestation across all watersheds were conducted for *A. donax* leaf tissue nutrients in small and large infestations to compare foliar nutrient concentrations between infestation levels. Tukey's post hoc tests were conducted to determine significant differences between factor means in these one-way ANOVAs.

Linear regression analyses were performed to investigate relationships between *A. donax* and *S. laevigata* leaf total N and P content and various shallow groundwater and soil nutrient analyte concentrations on floodplains and terraces. Significance levels for regressions were determined from P values (ANOVA). I selected shallow groundwater and soil nutrient analytes with the strongest relationships to leaf tissue nutrients to analyze further in one- and three-way ANOVAs. All forms of N and P in the shallow groundwater in floodplains were analyzed. However, only soil NO_3-N and PO_4-P were analyzed along floodplains and terraces on the Santa Clara River.

Probability plots were used to test for normality of data and to identify data that required transformation. Most of the data were $\log_{10}$ base transformed. Raw data were used for leaf tissue N and K and shallow groundwater PO_4-P and pH. Square root transformations were used on percent silt + clay. When means and standard errors were used to describe or present statistical differences, data were back-transformed and reported in original units as an asymmetrical range.

RESULTS

Naturally Occurring Nutrient Levels

I used reference watershed data collected in this study to represent natural conditions for comparison to study watersheds, since historic data on natural conditions in neither study watersheds nor other watersheds in the southern California region were not available. Mean total soil N was much higher in reference watersheds than in floodplain or terraces of study watersheds (Table 7). However, NO_3-N and PO4-P levels in reference watersheds were similar to study floodplains but much lower than levels found on terraces. N and P levels of the shallow groundwater in reference watersheds were low (mean 0.13-1.11 mg/L) compared to study watersheds (mean 0.37-5.74 mg/L). The mean shallow groundwater molar N:P ratio (NO_3-N:PO_4-P) from reference sites was 2.4:1 (SE 2.0:1–3.0:1), which is considered to be N limiting according to the Redfield ratio (< 15:1 = N limiting and > 15:1 = P limiting for sea water or 15 atoms of N for every 1 atom of P). The N:P ratio of shallow groundwater in study watersheds was higher than found in reference watersheds but also in the range of N limiting [4.4:1 (SE 3.9:1–5.0:1)].

The mean N:P ratio of *S. laevigata* leaf tissue from the reference sites was 12.1:1 (SE 11.5:1–12.8:1), which is also considered to be N limiting (< 14:1 = N limiting and > 16:1 = P limiting on a per mass basis) (Koerselman and Meuleman 1996) (Table 8). Mean leaf tissue of both *S. laevigata* and *A. donax* collected from study watersheds had much higher N:P ratios, but considered neither N nor P limiting. The *S. laevigata* leaf tissue N:K ratio of 1.5:1 (SE 1.4:1–1.6:1) from the reference sites was optimal for plant growth (< 1.5:1 = N limiting and > 1.5:1 = K limiting) (Knecht and Goransson 2004). However, the N:K ratio is below the N limiting threshold for *A. donax* in study watersheds [0.99:1 (SE 0.96:1.02)].

Shallow Groundwater Nutrients

The three-way ANOVA (watershed x land use x degree of infestation) showed that the two-way interaction of watershed and land use factors best explained total N distribution in the shallow groundwater along the floodplains studied (Table 9). Concentrations of total N in the shallow groundwater were significantly higher in Calleguas Creek than in the Santa Clara River adjacent to agricultural and open space land uses (Figure 10a). No variation between the two watersheds existed for total N concentrations adjacent to residential land uses. However, shallow groundwater total N levels were significantly lower adjacent to residential land uses compared to agriculture and open space within Calleguas Creek. Results of the one-way ANOVA by watershed indicated that reference sites contained significantly lower total N in the shallow groundwater compared to any of the three study watersheds (Table 10). TKN results in shallow groundwater were similar to those of total N.

The watershed main effect for the three-way ANOVA was very highly significant for NO_3-N + NO_2-N concentration in the shallow groundwater (Table 9). These concentrations were significantly higher throughout Calleguas Creek (1.08 mg/L, SE 0.80–1.46 mg/L) compared to the Santa Clara River watershed (0.27 mg/L, SE 0.23–0.31 mg/L). When data from small *A. donax* infestations were removed, the interaction of watershed and land use type was significant for the three-way ANOVA ($F_{(2,50)} = 3.866$; $P = 0.027$). NO_3-N + NO_2-N concentrations in the shallow groundwater adjacent to agricultural land uses were significantly higher along Calleguas Creek than any other combination of land use and watershed (Figure 10b). The one-way ANOVA for NO_3-N + NO_2-N concentrations by watershed was very highly significant (Table 10). Shallow groundwater NO_3-N + NO_2-N levels were significantly higher along floodplains in Calleguas Creek compared to levels measured along the Santa Clara River, Topanga Canyon, or reference watersheds.

The three-way ANOVA resulted in a significant three-way interaction for shallow groundwater NH_4-N levels found in floodplains (Table 9). Significantly higher mean NH_4-N concentrations in the shallow groundwater were associated with small infestations next to open space along Calleguas Creek compared to sites with any other combination of land use and degree of infestation (Figure 10d and e). Large infestations adjacent to open space on Calleguas Creek contained higher shallow groundwater NH_4-N levels than many other combinations of factors. However, the one-way ANOVA by watershed indicated that levels of NH_4-N in shallow groundwater did not differ significantly between reference watersheds and any of the main study watersheds (Table 10).

Reference watersheds contained an average of 0.26 mg/L (SE 0.21–0.33) NH_4-N in shallow groundwater, which is lower only than levels found within small *A. donax* infestations on floodplains adjacent to open space within the Calleguas Creek watershed.

The main effect of watershed was very highly significant for PO_4-P in the three-way ANOVA (Table 9). The watershed with the highest proportion of total anthropogenic land cover, Calleguas Creek, contained the highest shallow groundwater PO_4-P concentrations (Figure 8). Orthophosphate concentrations in the shallow groundwater were significantly higher along Calleguas Creek (2.67 ± SE 0.38 mg/L) than Santa Clara River (0.64 ± SE 0.10 mg/L). The one-way ANOVA for shallow groundwater PO_4-P levels by watershed was also very highly significant (Table 10). Shallow groundwater PO_4-P concentrations on floodplains were significantly lower at reference sites and along the Santa Clara River compared to Calleguas Creek.

The one-way ANOVA for shallow groundwater pH levels by watershed was very highly significant (Table 10). Calleguas Creek and the Santa Clara River had significantly more acidic shallow groundwater than did Topanga Canyon and the reference watersheds.

Soils Nutrients and Grain Size

Nutrients

The relative availability of nutrients in soil made the soil nutrient results quite complex, due to variability in soil grain size and pH levels among sites, as well as different rooting depths of the two plant species (Figure 9). Availability of nitrogen varies considerably depending on soil grain size, which determines cation exchange

capacity and moisture holding capacity. NH_4^+ and NO_3^- are highly charged ions that readily dissolve in water. Percent silt + clay grain size was used as a covariate in ANOVAs for soil nutrients to account for variation due to soil grain size. Significant relationships between *A. donax* leaf tissue N and soil total N, NH_4-N and NO_3-N found on riparian terraces suggested that this species may rely more heavily on soil nutrients in the upper 30 cm of soil on terraces than *S. laevigata*, which may have much deeper roots in these areas (Figure 11).

HPO_4^{-2} adsorbs readily to soil particles (especially finer textured soils) and is most available to plants when dissolved in water at pH ~6.5 (Havlin et al. 1999). The mean soil pH of floodplains of reference watersheds was 7.38 (SE 7.26–7.50), which was similar to floodplains (7.41, SE 7.38–7.45) and terraces (7.38, SE 7.33–7.43) along the Santa Clara River. Higher than optimal pH levels in these areas may cause lower PO_4-P availability for both plant species. The three-way ANOVA (land use x location x degree of infestation) of soil pH resulted in a very highly significant land use main effect (Table 6). Mean soil pH levels varied significantly from one another by land use type as follows: open space (7.57, SE 7.51–7.62), agricultural (7.40, SE 7.35–7.45), and residential (7.23, SE 7.18–7.28). Thus, PO_4-P may be more available to plants adjacent to land use with higher anthropogenic inputs due to lower soil pH.

In the three-way ANOVA (watershed x land use x degree of infestation), the main effect of watershed was significant for percent total N content in the soil (Table 9); floodplain soils in Calleguas Creek (0.05%, SE 0.047–0.052%) contained significantly lower levels of mean total N than did soils along the Santa Clara River (0.06 ± SE

0.003%). NO_3-N levels in the soil varied significantly by all factors (all main effects significant). The mean content of NO_3-N was significantly higher in Calleguas Creek (2.1 ppm, SE 1.8–2.6ppm) than the Santa Clara River (0.7 ppm, SE 0.6–0.9 ppm). Floodplains adjacent to agricultural (1.6 ± 0.4 ppm) and open space (1.4 ppm, SE 1.1–1.8 ppm) contained significantly higher levels of NO_3-N than those adjacent to residential land uses (0.9 ± 0.2 ppm). Both large and small degrees of infestation were found to contain significantly higher mean NO_3-N soil levels (1.6 SE 0.4 ppm and 1.5 ppm, 1.1 –1.8 ppm, respectively) then non-infested areas (0.8 ppm, SE 0.7–1.1 ppm). Levels of NH_4-N were found to be significantly higher in floodplain soils of Calleguas Creek (1.5 ± 0.1 ppm) compared to the Santa Clara River (1.4 ± 0.1 ppm). The three-way interaction for mean PO_4-P levels found in floodplain soils was significant (Table 9). In most cases, levels of soil PO_4-P were higher in Calleguas Creek than along the Santa Clara River (Figure 12). Levels of PO_4-P in floodplain soils adjacent to agricultural land uses in Calleguas Creek were higher than levels found in soil anywhere along the Santa Clara River. Large infestations of *A. donax* were associated with higher soil PO_4-P levels than small or non-infested floodplains next to open space along the Santa Clara River.

Soil NO_3-N and PO_4-P concentrations were significantly higher on terraces versus floodplains of the Santa Clara River for all degrees of *A. donax* infestation according to the land use x fluvial geomorphic location x degree of infestation three-way ANOVA (Figure 13a and c). Soil nutrient levels did not differ significantly along floodplains, with the exception of lower PO_4-P levels adjacent to residential compared to agricultural land uses (Figure 13d). However, soil associated with the deeper-rooted *S. laevigata* from

non-infested riparian terraces contained significantly higher NO_3-N and PO_4-P concentrations than soil associated with either *A. donax* infestation stage (Figure 13a and c). Soil PO_4-P levels associated with all land uses were significantly higher on terraces compared to floodplains (except between terrace open space and floodplain agricultural areas) (Figure 13d). Terrace sites adjacent to anthropogenic land uses had significantly higher soil PO_4-P concentrations (as well as lower pH values allowing for greater availability) versus open space. Small and large *A. donax* infestations contained significantly more soil PO_4-P adjacent to agricultural versus open space land use (Figure 13e).

One-way ANOVAs for mean soil NO_3-N and PO_4-P content by watershed were very highly significant (Table 10). Mean NO_3-N content of soil along the floodplains of Calleguas Creek was significantly higher than content of soil along Santa Clara River. Soils sampled along Calleguas Creek contained significantly higher mean PO_4-P content than soils along the Santa Clara River or Topanga Canyon.

Grain Size

In general, soil grain size was highly correlated with the watershed from which it was sampled and adjacency to certain land use types. However, the combination of fluvial geomorphic location and degree of infestation affected soil grain size distribution in the 3-way ANOVA (land use x geomorphic location x degree of infestation, Santa Clara River only) (Table 11). Percent silt + clay content was significantly higher on terraces verses floodplains in non-infested sites and small infestations of *A. donax* (Figure 13b). However, this parameter did not differ significantly by geomorphic landform

within large infestations of *A. donax*. In addition, percent silt + clay did not differ by degree of infestation within floodplains but was significantly higher in non-infested sites versus large *A. donax* infestations on terraces. Reference sites contained 20.1% (SE 17.4–22.9%) silt + clay in floodplains, which was similar to small infestations of *A. donax* along floodplains but much lower than non-infested sites and small infestations along terraces. One-way ANOVAs for mean percent silt + clay in floodplains by watershed were very highly significant (Table 11). Mean silt + clay content found in floodplain soils along the Santa Clara River was significantly higher than silt + clay content found along Calleguas Creek or Topanga Canyon floodplains.

Relationship between Shallow Groundwater, Soil, and Leaf Tissue Nutrients

Various forms of N and P found in the shallow groundwater and soils had positive linear relationships with N and P content of *A. donax* and *S. laevigata* leaves (Figure 11 and Figure 14). However, pools of N and P available to plants varied considerably by species, medium, and fluvial geomorphic location. In floodplains, linear regressions showed significant positive relationships between *A. donax* leaf tissue N and each form of N individually (total N, NO_3-N + NO_2-N, and NH_4-N) in the shallow groundwater (Figure 14). In fact, as groundwater nutrients increased, *A. donax* N content increased more than *S. laevigata* N content in each case. However, only relationships between total N and NO_3-N + NO_2-N in the shallow groundwater and *S. laevigata* leaf tissue N content were significant. Relationships between P content of *S. laevigata* leaves and shallow groundwater PO_4-P levels were highly significant in floodplains, but were not found between *A. donax* leaves and shallow groundwater PO_4-P levels. A strong positive

relationship was found between *A. donax* leaf N content and soil NO_3-N on riparian terraces (Figure 11). Also, *A. donax* leaf N content indicated a positive relationship with both soil total N and NH_4-N on terraces and NO_3-N on floodplains; similar trends were not found for *S. laevigata*. No significant relationships were found between mean P content found in leaves of either species and soil PO_4-P concentrations in terrace or floodplain locations.

Leaf tissue Nutrients

Total Nitrogen

Mean leaf tissue N content of *A. donax* varied by watershed and land use in the three-way ANOVA (watershed x land use x degree of infestation – non-infested sites excluded) (Table 9). N content of *A. donax* leaves was significantly higher adjacent to open space land use within Calleguas Creek than any other land use types along either stream (Figure 15a). The three-way ANOVA (land use x fluvial geomorphic location x degree of infestation – non-infested sites excluded) for *A. donax* leaf tissue N content revealed significant main effects for land use and degree of infestation on the Santa Clara River (Table 11). Mean leaf tissue N content was higher in sites adjacent to agricultural (2.54 ± SE 0.08%) and residential (2.64 ± SE 0.08%) land uses compared to open space (2.21 ± SE 0.09%). Large *A. donax* infestations (2.59 ± SE 0.07%) contained significantly higher mean leaf tissue N than small infestations (2.36 ± SE 0.08%).

The one-way ANOVA for mean N content of *A. donax* leaf tissue by infestation stage for all study watersheds was highly significant ($F_{(1,79)} = 8.858$; $P = 0.004$). Mean N of *A. donax* leaves was higher in large infestations (2.67 ± SE 0.06%, n = 62) than in

small infestations (2.38 ± SE 0.07%, n = 60). The one-way ANOVAs for mean N leaf content by watershed were very highly significant for *A. donax* only and *S. laevigata* only (Table 10). N content of *S. laevigata* leaves in reference sites and from Topanga Canyon was significantly lower than N content sampled along the floodplains of Calleguas Creek or the Santa Clara River. *Arundo donax* leaves sampled in Calleguas Creek contained significantly higher N content than leaves from either the Santa Clara River or Topanga Canyon. Although leaf tissue nutrient content could not be compared statistically between species because species-specific differences might confound comparisons, N content of *A. donax* leaves from all watersheds was higher than that of *S. laevigata* leaves in reference sites.

Total Phosphorus

Mean P content of *A. donax* leaves varied by watershed only in the three-way ANOVA (watershed x land use x degree of infestation – non-infested sites excluded)(Table 9). Leaf tissue mean P content was higher in Calleguas Creek (0.19%, SE 0.184–0.193%) than in the Santa Clara River (0.17 ± SE 0.006%). The three-way ANOVA (land use x fluvial geomorphic location x degree of infestation – non-infested sites excluded) for *A. donax* leaf tissue P content was not significant for any main effects or interactions (Table 11).

The one-way ANOVA for mean P content of *A. donax* leaf tissue by degree of infestation for all study watersheds was significant ($F_{(1,79)} = 4.817$; $P = 0.031$). Mean P of *A. donax* leaves was higher in large infestations (0.18% SE 0.173–0.180%, n = 62) than in small infestations (0.16% SE 0.155–0.164%, n = 60).

One-way ANOVAs for mean P content of leaves by watershed were significant for *S. laevigata* only and *A. donax* only (Table 10). *Salix laevigata* leaves contained higher P content along floodplains of Calleguas Creek than along floodplains of the Santa Clara River, Topanga Canyon, or reference sites. Mean leaf P content of *A. donax* leaves was significantly higher in Calleguas Creek than in the Santa Clara River. Although leaf tissue nutrient content could not be compared statistically between species, P content of *A. donax* leaves from all watersheds was higher than that of *S. laevigata* leaves in reference sites.

Total Potassium

Mean K content of leaf tissue varied by land use and degree of infestation in the three-way ANOVA (watershed x land use x degree of infestation – non-infested sites excluded) (Table 9). Leaf tissue K content was significantly higher in large infestations adjacent to residential land uses than in any other combination of land use and infestation stage (Figure 15b). The degree of infestation main effect was highly significant in the three-way ANOVA (land use x fluvial geomorphic location x degree of infestation – non-infested sites excluded) for *A. donax* leaf tissue K (Table 11). Mean leaf tissue K content was significantly higher in large *A. donax* infestations (2.94 ± SE 0.08%) than in small infestations (2.66 ± SE 0.06%).

Although the one-way ANOVA for mean K content of *A. donax* leaf tissue by degree of infestation for all study watersheds was not significant ($F_{(1,79)} = 3.578$; $P = 0.062$), mean K of *A. donax* leaves was higher in large infestations (2.79 ± SE 0.07%, n = 62) than in small infestations (2.55 ± SE 0.05%, n = 60). The one-way ANOVA for K

content by watershed was not significant for *S. laevigata* leaves, but K content of *A. donax* leaves was significantly higher in the Santa Clara River compared to Calleguas Creek or Topanga Canyon (Table 10). Leaf tissue nutrient content could not be compared statistically between species, but K content of *A. donax* leaves from all watersheds was higher than that of *S. laevigata* leaves from reference sites or any of the study watersheds.

N:P and N:K Ratios

Shallow groundwater molar N:P ratios did not vary significantly in either three-way ANOVA or the one-way ANOVA by watershed. However, reference watersheds [2.1:1 (SE 2.0–3.0:1)] had lower mean N:P ratios than all study watersheds and Calleguas Creek [5.7:1 (SE 4.4:1–7.5:1) had the highest ratio (Table 8). All mean N:P ratios were in the N limiting range (<15:1) according to the Redfield Ratio.

Arundo donax leaf tissue N:P ratios did not vary significantly in either of the three-way ANOVAs performed for the study watersheds (Table 8). When only *S. laevigata* leaves from floodplain locations were examined in the one-way ANOVA by watershed, leaf N:P ratios within reference watersheds were significantly lower than those within the Santa Clara River, and N:P ratios in Calleguas Creek were significantly lower than those in the Topanga Canyon or the Santa Clara River. In addition, the mean N:P ratio of *A. donax* leaf tissue was significantly higher in Calleguas Creek and the Santa Clara River compared to Topanga Canyon. Although statistical comparisons could not be made between the plant species, the mean N:P ratios of *S. laevigata* leaf tissue in

reference sites were lower than the N:P ratio of *A. donax* leaf tissue in all study watersheds.

The land use x location x degree of infestation ANOVA for N:K revealed a significant land use main effect ($F_{(2,60)} = 4.589$; $P = 0.014$). Higher N:K ratios of *A. donax* leaf tissue were observed adjacent to residential (0.93:1, SE 0.89:1–0.96:1) and agricultural land uses (0.91:1, SE 0.88:1–0.94:1) compared to open space (0.78:1, SE 0.75:1–0.82:1). Mean N:K ratios of *S. laevigata* leaf tissue from floodplains did not vary among watersheds in the one-way ANOVA by watershed (Table 8). However, *A. donax* leaf tissue mean N:K was significantly higher in Calleguas Creek compared to either Santa Clara River or Topanga Canyon. Although statistical comparisons were not possible, the mean leaf N:K of *S. laevigata* was much higher in reference watersheds compared to *A. donax* leaf mean N:K ratios found in other watersheds.

DISCUSSION

Anthropogenic nutrient enrichment of natural ecosystems has been linked to plant invasions worldwide (Mooney et al. 1986, Drake et al. 1989, D'Antonio and Vitousek 1992, Hobbs and Huenneke 1992, Vitousek et al. 1996, Brooks 2003). However, little is known about the influence of elevated nutrients on invasions in river systems of Mediterranean-type climates such as California (Rundel 2000, Kim 2003, Robinson et al. 2005). This analysis of nutrient levels in several river systems in southern California supports the hypothesis that excess nutrients associated with anthropogenic land use activities have helped promote the recent invasion of riparian ecosystems by *A. donax* in southern California. I tested this hypothesis by evaluating N and P pools in shallow

groundwater and soil within riparian ecosystems invaded to various degrees by *A. donax* adjacent to several land uses. All factors investigated – land use, watershed, and fluvial geomorphic location – were important in explaining nutrient distribution and *A. donax* invasion. Furthermore, my results indicate that the greater supply and availability of N and K to *A. donax* compared to native plants may contribute to invasion of riparian ecosystems by *A. donax* in southern California (Charbonneau and Kondolf 1993, CRWQCB-LA 1995).

Natural Nutrient Levels

Naturally occuring nutrient levels essential for terrestrial plant growth (primarily N and P) vary widely in soils and shallow groundwater due to climate, topography, organisms, parent material, and soil texture. Precipitation and nitrogen fixation are the main natural sources of N, but all other essential soil nutrients (including P and K) are inherited from the parent material or added anthropogenically (Day 1983, Rundel et al. 1983, Stark 1994). Soils in Mediterranean-type climate regions of the world are naturally deficient in N and/or P compared to other regions (Day 1983, diCastri 1991, Dallman 1998), but vary considerably within these regions especially in the extent to which they are available to plants.

Historical soil and shallow groundwater nutrient data for natural or undisturbed riparian ecosystems in southern California were not available for comparison with my study results. The highly erosive soils found throughout this region likely transport associated nutrients to the alluvium of low-lying river systems, especially after fire. Average total N levels found in floodplain soils of my reference watersheds were within

the range of levels (slightly nutrient-rich) found in adjacent shrubland ecosystems of California (Day 1983, diCastri 1991) (Table 2). The young sedimentary geology of my study region is composed primarily of marine deposits containing organisms very high in P (Pettijohn 1975), creating soils higher in P than found in older more weathered geologies (Walker and Syers 1976, Groves et al. 1983). N and P levels found in the shallow groundwater of reference watersheds were low, although slightly higher than flow-weighted nutrient concentrations found in streams of many other small undeveloped basins in the U.S. (Williams et al. 1998, Clark et al. 2000) (Table 2).

Nutrient Limitation

N, P, and K alone and in combination were found to limit terrestrial and wetland plant production in the eastern U.S. and Europe (Koerselman and Meuleman 1996, Verhoeven et al. 1996, Svengsouk and Mitsch 2001, Knecht and Goransson 2004). Researchers have shown that N limits plant production on young substrates, such as southern California, whereas P is limiting on older substrates (Walker and Syers 1976, Vitousek 1996). Although nutrient limitations in riparian ecosystems of southern California are undocumented, they may provide important insight into the invasion process; anthropogenic N inputs may be relatively more important to plant production than P in younger geologies of southern California.

Results of this study indicate that N limiting conditions (relatively higher P levels) may naturally occur in riparian ecosystems in this geologically young landscape as suggested by several researchers (Walker and Syers 1976, Vitousek 1996). The N:P (molar ratio) in shallow groundwater of reference sites in this study (2.4:1) was much

lower than levels in sea water (<15:1 = N limiting conditions) or freshwater (19-48:1) reported in the literature, indicating naturally N limiting conditions in floodplains of southern California (Redfield 1958, Hecky et al. 1993). Also, leaf tissue N:P for *S. laevigata* in reference sites [12:1 (SE 11.5–12.8:1] suggests that N may be naturally limiting to plants in this region (<14:1 = N limiting) (Koerselman and Meuleman 1996, Verhoeven et al. 1996).

Groundwater and leaf tissue N:P ratios found in this study suggest that N is naturally limiting in riparian ecosystems of southern California, but anthropogenic nutrient inputs have contributed to elevated ratios in more developed watersheds. Shallow groundwater N:P ratios were higher in study watersheds with higher anthropogenic nutrient inputs compared to no nutrient input reference sites. Mean surface water N:P ratios for rivers worldwide were much higher (24:1 or P limited according to the Redfield Ratio) than in my reference or study watersheds (Hecky et al. 1993). Warrick et al. (2005) found N:P molar ratios in the surface water of the Santa Clara River to be 5:1 during a winter storm event and <1:1 during the low-flow summer months, in a similar range (N limiting) to results found for reference and study watersheds.

The N:P and N:K ratios in leaf tissue have been used to indicate nutrient limitations in freshwater wetland plant communities (Koerselman and Meuleman 1996, Verhoeven et al. 1996, Svengsouk and Mitsch 2001, Knecht and Goransson 2004). According to Koerselman and Meuleman (1996), N:P ratios by mass ≤ 14:1 (molar ratio 31:1) indicate N limiting conditions and ratios ≥ 16:1 indicate P limitations. Similar to

the trend in shallow groundwater N:P ratios, *S. laevigata* and *A. donax* leaf tissue N:P ratios found in reference watersheds were in the N limiting range (12:1) and adequate levels for both nutrients (14:1). Knecht and Göransson (2004) suggested optimal N:K nutrient ratios should be around 1.5:1 for deciduous and herbaceous plants based on a free supply of these nutrients under laboratory conditions. N:K ratios associated with *S. laevigata* leaf tissue in this study were similar to this optimal index (1.4:1–1.7:1) and did not differ by watershed. The *A. donax* leaf tissue N:K ratio was much lower (1:1) than that of optimal N:K, indicating that *A. donax* can assimilate K in excess of requirements (luxury consumption) or N may be limiting in relation to K.

Anthropogenic Nutrient Levels

Nutrient enrichment of rivers due to land use inputs is a global phenomenon. Increased use and composition of N and P in fertilizer have contributed to nutrient enrichment in rivers in agricultural landscapes (Charbonneau and Kondolf 1993, USEPA 1999, Nicola 2003). Surface and shallow groundwater run off from both agricultural and residential land use types contains excess N and P from fertilizers and drains into streams. Sewage treatment plants discharge treated wastewater that contains N, P, and K constituents into streams and rivers in southern California. Rural residential development throughout all of the studied watersheds may contribute NH_4-N, NO_3-N, and NO_2-N from septic tank leakage. In addition, levels of atmospheric N deposition are known to be high (from 1-45 kg/ha/year) around the Metropolitan Los Angeles Area (Padgett et al. 1999, Bytnerowicz et al. 2001, Meixner 2003, Lu et al. unpublished data). Although not widely known, K is required for biological phosphorus removal processes in sewage treatment

plants (Brdjanovic et al. 1996). Thus, excess amounts of K may be associated with wastewater discharged into rivers in this study, especially Calleguas Creek or the Santa Clara River that receive sewage discharge throughout their course. Alternatively, if not enough K is used in wastewater treatment, treated water may contain higher levels of P. Levels of K were not measured in shallow groundwater or soil in this study but may be important in understanding higher K content of *A. donax* versus *S. laevigata* leaf tissue found and thus invasion success of *A. donax*.

Higher levels of N and P in the shallow groundwater and soil of riparian ecosystems were associated with sites invaded by *A. donax*. However, nutrient levels in riparian ecosystems were found to vary considerably by watershed, land use, and fluvial geomorphic location. These factors helped explain the influence of nutrients from anthropogenic inputs on invasion of riparian ecosystems by *A. donax* on both floodplains and terraces throughout the study area.

Watershed

Many studies have shown that nutrient inputs from agricultural and urban land uses result in elevated N and P concentrations in adjacent water bodies (Peterjohn and Correll 1984, Fail et al. 1986, Frink 1991, Correll et al. 1992, Rodda 1995, Warrick et al. 2005), but few have focused on variation among multiple watersheds or cumulative effects of upstream land use inputs (Correll 1984, Correll et al. 1992, Basnyat et al. 1999, Ahearn et al. 2005, Robinson et al. 2005). Although many similarities exist between watersheds located within a given region (i.e., geology, climate, riparian vegetation), variation in factors such as land use composition and soil type can greatly influence

nutrient levels found in riparian ecosystems (Ahearn et al. 2005, Robinson et al. 2005). By comparing multiple watersheds with varying levels of anthropogenic nutrient inputs, my findings help disentangle the cumulative effects of both agricultural and residential land use on nutrient supply in floodplains at a watershed-scale. The general trend observed in total N, NO_3-N + NO_2-N, NH_4-N, and PO_4-P concentrations in the shallow groundwater and soil on floodplains was Calleguas Creek > Santa Clara River > Topanga Canyon > reference sites. In addition, pH of the shallow groundwater was more acidic in the watersheds with the highest anthropogenic land use.

Shallow groundwater and soil in floodplains of Calleguas Creek contained much higher levels of PO_4-P than the other study and reference watersheds. The higher percentage of agricultural and residential land uses and associated nutrients in this watershed compared to the other study watersheds might account for the observed P enrichment and lower pH levels. Agricultural nutrient sources may be the primary contributor to the elevated NO_3-N + NO_2-N levels found in groundwater in the floodplains of Calleguas Creek. Similar relationships between agricultural inputs and elevated nitrate were reported in other watershed-scale studies (Correll 1984, Peterjohn and Correll 1984, Correll et al. 1992, Rodda 1995, Basnyat et al. 1999, Ahearn et al. 2005, Robinson et al. 2005, Warrick et al. 2005).

Land Use

At a more local scale, adjacency to land uses was found to be important in characterizing nutrient supply on riparian terraces and floodplains. Adjacency to land use helped explain variation in nutrient supply in shallow groundwater total N and NH_4-N in

floodplain locations. Although NO_3-N and PO_4-P levels were higher in groundwater and soil on floodplains adjacent to agriculture than next to residential and open space land use in several cases, clearer trends were found on terraces in which PO_4-P levels were higher adjacent to both agriculture and residential land use than next to open space.

Fluvial Geomorphic Location

N and P levels in the soil were much higher on riparian terraces than on floodplains regardless of land use type or degree of infestation. NO_3-N and PO_4-P soil content was lower in floodplains of reference sites than on riparian terraces of the rivers with anthropogenic inputs. Lower soil pH as well as percent silt + clay grain size (no and small infestations) on terraces contributed to higher availability of PO_4-P on terraces compared to floodplains.

Degree of Infestation

Riparian ecosystems infested by *A. donax* contained higher NO_3-N levels in floodplain soils than did non-infested or reference sites, which may be the result of high nutrient input and adjacency to agricultural land use of invaded sites. Non-infested riparian terrace sites contained higher NO_3-N and PO_4-P levels than did sites invaded by *A. donax* on the Santa Clara River. This trend likely reflects the better utilization of surface soil nutrients on terraces by the shallow, extensive root system of *A. donax* compared to the much deeper tap root of *S. laevigata* trees (Phillips 1963, Russell 1963) (Figure 9). Conversely, *A. donax* and *S. laevigata* are likely to derive nutrients from similar depths in floodplains where available nutrients (and water) are much closer to the surface. Relationships among nutrient sources, nutrient pools, and *A. donax* infestation

level also were controlled by differences in nutrient availability to plant species, which in turn were controlled by physical constraints in the environment and species-specific rates of nutrient uptake, assimilation, metabolism, and limitation.

Factors Controlling Nutrient Availability

Nutrient availability in relation to supply of nutrients is key to understanding the *A. donax* invasion process, but quantification of nutrient availability is complex (Day 1983). Wetting and drying cycles, high soil temperatures, and wildfires characteristic of Mediterranean-type climates promote the release of nutrients by increasing the turnover of microbial biomass and organic matter that is otherwise sequestered (Stark 1994). Decomposition of litter releases nutrients, but quantities may vary by leaf species. Nutrients are thought to be most available in spring and autumn when water availability and temperature do not limit plant productivity (Day 1983). However, nutrient supply to floodplains of river systems in California was found to be greatest during winter storms (Robinson et al. 2005, Warrick et al. 2005). Supply to riparian terraces may occur throughout the year due to nutrient inputs from agricultural runoff, and supply to floodplains may occur year round due to sewage treatment plant releases. Ash from wildfires may contribute high proportions of N to riparian ecosystems and is considered to be a main factor promoting growth after fire (Day 1983).

Supply of N and P in the soil and their availability to plants vary greatly based on grain size, pH, and rooting depth (Metz et al. 1966). Variability in soil grain size and associated cation exchange and moisture holding capacity affects rates of diffusion transport of nutrients in the soil. Soil grain size has a strong influence on water and

nutrient retention in soils: Coarser soils retain less water than finer particle soils, such as clay and silt, and have a lower cation exchange capacity due to lower surface area (Kozlowski et al. 1991, Taiz and Zeiger 1991). Soils with higher cation exchange capacity supply more minerals to roots. In this study, nutrient content in the soil was strongly correlated with grain size. On riparian terraces, different degrees of infestation had similar trends in soil grain size and NO_3-N and PO_4-P concentrations. The relatively higher amount of finer soil particles in non-infested terrace sites relative to infested sites may have contributed to the higher soil nutrient levels found in the former.

Rate of P uptake by plants is strongly related to soil pH. Typically, basic soil pH values result in lower solubility of phosphate salts and thus a lowered ability of plant roots to assimilate P (Taiz and Zeiger 1991). At soil pH levels near 7.5 found in this study, P was slightly less available to plants than at optimal pH conditions (optimal pH = 6.5). However, native plants that have evolved under these conditions may have adapted mechanisms to extract P under lower than optimal pH conditions (Koerselman and Meuleman 1996). The ability to assimilate nutrients available in the surrounding soil and groundwater depends on development of an extensive root system and rooting structure, as well as mycorrhizal symbionts that maximize uptake (Kozlowski et al. 1991). For example, higher root surface area increases uptake rates and high P influx and root/shoot ratio results in higher P efficiency. Root morphology and architecture differ between monocots, such as *A. donax,* and dicots, like *S. laevigata* (Taiz and Zeiger 1991). Roots of *A. donax* are composed primarily of fibrous roots and tend to be much shallower than those of *S. laevigata*, which has a taproot that can extend 20 m or more to groundwater

(Figure 9). Physiological strategies of these plants differ greatly due to their inherent structure. Although *A. donax* has a shallower and less extensive rooting system, it is aided by a large rhizome that stores carbohydrates, water, and minerals under stressful conditions (Else 1996, Wijte et al. 2005). In contrast, *S. laevigata*, a large woody phreatophyte, has a long taproot and well-developed root system that can reach deeper groundwater and associated nutrients (Robinson 1958). Nutrient availability of N, P, and K to terrestrial plants is usually higher in surface layers of the soil, due to the more neutral pH, ease of root penetration, and accumulation of organic matter. Thus, *A. donax* may utilize nutrients in the upper soil profile and shallower groundwater, whereas *S. laevigata* may rely on a greater percentage of nutrients from deeper sources where a higher percentage of its roots are distributed.

On riparian terraces in which shallow groundwater occurs at a much greater depth than in floodplains, the differences in rooting structure of *A. donax* versus *S. laevigata* must be considered. *Salix laevigata* can use much deeper water (and associated nutrient sources) than *A. donax*. Results of this study reflect this difference, indicating significantly higher concentrations of NO_3-N and PO_4-P in terrace soils associated with *S. laevigata* in non-infested sites. However, higher soil nutrient levels observed next to non-infested sites may be due partly to variation in nutrient fluctuation rates as well. It follows that growth and invasion of *A. donax* depends more on shallower soil moisture and associated nutrients than *S. laevigata* (Figure 9). Soil nutrient results suggest that these two species may avoid competition for nutrients on riparian terraces after establishment, due to their varying rooting depths at maturity (Verhoeven et al. 1996).

However, *A. donax* may have other adaptations as well, such as higher growth response to N or nitrogen-use efficiency that result in its invasion success on terraces.

Variation in availability of N, P, and K to *A. donax* versus native *S. laevigata* is important in understanding the invasion process. Rates of nutrient assimilation and efficiency vary genetically by plant species (Duncan 1994). Plants adapted to more-fertile soils exhibit higher maximum potential growth rates compared with plants that have evolved under low soil nutrient conditions (Chapin et al. 1986). Thus, levels of available N, P, and K may vary greatly in their importance to the growth response of *A. donax* compared to *S. laevigata*. Data are not currently available on species-specific growth response of *A. donax* or *S. laevigata*, but fertilization studies should be conducted to measure their growth response to N, P, and K levels. Due to unknown species-specific assimilation rates and efficiency, leaf nutrient content of *A. donax* and *S. laevigata* could not be compared statistically to evaluate nutrient content of leaf tissue with respect to degree of infestation and other factors. However, several analyses are presented below in which availability to both species could be assessed.

Nutrient Supply and Availability

The nutrient content of leaf tissue is closely correlated with changes in nutrient availability due to supply during the growing season (Bouma 1983, Chapin and Cleve 1989). Relationships between N and P content of *A. donax* and *S. laevigata* leaf tissue and concentrations of nutrient in the surrounding shallow groundwater and soil indicate relative sources of N and P that may be used by each species on riparian floodplains versus terraces in this study. In floodplains, *A. donax* exhibited a significant positive

response to all forms of N in the shallow groundwater and NO_3-N in the soil, whereas *S. laevigata* showed a significant positive response to only NO_3-N + NO_2-N and PO_4-P pools in shallow groundwater. No significant relationships were found between soil N or P and *S. laevigata* leaf tissue nutrients in either floodplains or terraces, which suggests that this species may use primarily deeper nutrient pools. On riparian terraces, *A. donax* appears to use all forms of soil N, unlike *S. laevigata*. Relationships between nutrient supply and nutrient status of leaves support the assertion that these two plants may use different sources of nutrients on riparian terraces. These findings suggest that *A. donax* may have two main advantages over *S. laevigata*: (1) it is better able to uptake nutrients in the surface soils of riparian terraces due to different root distribution of the two species; and (2) it does not appear to require as much P.

Analysis of leaf tissue nutrient content revealed a clear link between *A. donax* invasion and anthropogenic supply of nutrients. In general, for both species percent total N, P, and K content of leaf tissue was higher in watersheds with greater anthropogenic inputs. In addition, *A. donax* leaf tissue N was higher in riparian ecosystems adjacent to both agricultural and residential land use types compared to open space. Total N, P, and K content of leaf tissue were much higher in areas heavily infested by *A. donax* than in areas with small infestations. These results suggest that a greater supply of N, P, and K from anthropogenic nutrient sources may be more available to *A. donax* in highly invaded riparian ecosystems than elsewhere. Preliminary analyses show that *A. donax* leaf litter contains significantly lower N content and higher C:N than litter from a mix of native species including *Salix* spp. (Lambert unpublished data). However, species-specific

nutrient assimilation and efficiency may vary and must be considered when comparing results for both species.

High levels of K found in *A. donax* leaf tissue were of particular interest and may be critical to the invasion process. Spencer et al. (2005) found that soluble K levels in the soil were higher where *A. donax* relative growth rate was greatest in northern California. K fertilization studies indicate a positive growth response and an increase in tissue K with increasing K availability in forest soils (Tripler et al. 2006). Although soil K was not measured in this study, *A. donax* leaves exhibited higher K levels in heavily infested sites adjacent to residential land use compared to areas with small infestations and were found to contain almost twice as much K as the native *S. laevigata*. Terrestrial plants use large amounts of K for various physiological activities, including stomatal regulation, but uptake mechanisms and efficiencies vary among plant species (Stark 1994). Adequate K is also known to prevent drought stress in crop plants (Spencer et al. 2005). High levels of K supply may give *A. donax* a competitive advantage during the hot, dry summer months in southern California. *Arundo donax* may either assimilate K more effectively than *S. laevigata* and/or levels of K in the soil or shallow groundwater may have been higher around *A. donax*. Fertilization studies measuring K uptake by *A. donax* compared to other native riparian species are needed to further understand its role in *A. donax* invasion.

MANAGEMENT AND RESTORATION IMPLICATIONS

This study elucidated the influence of anthropogenic nutrient inputs on invasion of riparian ecosystems of southern California by an alien plant species. Enrichment of

shallow groundwater with excess total N, NO_3-N, and NH_4-N from adjacent land appeared to have facilitated the rapid expansion of *A. donax* in the riparian ecosystems studied. Riparian terraces heavily invaded by the large, perennial grass *A. donax* were associated with nutrient inputs from adjacent agricultural and residential land uses. Contribution of nutrients from a combination of land use practices had an even stronger cumulative effect on invasion in floodplains at a watershed scale. Although not addressed in this study, the role of atmospheric N deposition as an important source of NO_3^- around large urban areas in *A. donax* invasion requires further attention.

Arundo donax will likely continue to spread rapidly in watersheds and locations within watersheds with higher anthropogenic nutrient loading regardless of the source. Reducing nutrient inputs to riparian ecosystems in California and other Mediterranean-type climate regions may help reduce the rate of spread of *A. donax* in watersheds where its distribution is low or it is not yet present. Within these watersheds, evaluation of nutrient levels in riparian ecosystems may help predict the threat of invasion; however, other factors (i.e., water availability) likely contribute to the invasion process. Results of this study indicate that riparian ecosystems adjacent to intensive agricultural operations or wastewater treatment plant discharge on terraces are at the greatest risk of invasion by *A. donax* if this species is introduced. Also, watersheds with high percentage of agricultural and residential land use composition are at risk. Recent expansion of urbanization and agricultural practices in watersheds of other Mediterranean-type climate regions, such as the Western Cape of South Africa, has resulted in similar trends in rapid expansion of *A. donax* in more urbanized streams and rivers (Samuels and Knight 2003).

Land management practices related to both agricultural and residential development should be evaluated to determine their nutrient inputs to riparian ecosystems, and best management practices should be employed to lower nutrient inputs to help control *A. donax* invasion along river systems.

Fluvial processes of flooding or scouring of streams in years with heavy rainfall are certainly primary factors in promoting spread of *A. donax*. My results showed that higher supply and availability of N, P, and K may also contribute to *A. donax* invasion after it is dispersed. However, manipulative experiments are needed to determine clear causal relationships between nutrient supply and availability to *A. donax* compared to dominant native riparian species under various water availability conditions. Further experimental investigation of the effects of light, water, and fire relative to nutrients on invasion of riparian ecosystems by *A. donax* will help elucidate the invasion process. Investigation of *A. donax* distribution and age of infestation related to land use change over time throughout watersheds in Mediterranean-type climates may provide further insight into contribution of anthropogenic land use to the invasion process.

Removal of invader species is often the initial step and prime component of stream restoration and mitigation in southern California (Coffman et al. 2004). Restoration plans for river systems and associated riparian revegetation must address anthropogenic nutrient levels if eradication or control of *A. donax* is a desired objective. In watersheds where nutrient levels are high, dam or levee removal projects need to consider the possibility that restoration actions might further distribute *A. donax* and promote its invasion. Revegetation or restoration on high terrace locations should

proceed with caution; high levels of nutrients added by land use practices or released by wildfires may promote *A. donax* invasion. With nutrient enrichment that exists throughout urbanized watersheds in southern California, aggressive maintenance programs and native riparian plant revegetation are essential elements of comprehensive *A. donax* removal and control programs.

TABLES

Table 6. Number and distribution of sampling locations in three study watersheds.

	Santa Clara River	**Calleguas Creek**	**Topanga Canyon**
Land use type	3	3	2 (no agricultural)
Floodplain/terrace	2	1 (no terrace)	1 (no terrace)
Degree of *A. donax* infestation	3	3	3
Number of replicates	5–6	5	5
TOTAL	93	45	30

Table 7. Natural and anthropogenic soil and shallow groundwater nutrient levels (means ± SE).

	Shrubland Ecosystems[3]			Streams draining undeveloped basins in U.S. (median)[4]	Riparian Ecosystems		
	Nutrient-poor; strongly-leached; oligotrophic	Nutrient-rich; moderately-leached; mesotrophic	Agriculturally-rich; weakly-leached; eutrophic		Reference watersheds (mean)	All study watersheds (mean)	
					Floodplains	Floodplains	Terraces
Soil							
Total N (%)	< 0.12 (CA: 0.03–0.12)	0.12–0.30 (CA: 0.12–0.21)	> 0.30	-	0.13 (0.11–0.16)	0.056 ± 0.002	0.095 (0.088–0.103)
NO_3-N (ppm)	-	-	-	-	1.3 (0.9–2.0)	1.2 (1.1–1.4)	3.8 (3.2–4.5)
Total P (%)	< 0.022	0.022–0.06 (CA: 0.022–0.06)	0.06 (CA: 0.06–0.082)	-	-	-	-
PO_4-P (ppm)	-	-	-	-	7.2 (6.1–8.6)	5.9 ± 0.4	12.2 (10.8–13.7)
Shallow groundwater							
Total N (mg/L)	-	-	-	0.26	1.11 (0.87–1.43)	5.74 (5.30–6.22)	-
NO_3-N (mg/L)	-	-	-	0.087	0.13 (0.11–0.16)[3]	0.40 (0.34–0.46)	-
NH_4-N (mg/L)	-	-	-	0.02	0.26 (0.21–0.33)	0.37 (0.33–0.40)	-
PO_4-P (mg/L)	-	-	-	0.01	0.53 (± 0.03)	1.39 (± 1.22–1.56)	-
N:P (molar)	-	-	-	19.2:1	2.4:1 (2.0:1–3.0:1)	4.4:1 (3.9:1–5.0:1)	-

Legend: CA = nutrient levels found in California SE = standard error

[3] Shrubland ecosystem soil nutrient data for 5 Mediterranean-type climate regions (Day 1983).
[4] Clark et al. 2000
[3] Values are NO_3-N + NO_2-N for reference and study watersheds.

Table 8. N:P and N:K ratios (on a mass basis) of *Salix laevigata* and *Arundo donax* leaf tissue and associated shallow groundwater (molar ratio) along floodplains of study watersheds (mean ± SE) and results of one-way ANOVAs by watershed.

	Reference Watersheds	**Topanga Canyon**	**Santa Clara River**	**Calleguas Creek**	**All Study Watersheds**	**Significance values**[5]
N:P						
Shallow groundwater	2.4:1 (2.0:1–3.0:1)	2.7:1 (2.3:1–3.2:1)	4.7:1 (3.9:1–5.7:1)	5.7:1 (4.4:1–7.5:1)	4.4:1 (3.9:1–5.0:1)	$F_{(3,128)} = 2.385$; $P = 0.072$
Leaf tissue (*S. laevigata*)	12.1:1 (11.5–12.8)	14.2:1 (13.5–14.9)	15.2:1 (14.4–16.1)	11.8:1 (11.2–12.7)	13.7:1 (13.2–14.1)	$F_{(3,47)} = 5.250$; $P = 0.003$**
Leaf tissue (*A. donax*)	ND	13.3:1 (13.0-13.6)	14.9:1 (14.5-15.3)	13.8:1 (13.4-14.3)	14.4:1 (14.1-14.6)	$F_{(2,78)} = 6.289$; $P = 0.003$**
N:K						
Leaf tissue (*S. laevigata*)	1.5:1 (1.4–1.6)	1.4:1 (1.3–1.5)	1.7:1 (1.6–1.8)	1.6:1 (1.5–1.7)	1.6:1 (1.5–1.6)	$F_{(3,47)} = 1.015$; $P = 0.356$
Leaf tissue (*A. donax*)	ND	0.9:1 (0.86-0.93)	0.9:1 (0.88-0.94)	1.2:1 (1.10–1.22)	1.0:1 (0.96–1.02)	$F_{(2,78)} = 12.109$; $P < 0.001$***

Legend:
SE = standard error
ND = no data since no *A. donax* in reference watersheds
* = $0.05 \geq P > 0.01$ = significant
** = $0.01 \geq P > 0.001$ = highly significant
*** = $P \leq 0.001$ = very highly significant

[5] No terrace data used in this analysis

Table 9. Three-way ANOVA significance table for shallow groundwater, soil, and leaf tissue nutrients by watershed (Santa Clara River[6], Calleguas Creek), land use (agricultural, residential, open space) and degree of infestation (none, small, large).

	Factors						
Nutrient analyte	**Watershed**	**Land use**	**Degree of infestation**	**Watershed x land use**	**Watershed x degree of infestation**	**Land use x degree of infestation**	**Watershed x land use x degree of infestation**
Shallow Groundwater							
Total N (mg/L)[7]	**$F_{(1,74)} = 5.474$; $P = 0.022$***	**$F_{(2,74)} = 3.630$; $P = 0.031$***	$F_{(2,74)} = 1.639$; $P = 0.201$	**$F_{(2,74)} = 3.848$; $P = 0.026$***	$F_{(2,74)} = 0.323$; $P = 0.725$	$F_{(4,74)} = 1.030$; $P = 0.398$	$F_{(4,74)} = 0.981$; $P = 0.423$
NO_3-N + NO_2-N (mg/L)	**$F_{(1,74)} = 18.788$; $P < 0.001$*** **	$F_{(2,74)} = 1.559$; $P = 0.217$	$F_{(2,74)} = 0.168$; $P = 0.846$	$F_{(2,74)} = 2.969$; $P = 0.057$	$F_{(2,74)} = 1.520$; $P = 0.225$	$F_{(4,74)} = 0.897$; $P = 0.470$	$F_{(4,74)} = 1.725$; $P = 0.154$
NH_4-N (mg/L)	**$F_{(1,74)} = 5.553$; $P = 0.021$***	**$F_{(2,74)} = 5.466$; $P = 0.006$****	**$F_{(2,74)} = 3.552$; $P = 0.034$***	**$F_{(2,74)} = 10.340$; $P < 0.001$*** **	**$F_{(2,74)} = 3.510$; $P = 0.035$***	$F_{(4,74)} = 1.044$; $P = 0.390$	**$F_{(4,74)} = 3.266$; $P = 0.016$***
PO_4 (mg/L)	**$F_{(1,74)} = 28.012$; $P < 0.001$*** **	$F_{(2,74)} = 0.160$; $P = 0.852$	$F_{(2,74)} = 1.276$; $P = 0.285$	$F_{(2,74)} = 0.383$; $P = 0.683$	$F_{(2,74)} = 2.201$; $P = 0.118$	$F_{(4,74)} = 0.948$; $P = 0.441$	$F_{(4,74)} = 0.982$; $P = 0.423$
pH	$F_{(1,74)} = 3.768$; $P = 0.056$	$F_{(2,74)} = 2.638$; $P = 0.078$	$F_{(2,74)} = 0.036$; $P = 0.964$	$F_{(2,74)} = 1.283$; $P = 0.283$	$F_{(2,74)} = 1.317$; $P = 0.274$	$F_{(4,74)} = 0.176$; $P = 0.950$	$F_{(2,74)} = 0.948$; $P = 0.441$
Soil[8]							
Total N (%)	**$F_{(1,73)} = 3.987$; $P = 0.050$***	$F_{(2,73)} = 0.859$; $P = 0.428$	$F_{(2,73)} = 0.002$; $P = 0.998$	$F_{(2,73)} = 0.241$; $P = 0.787$	$F_{(2,73)} = 0.931$; $P = 0.399$	$F_{(4,73)} = 1.313$; $P = 0.273$	$F_{(4,74)} = 2.071$; $P = 0.093$
NO_3-N (ppm)	**$F_{(1,73)} = 28.540$; $P < 0.001$*** **	**$F_{(2,73)} = 3.578$; $P = 0.033$***	**$F_{(2,73)} = 3.566$; $P = 0.033$***	$F_{(2,73)} = 0.544$; $P = 0.583$	$F_{(2,73)} = 1.983$; $P = 0.145$	$F_{(4,73)} = 1.771$; $P = 0.144$	$F_{(4,73)} = 0.390$; $P = 0.815$
NH_4-N (ppm)	**$F_{(1,73)} = 22.267$; $P < 0.001$*** **	$F_{(2,73)} = 2.286$; $P = 0.109$	$F_{(2,73)} = 0.347$; $P = 0.708$	$F_{(2,73)} = 2.340$; $P = 0.103$	$F_{(2,73)} = 1.750$; $P = 0.181$	$F_{(4,73)} = 0.871$; $P = 0.485$	$F_{(4,73)} = 1.340$; $P = 0.263$
PO_4 (ppm)	**$F_{(1,73)} = 102.353$; $P < 0.001$*** **	**$F_{(2,73)} = 14.664$; $P < 0.001$*** **	$F_{(2,73)} = 0.027$; $P = 0.974$	**$F_{(2,73)} = 3.162$; $P = 0.048$***	$F_{(2,73)} = 1.708$; $P = 0.188$	**$F_{(4,73)} = 5.517$; $P = 0.001$*** **	**$F_{(4,73)} = 3.259$; $P = 0.016$***

Legend: * = $0.05 \geq P > 0.01$ = significant, ** = $0.01 \geq P > 0.001$ = highly significant, *** = $P \leq 0.001$ = very highly significant

[6] No terrace data used in this analysis.
[7] All data log base 10 transformed except raw data were used for groundwater PO_4 and pH; and plant total N and K.
[8] Percent silt + clay (square root transformed) used as a covariate (significant for all soil nutrient analytes)

Table 9 (continued). Three-way ANOVA significance table for shallow groundwater, soil, and leaf tissue nutrients by watershed (Santa Clara River[9], Calleguas Creek), land use (agricultural, residential, open space), degree of infestation (none, small, large).

	Factors						
Nutrient analyte	**Watershed**	**Land use**	**Degree of infestation**	**Watershed x land use**	**Watershed x degree of infestation**	**Land use x degree of infestation**	**Watershed x land use x degree of infestation**
***Arundo donax* Leaf Tissue**							
Total N (%)	**$F_{(1,49)}$ = 10.511; P = 0.002****	$F_{(2,49)}$ = 2.223; P = 0.119	**$F_{(1,49)}$ = 5.081; P = 0.029***	**$F_{(2,49)}$ = 4.974; P = 0.011***	$F_{(1,49)}$ = 0.088; P = 0.522	$F_{(2,49)}$ = 0.799; P = 0.456	$F_{(2,49)}$ = 0.771; P = 0.468
Total P (%)	**$F_{(1,49)}$ = 7.947; P = 0.007****	$F_{(2,49)}$ = 2.424; P = 0.099	$F_{(1,49)}$ = 0.425; P = 0.517	$F_{(2,49)}$ = 1.927; P = 0.156	$F_{(1,49)}$ = 0.071; P = 0.792	$F_{(2,49)}$ = 0.535; P = 0.589	$F_{(2,49)}$ = 0.254; P = 0.777
Total K (%)	**$F_{(1,49)}$ = 5.651; P = 0.021***	**$F_{(2,49)}$ = 5.713; P = 0.006****	**$F_{(1,49)}$ = 4.528; P = 0.038***	$F_{(2,49)}$ = 0.315; P = 0.731	$F_{(1,49)}$ = 0.040; P = 0.843	**$F_{(2,49)}$ = 3.386; P = 0.042***	$F_{(2,49)}$ = 0.234; P = 0.793

Legend: * = 0.05 ≥ P > 0.01 = significant, ** = 0.01 ≥ P > 0.001 = highly significant, *** = P ≤ 0.001 = very highly significant

[9] No terrace data used in this analysis.

Table 10. Mean concentrations of shallow groundwater, soil, and leaf tissue nutrients and soil grain size in floodplains and results of the one-way ANOVA by watershed factor.

	Mean (± SE)				
Nutrient analyte	**Reference sites**	**Topanga Canyon**	**Santa Clara River**	**Calleguas Creek**	**Significance values[10]**
Shallow Groundwater Nutrients					
Total N (mg/L)[11]	1.11 (0.87–1.43)	4.03 (3.68–4.41)	5.22 (4.60–5.93)	8.02 (6.92–9.29)	**$F_{(3,128)}$ = 16.119; P < 0.001*** **
NO_3-N + NO_2-N (mg/L)	0.14 (0.11–0.16)	0.17 (0.14–0.19)	0.27 (0.23–0.32)	1.08 (0.80–1.46)	**$F_{(3,128)}$ = 14.711; P < 0.001*** **
NH_4-N (mg/L)	0.26 (0.21–0.33)	0.33 (0.27–0.40)	0.31 (0.28–0.35)	0.46 (0.39–0.54)	$F_{(3,128)}$ = 1.710; P = 0.168
PO_4 (mg/L)[12]	0.53 ± 0.03	0.66 ± 0.09	0.64 ± 0.10	2.67 ± 0.38	**$F_{(3,128)}$ = 16.664; P < 0.001*** **
pH	7.75 ± 0.09	7.80 ± 0.06	7.39 ± 0.05	7.25 ± 0.05	**$F_{(3,128)}$ = 20.847; P < 0.001*** **
Soil Nutrients and Grain Size[13]					
NO_3-N (ppm)	1.33 (0.89–1.98)	1.11 (0.91–1.36)	0.75 (0.65–0.87)	2.13 (1.75–2.60)	**$F_{(3,127)}$ = 9.047; P < 0.001*** **
PO_4-P (ppm)	7.23 (6.10–8.57)	4.84 (4.27–5.50)	4.14 (3.72–4.60)	9.71 (8.85–10.64)	**$F_{(3,12)}$ = 23.592; P < 0.001*** **
silt + clay (%)	20.1 (17.4–22.9)	12.8 (11.6–14.0)	25.3 (22.9–27.9)	11.18 (9.9–12.5)	**$F_{(3,128)}$ = 13.510; P < 0.001*** **
Leaf Tissue Nutrients					
Total N (%) (*Salix laevigata*)	1.78 ± 0.15	1.87 ± 0.13	2.40 ± 0.12	2.27 ± 0.10	**$F_{(3,47)}$ = 6.113; P = 0.001*** **
Total N (%) (*Arundo donax*)	No Data	2.19 ± 0.10	2.50 ± 0.08	2.88 ± 0.10	**$F_{(2,78)}$ = 11.982; P < 0.001*** **
Total P (%) (*Salix laevigata*)	0.14 ± 0.01	0.13 (0.125-0.134)	0.16 (0.147-0.164)	0.19 ± 0.01	**$F_{(3,47)}$ = 8.595; P < 0.001*** **
Total P (%) (*Arundo donax*)	No Data	0.17 ± 0.008	0.17 ± 0.006	0.19 (0.184-0.193)	**$F_{(2,78)}$ = 4.364; P = 0.016* **
Total K (%) (*Salix laevigata*)	1.25 ± 0.17	1.33 ± 0.06	1.44 ± 0.07	1.41 ± 0.07	$F_{(3,47)}$ = 0.860; P = 0.469
Total K (%) (*Arundo donax*)	No Data	2.49 ± 0.10	2.73 ± 0.07	2.49 ± 0.09	**$F_{(2,78)}$ = 3.172; P = 0.047* **

Legend: * = 0.05 ≥ P > 0.01 = significant, ** = 0.01 ≥ P > 0.001 = highly significant*** = P ≤ 0.001 = very highly significant
SE = standard error

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[10] No terrace data used in this analysis.
[11] All data log base 10 transformed except those noted otherwise.
[12] Raw data were used for groundwater PO_4 and pH; and plant total N and K.
[13] Percent silt + clay (square root transformed) was used as a covariate

Table 11. Three-way ANOVA significance table for soil and leaf tissue nutrients by land use (agricultural, residential, and open space), fluvial geomorphic location (terrace and floodplain), and degree of infestation (none, small, and large). Analyses were only conducted on Santa Clara River sites. Only *A. donax* from small and large infestations (levels) were used in leaf tissue ANOVAs.

	Factors						
Nutrient analyte	**Land use**	**Fluvial geomorphic location**	**Degree of infestation**	**Land use x fluvial geomorphic location**	**Land use x degree of infestation**	**Location x degree of infestation**	**Land use x location x degree of infestation**
Soil[14]							
NO_3-N (ppm)[15]	**$F_{(2,84)}$ = 5.101; P = 0.008***	**$F_{(1,84)}$ = 51.453; P < 0.001*****	$F_{(2,84)}$ = 2.662; P = 0.076	$F_{(2,84)}$ = 3.643; P = 0.030	$F_{(4,84)}$ = 1.661; P = 0.167	**$F_{(2,84)}$ = 4.626; P = 0.012***	$F_{(4,84)}$ = 1.636; P = 0.173
PO_4-P (ppm)	**$F_{(2,84)}$ = 8.081; P = 0.001*****	**$F_{(1,84)}$ = 60.137; P < 0.001*****	**$F_{(2,84)}$ = 4.613; P = 0.013***	**$F_{(2,84)}$ = 12.129; P < 0.001*****	**$F_{(4,84)}$ = 4.507; P = 0.002****	**$F_{(2,84)}$ = 3.689; P = 0.029***	**$F_{(2,84)}$ = 3.205; P = 0.017***
Silt + Clay (%)	$F_{(2,85)}$ = 1.772; P = 0.176	**$F_{(1,85)}$ = 4.343; P = 0.040***	$F_{(2,85)}$ = 1.517; P = 0.225	$F_{(2,85)}$ = 0.593; P = 0.555	$F_{(4,85)}$ = 0.865; P = 0.488	**$F_{(2,85)}$ = 3.206; P = 0.045***	$F_{(4,85)}$ = 0.343; P = 0.848
pH	**$F_{(2,85)}$ = 9.685; P < 0.001*****	$F_{(1,85)}$ = 0.297; P = 0.587	$F_{(2,85)}$ = 0.970; P = 0.383	$F_{(2,85)}$ = 2.366; P = 0.100	$F_{(4,85)}$ = 0.991; P = 0.417	$F_{(2,85)}$ = 1.738; P = 0.182	$F_{(4,85)}$ = 1.144; P = 0.341
***Arundo donax* Leaf Tissue**							
Total N (%)[16]	**$F_{(2,60)}$ = 6.029; P = 0.004****	$F_{(1,60)}$ = 0.862; P = 0.357	**$F_{(1,60)}$ = 5.876; P = 0.018***	$F_{(2,60)}$ = 2.572; P = 0.085	$F_{(2,60)}$ = 0.109; P = 0.897	$F_{(1,60)}$ = 0.964; P = 0.330	$F_{(2,60)}$ = 0.239; P = 0.788
Total P (%)	$F_{(2,60)}$ = 1.009; P = 0.371	$F_{(1,60)}$ = 3.015; P = 0.088	$F_{(1,60)}$ = 2.425; P = 0.125	$F_{(2,60)}$ = 1.172; P = 0.317	$F_{(2,60)}$ = 0.174; P = 0.841	$F_{(1,60)}$ = 1.481; P = 0.228	$F_{(2,60)}$ = 0.508; P = 0.604
Total K (%)	$F_{(2,60)}$ = 0.587; P = 0.559	$F_{(1,60)}$ = 1.637; P = 0.206	**$F_{(1,60)}$ = 9.909; P = 0.003****	$F_{(2,60)}$ = 2.775; P = 0.070	$F_{(2,60)}$ = 1.012; P = 0.370	$F_{(1,60)}$ = 1.198; P = 0.278	$F_{(2,60)}$ = 2.879; P = 0.064

Legend: * = 0.05 ≥ P > 0.01 = significant, ** = 0.01 ≥ P > 0.001 = highly significant*** = P ≤ 0.001 = very highly significant

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[14] Percent silt + clay (square root transformed) used as a covariate for all soil nutrients.
[15] Soil nutrient data and pH were $\log_{10}$ base transformed.
[16] Raw data was used for leaf tissue total N and K. Leaf tissue total P was $\log_{10}$ base transformed.

FIGURES

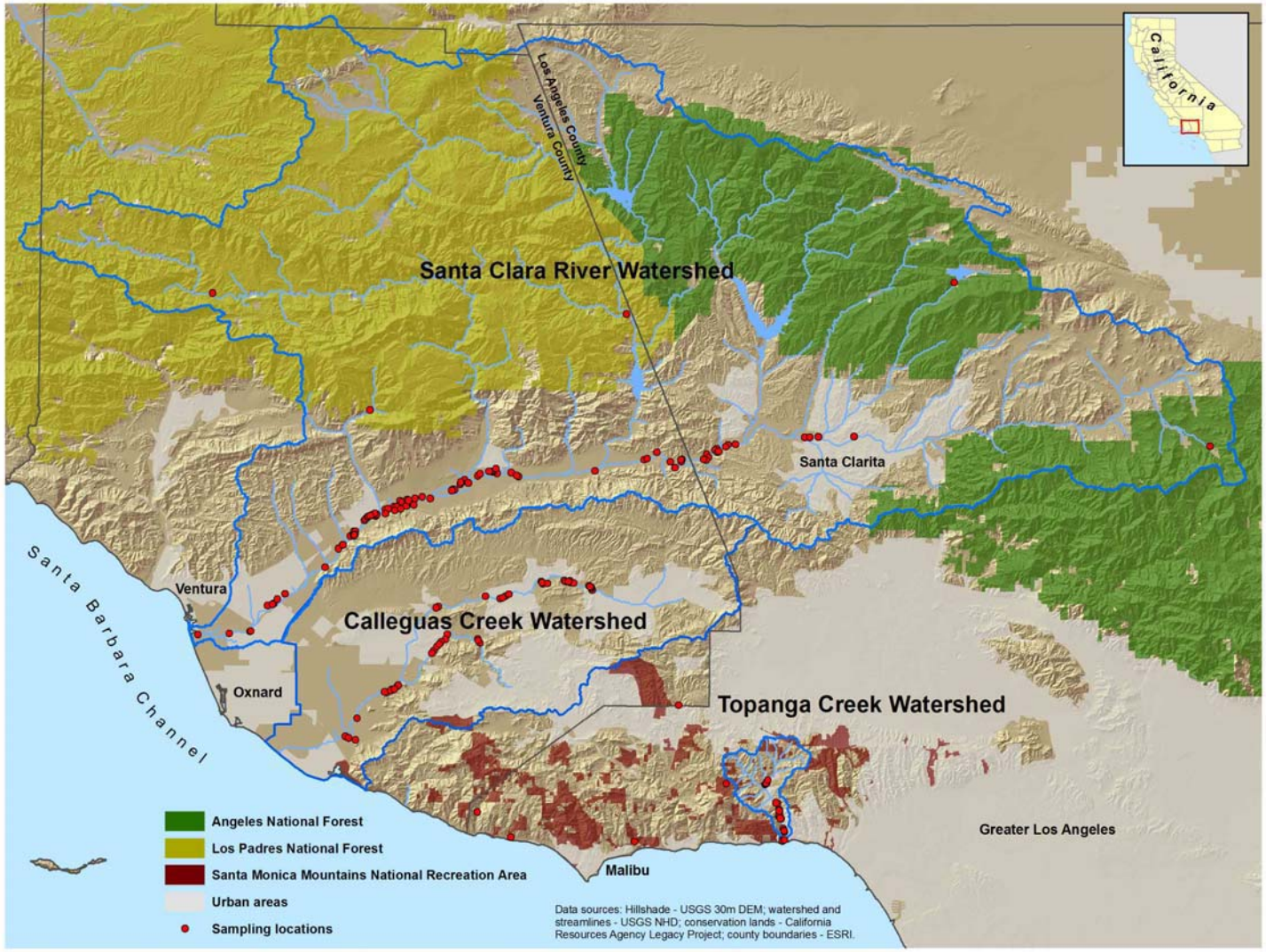

Figure 7. The three study watersheds in Ventura and Los Angeles Counties, California.

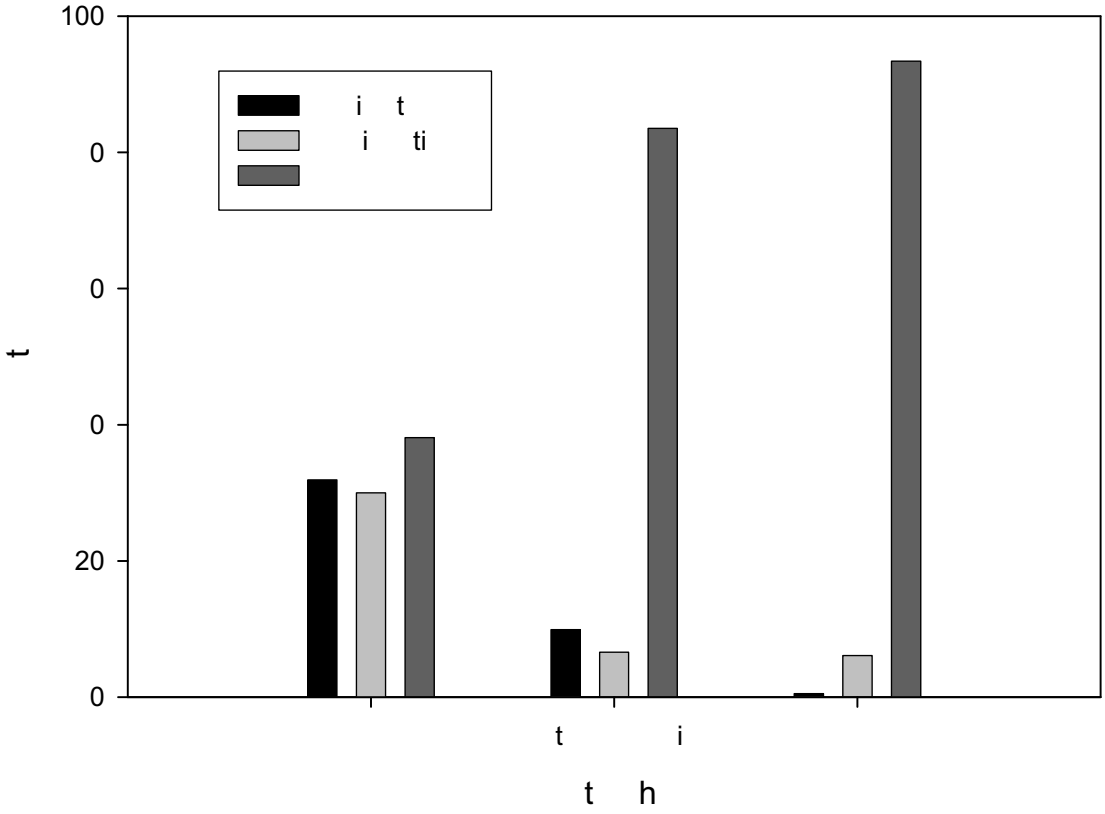

Figure 8. Distribution of land use type within the three studied watersheds.

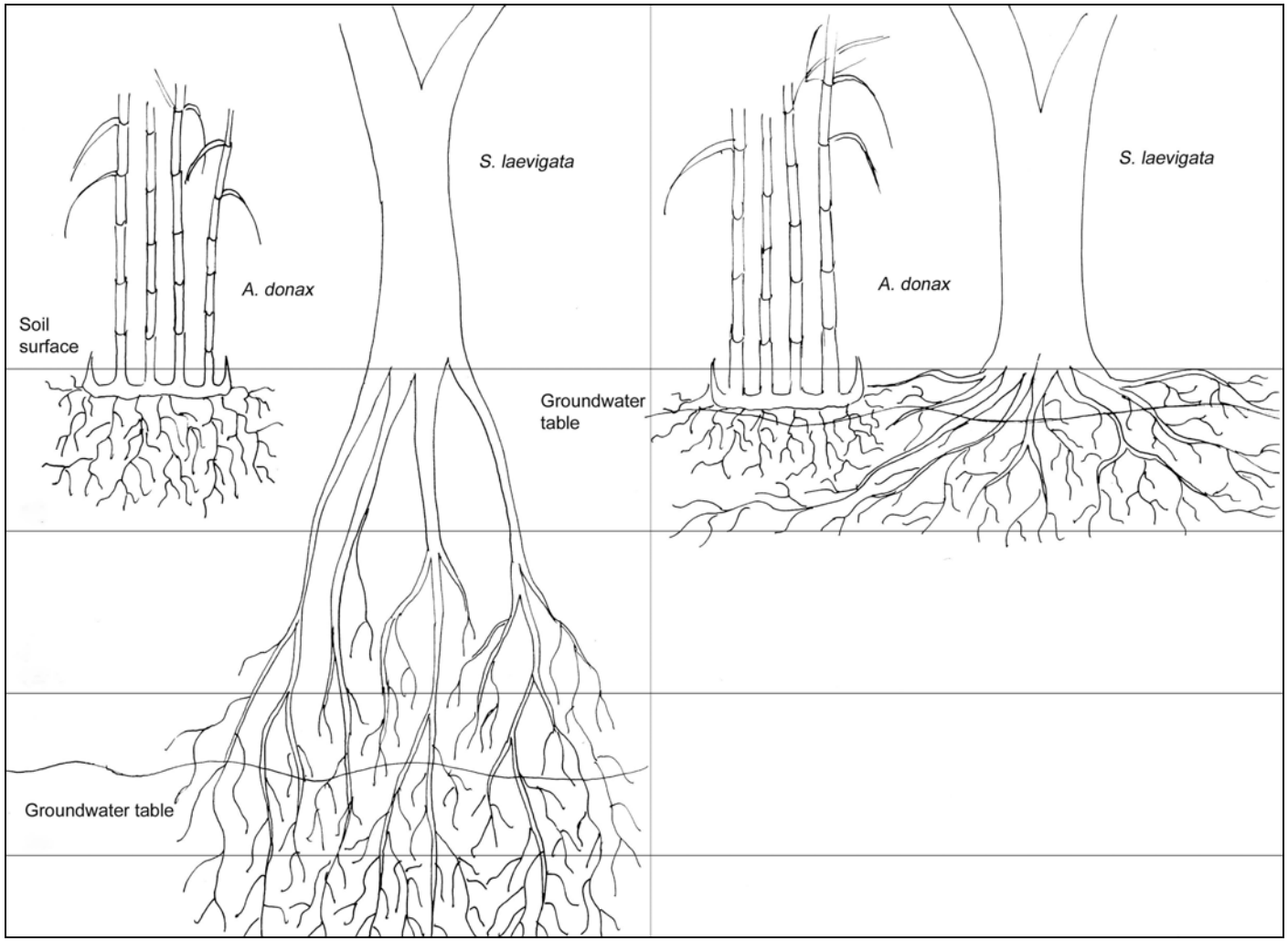

Figure 9. Diagram of *A. donax* and *S. laevigata* rooting depths and distribution in a) deep and b) shallow groundwater table conditions.

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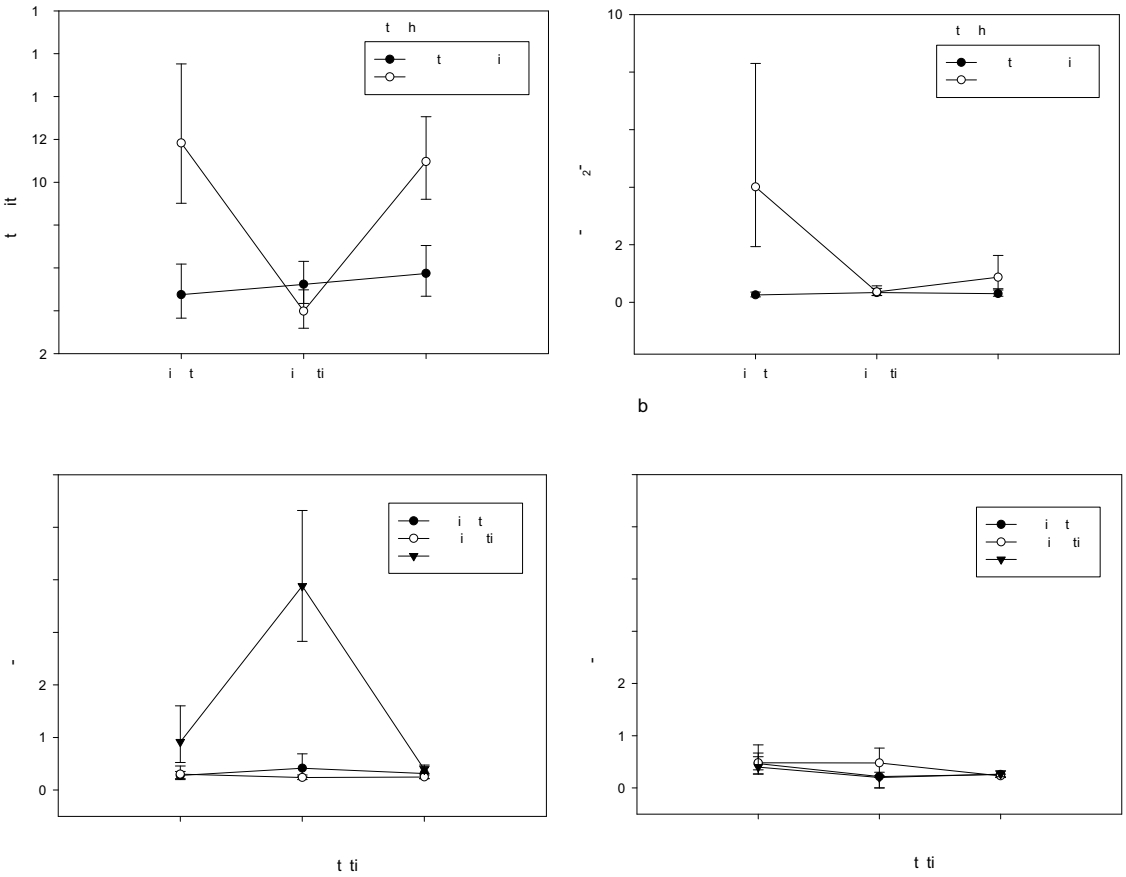

Figure 10. Interaction plots for 3-way ANOVA of shallow groundwater nutrients by watershed (Santa Clara River and Calleguas Creek only) x land use (A = agricultural, R = residential, and O = open space) x degree of infestation (N = none, S = small, and L = large). Plots include two-way interaction plots for shallow groundwater a) total N, and b) NO_3-N + NO_2-N (small infestation data removed), and three-way interaction plots for shallow groundwater NH_4-N in c) Calleguas Creek and d) Santa Clara River.

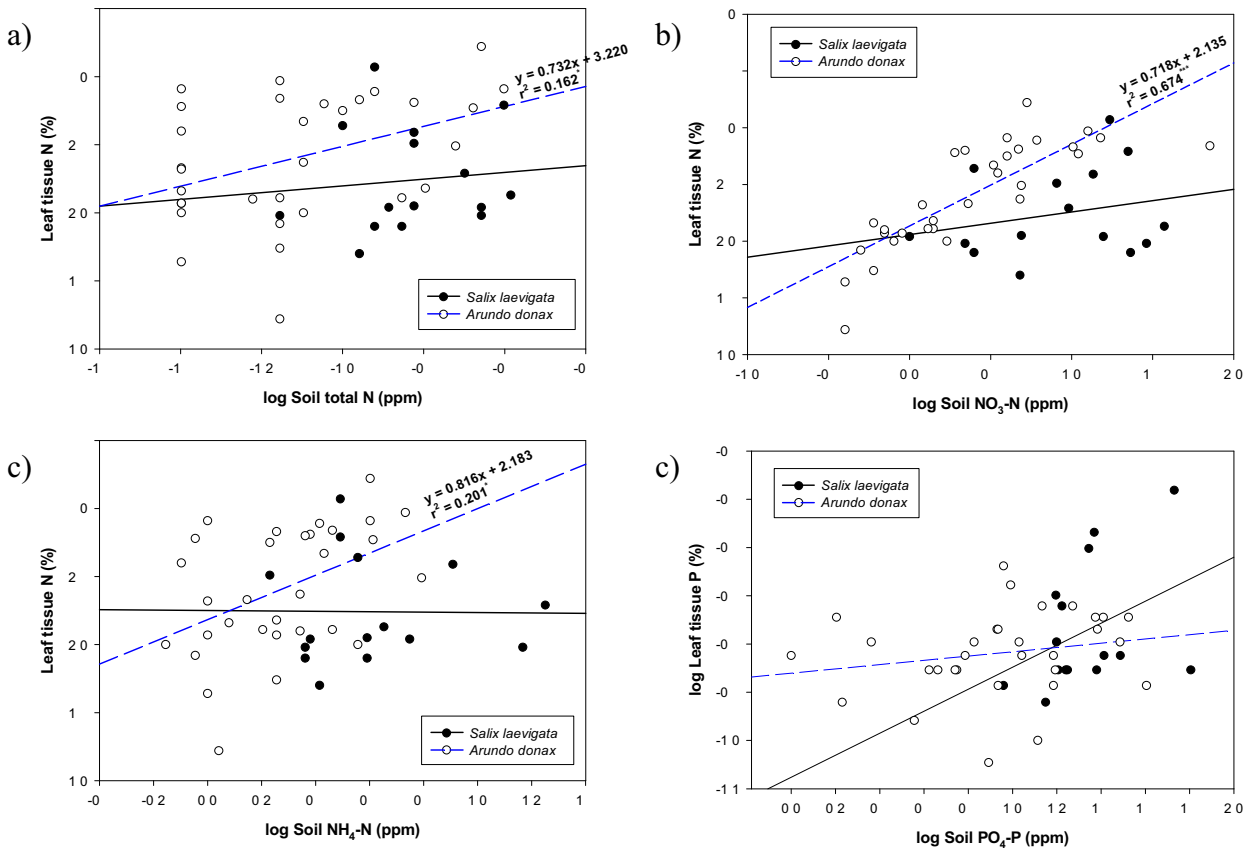

Figure 11. Linear regression relationships between shallow groundwater and soil nutrients (independent variable) found in terrace sites and associated leaf tissue nutrients (response variable) of target plants by plant species. Only Santa Clara River data was used. Equations were only included for significant relationships. Leaf tissue N/P and soil (a) total N, (b) NO_3-N, (c) NH_4-N, and (d) PO_4-P.

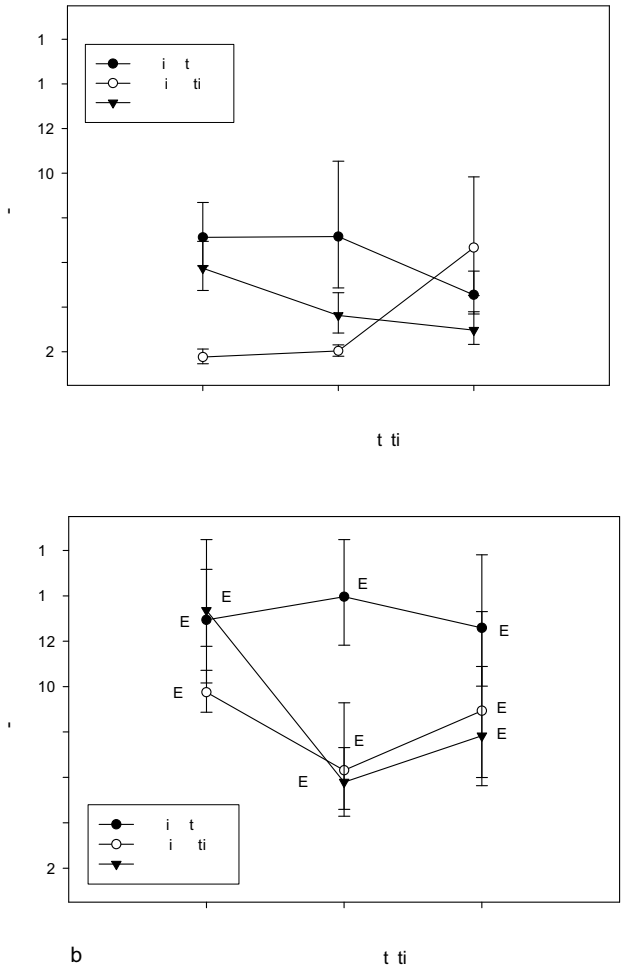

Figure 12. Interaction plots for 3-way ANOVA of soil nutrients by watershed (Santa Clara River and Calleguas Creek only) x land use (A = agricultural, R = residential and O = open space) x degree of infestation (N = none, S = small, and L = large). Plots show the three-way interaction for soil PO_4-P in a) Santa Clara River and b) Calleguas Creek.

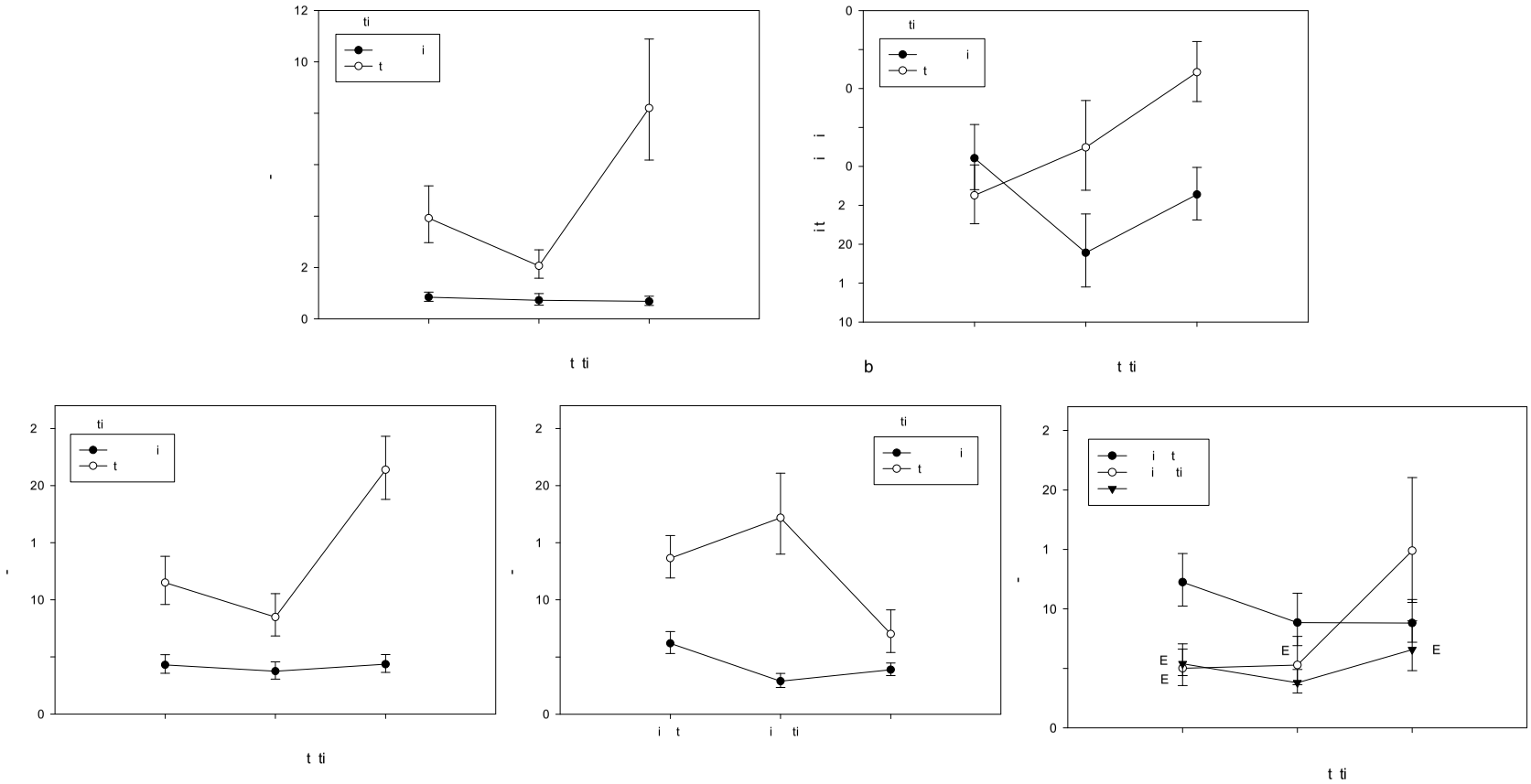

Figure 13. Interaction plots for 3-way ANOVA of soil nutrients and grain size for land use (A = agricultural, R = residential, and O = open space) x degree of infestation (N = none, S = small, and L = large) x fluvial geomorphic location (terrace and floodplain) for Santa Clara River only. Plots include 2-way interactions of a) soil NO_3-N and b) silt + clay and 3-way interaction of soil PO_4-P (c, d, and e).

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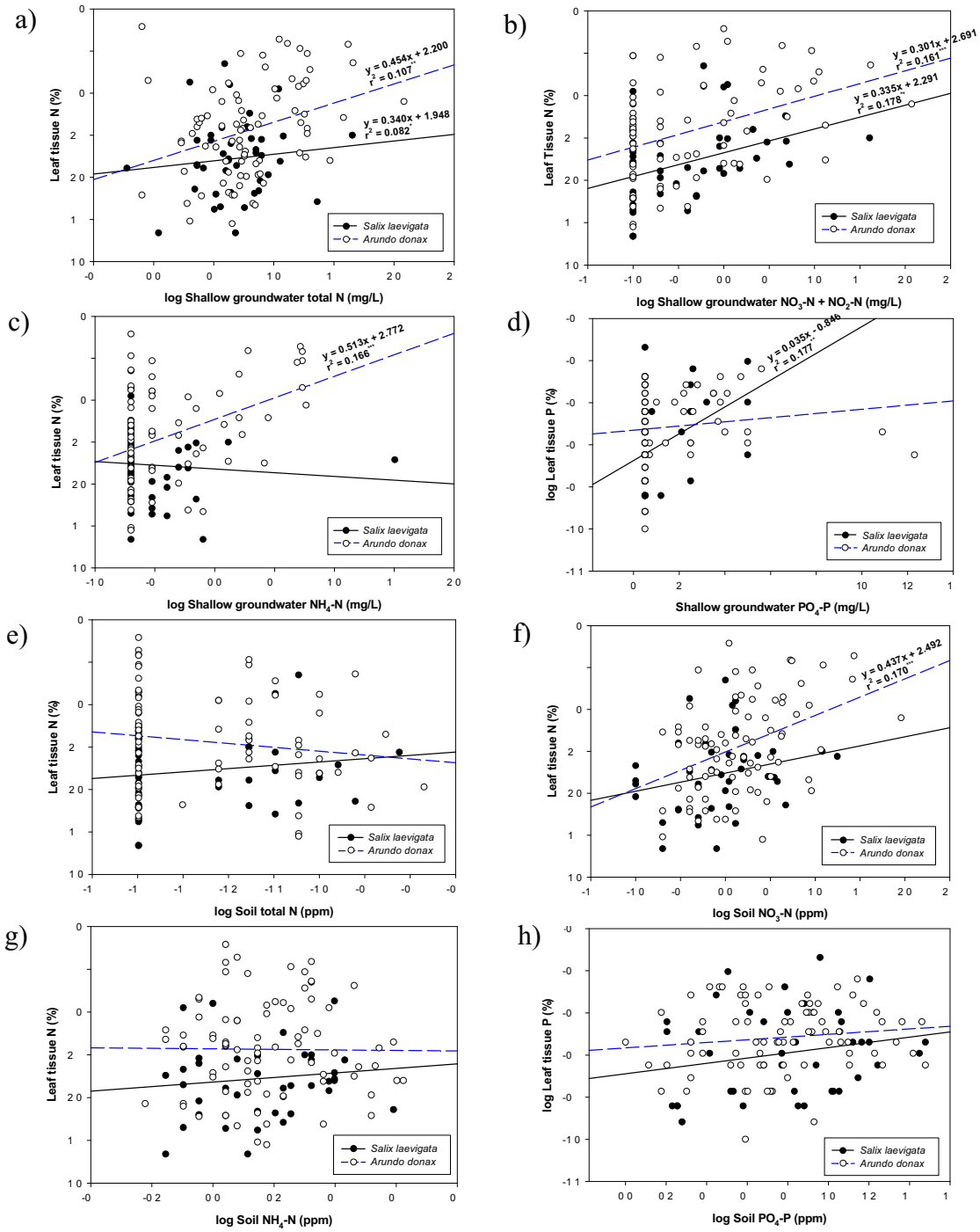

Figure 14. Linear regression relationships between shallow groundwater and soil nutrients (independent variable) found in floodplain sites and associated leaf tissue nutrients (response variable) of target plants by plant species. Equations were only included for significant relationships. Leaf tissue N/P and soil (a) total N, (b) NO_3-N, (c) NH_4-N, and (d) PO_4-P. Leaf tissue N/P and shallow groundwater (e) total N, (f) NO_3-N + NO_2-N, (g) NH_4-N, and (h) PO_4-P.

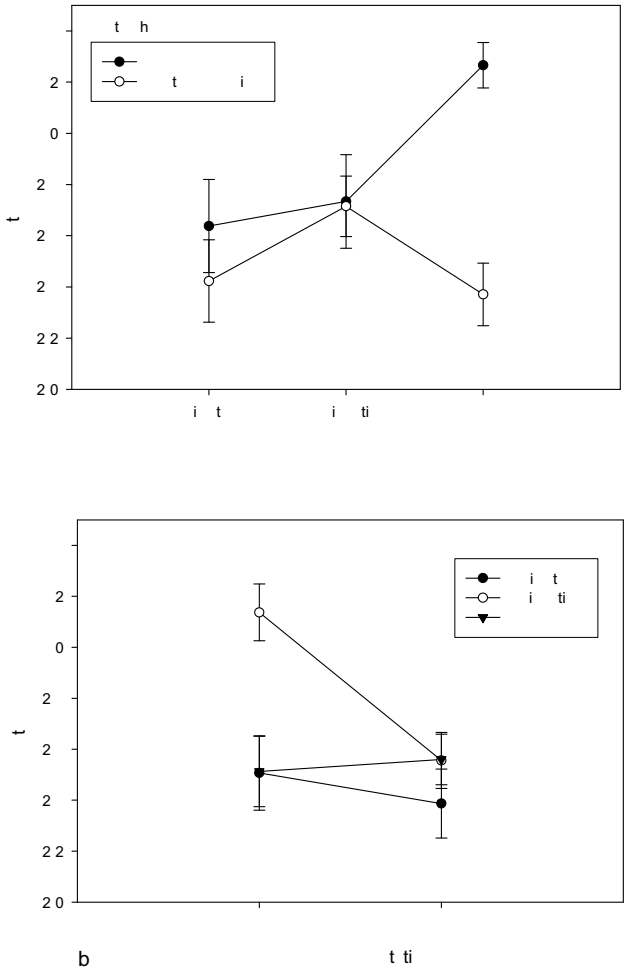

Figure 15. Interaction plots for 3-way ANOVA of *A. donax* leaf tissue nutrients by watershed (Santa Clara River and Calleguas Creek only) x land use (A = agricultural, R = residential, O = open space) x degree of infestation (S = small, L = large). Plots illustrate the two-way interaction for a) leaf tissue N and b) leaf tissue K.

APPENDIX

APPENDIX 3-1

TABLE 1. SAMPLING LOCATIONS

Site ID[17]	Latitude (degrees)	Longitude (degrees)
Calleguas Creek		
CAFL1	34.18181797	-119.03227547
CAFL2	34.18522848	-119.02564312
CAFL3	34.26126039	-118.97952396
CAFL4	34.26026671	-118.98207734
CAFL5	34.27144197	-118.92569614
CAFN1	34.13669625	-119.08521188
CAFN2	34.15400296	-119.07143463
CAFN3	34.17924422	-119.03796569
CAFN4	34.23487474	-118.96908212
CAFN5	34.18599115	-119.02471977
CAFS1	34.13507461	-119.08160741
CAFS2	34.13344902	-119.07335250
CAFS3	34.17960581	-119.04052360
CAFS4	34.21919798	-118.98473675
CAFS5	34.22309129	-118.98073481
COFL1	34.18100023	-119.03332044
COFL2	34.28386898	-118.85975520
COFL3	34.28732609	-118.83532254
COFL4	34.28502903	-118.82843195
COFL5	34.23055504	-118.93391920
COFN1	34.18210127	-119.02929805
COFN2	34.28435823	-118.85500057
COFN3	34.28635279	-118.83322028
COFN4	34.28214583	-118.80707444
COFN5	34.22688327	-118.93127832
COFS1	34.28637156	-118.83378790
COFS2	34.28705938	-118.82914742
COFS3	34.28464581	-118.82491607
COFS4	34.28645848	-118.83080796
COFS5	34.22922341	-118.93361712

[17] First character stands for watershed (S = Santa Clara River; C = Calleguas Creek; T = Topanga Cayon); Second character stands for land use (A = agricultural; O = open space; R = residential); Third character stands for fluvial geomorphic location (F = floodplain; T = terrace); Fourth character stands for degree of infestation (L = large infestation; S = small infestation; N = no infestation); and number stands for replicate.

TABLE 1 (continued). SAMPLING LOCATIONS

Site ID[18]	Latitude (degrees)	Longitude (degrees)
CRFL1	34.26952092	-118.90881867
CRFL2	34.27168974	-118.90275277
CRFL3	34.27363845	-118.89887664
CRFL4	34.28602137	-118.86197255
CRFL5	34.27015417	-118.90565316
CRFN1	34.27816652	-118.80317417
CRFN2	34.28010098	-118.80417497
CRFN3	34.28114930	-118.80471577
CRFN4	34.23009370	-118.97145169
CRFN5	34.28538610	-118.86089791
CRFS1	34.21678056	-118.98688914
CRFS2	34.22753965	-118.97609828
CRFS3	34.28504504	-118.86083965
CRFS4	34.28149489	-118.80560375
CRFS5	34.22546622	-118.97838193
Santa Clara River		
SAFL1	34.31599656	-119.09517872
SAFL2	34.38832736	-118.93290969
SAFL3	34.37853578	-118.95602329
SAFL4	34.35348068	-119.04170327
SAFL5	34.38983082	-118.89746865
SAFL6	34.40303776	-118.74487334
SAFN1	34.38109352	-118.95231379
SAFN2	34.38252431	-118.95086406
SAFN3	34.38010991	-118.95468604
SAFN4	34.38622895	-118.88881040
SAFN5	34.41809141	-118.64794627
SAFS1	34.38650915	-118.93600730
SAFS2	34.38889540	-118.91346602
SAFS3	34.37347672	-118.96392172
SAFS4	34.38713193	-118.89121969
SAFS5	34.40141788	-118.71480217
SATL1	34.37955360	-118.94674502

[18] First character stands for watershed (S = Santa Clara River; C = Calleguas Creek; T = Topanga Cayon); Second character stands for land use (A = agricultural; O = open space; R = residential); Third character stands for fluvial geomorphic location (F = floodplain; T = terrace); Fourth character stands for degree of infestation (L = large infestation; S = small infestation; N = no infestation); and number stands for replicate.

TABLE 1 (continued). SAMPLING LOCATIONS

Site ID[19]	Latitude (degrees)	Longitude (degrees)
SATL2	34.37299149	-118.96207594
SATL3	34.36193652	-119.02509629
SATL4	34.33253070	-119.07771637
SATL5	34.40404988	-118.74102739
SATLD1	34.23179138	-119.25541925
SATLD2	34.34685814	-119.05269706
SATLD3	34.36438361	-118.99051289
SATLD4	34.23333733	-119.21936131
SATLD5	34.32794371	-119.08172417
SATN1	34.41422937	-118.66145672
SATN2	34.40875657	-118.67276156
SATN3	34.36076590	-119.02292772
SATN4	34.41591941	-118.65056385
SATN5	34.40360916	-118.70071513
SATS1	34.37267943	-118.96522050
SATS2	34.38859608	-118.93302837
SATS3	34.38028551	-118.95542398
SATS4	34.40124856	-118.70185146
SATS5	34.39195890	-118.80118028
SATSD1	34.41272029	-118.66298717
SATSD2	34.37248522	-118.96579332
SATSD3	34.41051199	-118.66039256
SATSD4	34.41148815	-118.65905279
SATSD5	34.40319082	-118.70229227
SOFL1	34.35990047	-119.01475981
SOFL2	34.35719647	-119.01773538
SOFL3	34.36599487	-118.99932973
SOFL4	34.36452552	-119.00776427
SOFL5	34.39567518	-118.70910885
SOFN1	34.32881568	-119.07774386
SOFN2	34.31887373	-119.09080865
SOFN3	34.33239022	-119.07561427
SOFN4	34.35490100	-119.02514490

[19] First character stands for watershed (S = Santa Clara River; C = Calleguas Creek; T = Topanga Cayon); Second character stands for land use (A = agricultural; O = open space; R = residential); Third character stands for fluvial geomorphic location (F = floodplain; T = terrace); Fourth character stands for degree of infestation (L = large infestation; S = small infestation; N = no infestation); and number stands for replicate.

TABLE 1 (continued). SAMPLING LOCATIONS

Site ID[20]	Latitude (degrees)	Longitude (degrees)
SOFN5	34.35635107	-119.03155874
SOFN6	34.40588200	-118.67016896
SOFS1	34.31559457	-119.09520957
SOFS2	34.31924572	-119.09028830
SOFS3	34.35645919	-119.02864812
SOFS4	34.35424478	-119.03863080
SOFS5	34.35664217	-119.01821039
SOTL1	34.32809450	-119.07738880
SOTL2	34.32945983	-119.07627577
SOTL3	34.34939501	-119.04156798
SOTL4	34.35409910	-119.02377773
SOTL5	34.41041409	-118.73012722
SOTN1	34.36328583	-119.01684833
SOTN2	34.35810691	-119.00888879
SOTN3	34.41841671	-118.63987014
SOTN4	34.40295386	-118.67300430
SOTN5	34.42674807	-118.50331075
SOTS1	34.32863555	-119.07692595
SOTS2	34.35231283	-119.03071065
SOTS3	34.36246751	-119.01539817
SOTS4	34.40365333	-118.67624148
SOTS5	34.29775595	-119.11061701
SRFL1	34.34551662	-119.06320377
SRFL2	34.34638943	-119.06159009
SRFL3	34.34678681	-119.06052181
SRFL4	34.34727757	-119.05925003
SRFL5	34.34763791	-119.05837077
SRFN1	34.39021530	-118.91872273
SRFN2	34.39055946	-118.92006811
SRFN3	34.39047094	-118.92058108
SRFN4	34.34850996	-119.05502697
SRFN5	34.34279946	-119.06580761
SRFS1	34.34842966	-119.05599014

[20] First character stands for watershed (S = Santa Clara River; C = Calleguas Creek; T = Topanga Cayon); Second character stands for land use (A = agricultural; O = open space; R = residential); Third character stands for fluvial geomorphic location (F = floodplain; T = terrace); Fourth character stands for degree of infestation (L = large infestation; S = small infestation; N = no infestation); and number stands for replicate.

TABLE 1 (continued). SAMPLING LOCATIONS

Site ID[21]	Latitude (degrees)	Longitude (degrees)
SRFS2	34.34434206	-119.06444111
SRFS3	34.34619077	-119.06199317
SRFS4	34.34843880	-119.05402014
SRFS5	34.34869981	-119.05140314
SRTL1	34.34955376	-119.05358260
SRTL2	34.26270140	-119.16888054
SRTL3	34.27168856	-119.15589622
SRTL4	34.34653955	-119.06151641
SRTL5	34.23558016	-119.19549652
SRTL6	34.42552071	-118.56015748
SRTN1	34.39073430	-118.92195504
SRTN2	34.39069558	-118.92312767
SRTN3	34.26057022	-119.17577449
SRTN4	34.26676621	-119.16454090
SRTN5	34.42593033	-118.54444083
SRTS1	34.26179976	-119.17029432
SRTS2	34.34747539	-119.05919303
SRTS3	34.23591485	-119.19486805
SRTS4	34.42548039	-118.55383988
SRTS5	34.39371038	-118.91472976
Topanga Canyon		
TOFL1	34.06384511	-118.58723690
TOFL2	34.06142517	-118.58494202
TOFL3	34.05183099	-118.58190827
TOFL4	34.06960465	-118.58714193
TOFL5	34.06604201	-118.58649661
TOFN1	34.04854679	-118.58064923
TOFN2	34.06349609	-118.58599612
TOFN3	34.05022988	-118.58104510
TOFN4	34.06934339	-118.58688243
TOFN5	34.07574029	-118.58923590
TOFS1	34.04960300	-118.58127845
TOFS2	34.06511346	-118.58651371

[21] First character stands for watershed (S = Santa Clara River; C = Calleguas Creek; T = Topanga Cayon); Second character stands for land use (A = agricultural; O = open space; R = residential); Third character stands for fluvial geomorphic location (F = floodplain; T = terrace); Fourth character stands for degree of infestation (L = large infestation; S = small infestation; N = no infestation); and number stands for replicate.

TABLE 1 (continued). SAMPLING LOCATIONS

Site ID[22]	Latitude (degrees)	Longitude (degrees)
TOFS3	34.06168367	-118.58562925
TOFS4	34.06894994	-118.58698418
TOFS5	34.07637094	-118.59061053
TRFL1	34.04108514	-118.58094972
TRFL2	34.04112973	-118.58058594
TRFL3	34.04087928	-118.58260598
TRFL4	34.04068482	-118.58244010
TRFL5	34.03998594	-118.58274286
TRFN1	34.09726543	-118.60056496
TRFN2	34.09518739	-118.60157046
TRFN3	34.09382936	-118.60303125
TRFN4	34.09431375	-118.60276169
TRFN5	34.09441508	-118.60242583
TRFS1	34.09592609	-118.60095137
TRFS2	34.09501355	-118.60170339
TRFS3	34.09789693	-118.60000195
TRFS4	34.04005618	-118.58304461
TRFS5	34.04103183	-118.58065979
Reference Sites		
Agua Blanca	34.54197845	-118.76600772
Aliso Canyon	34.41807398	-118.09363894
Arroyo Sequit	34.06579390	-118.93263468
Bouquet Canyon	34.57381133	-118.38870624
Cold Creek	34.09425859	-118.64799891
Lachusa Creek	34.04172728	-118.89414808
Las Virgenes Creek	34.16885342	-118.70297916
Solstice Canyon	34.03844903	-118.75221346
Sespe Creek	34.55823516	-119.24346691
Santa Paula Creek	34.44816727	-119.06068350

[22] First character stands for watershed (S = Santa Clara River; C = Calleguas Creek; T = Topanga Cayon); Second character stands for land use (A = agricultural; O = open space; R = residential); Third character stands for fluvial geomorphic location (F = floodplain; T = terrace); Fourth character stands for degree of infestation (L = large infestation; S = small infestation; N = no infestation); and number stands for replicate.

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CHAPTER 4 -

WILDFIRE PROMOTES GIANT REED (*ARUNDO DONAX*) INVASION IN RIPARIAN ECOSYSTEMS

Abstract: Invasion of riparian ecosystems by the large bamboo-like grass species *Arundo donax* L. has caused major alterations to structure and ecosystem functions in streams of arid and Mediterranean-type climate regions. Although healthy riparian ecosystems function as natural barriers to wildfire, the extensive wildfires in southern California in October 2003 burned large expanses of riparian ecosystems along the Santa Clara River and appeared to promote *A. donax* invasion. I investigated post-fire plant colonization of riparian areas along the Santa Clara River to determine the influence of wildfire on *A. donax* invasion. Growth of *A. donax* was compared to native plants for 1 year after the fire. Pre- and post-fire plant abundance and soil nutrient concentrations were analyzed to ascertain the role of fire-derived nutrients in the invasion process. Due to its immediate re-growth after the fire and its high growth rate compared to native riparian plants, *A. donax* dominated these burned riparian ecosystems within a few months after the fire and reached 99% cover a year later. *Arundo donax* grew an average of 3–4 times faster than native woody riparian plants – up to 2.62 cm/day (average 0.72 cm/day) – and reached up to 2.3 m in height less than 3 months after the fire. One year post-fire, *A. donax* density was nearly 20 times higher and productivity was 14–24 times higher than native plants. Elevated soil NH_4-N and P levels post-fire may have stimulated the high growth rate of *A. donax*. Large quantities of *A. donax* biomass that

have replaced native woody species after wildfire have increased susceptibility of riparian ecosystems along the Santa Clara River to fire, creating an invasive plant-fire regime cycle. Wildfire not only promotes dominance of riparian ecosystems by *A. donax*, but also alters vital ecosystem processes and increases the risk of fire spreading to surrounding shrublands, towns, and agriculture.

Key Words: *Arundo donax,* wildfire, giant reed, invasive species, alien species, competition, nitrogen, riparian, Mediterranean-type climate, rivers, soil nutrients

INTRODUCTION

Historically, dense cover of chaparral biomass accumulating over a 30–50 years or more provided fuel for high-intensity wildfires in shrublands of southern California and in similar shrublands of other Mediterranean-type climate regions (Minnich 1983, Keeley et al. 1999, Keeley and Fotheringham 2001, 2005). However, riparian corridors may have acted as natural firebreaks (Dudley 1998, Rundel 2000, 2003) and refuge for wildlife in the landscape because of their low-lying topographic position and relative absence of flammable fuels. Lightning was the primary cause of wildfires, especially during dry, low humidity conditions that occur in the late summer and fall (Naveh 1975, Keeley 1982, Keeley et al. 1999). Currently, most wildfires in these areas are anthropogenic in origin (Rugen 1987, D'Antonio and Vitousek 1992, Keeley et al. 1999).

Invasion of annual grass species has been linked to altered fire regimes in rangelands, deserts, and wildlands of California and the western U.S. (Brooks and Pyke 2001, Brooks et al. 2004, Dukes and Mooney 2004). Grass/fire cycles, more recently termed invasive plant-fire regime cycles, may ensue when alien grass species colonize an area and provide fuel for fire propagation, increasing frequency, area, and intensity of fires (D'Antonio and Vitousek 1992, D'Antonio 2000, Brooks 2002, Brooks et al. 2004, Keeley 2004, Keeley and Fotheringham 2005). Rapid recovery of alien grass species compared to native species after fire leads to increased susceptibility of that ecosystem to fire.

In coastal shrubland watersheds in California, a large invasive grass species *Arundo donax* may be an even bigger problem in riparian ecosystems due to its perennial

growth form with a large volume of biomass produced, flammability compared to natives, and immediate rapid growth after fire (Rieger and Kreager 1989). *Arundo donax* was introduced from southern Eurasia into the Los Angeles region several hundred years ago for erosion control and building materials (Robbins et al. 1951, Perdue 1958, Dudley and Collins 1995), and now infests many stream and river system in coastal California (Gaffney 2002). The natural flood disturbance regime in this climate regime successfully distributes it along rivers, where it establishes readily on bare substrates (Else 1996, Else and Zedler 1996). Studies suggest that increased water and nutrient delivery to these systems have increased its invasion success (see Chapter 2 and 3), yet the influence of fire on its invasion in river systems remains relatively unexplored and undocumented. Several accounts suggest that infestations of *A. donax* have increased fuel load as well as fire frequency and intensity along riparian corridors (Robbins et al. 1951, Bell 1994, Scott 1994, D'Antonio 2000). Growing to between 4–8 m in height and as fast as 10 cm per day (Perdue 1958, Crampton 1974, Hickman 1993), it produces abundant flammable biomass that accumulates during the summer and fall months (Rundel 2000). The ability of its rhizomes to recover more rapidly than native plants after fire likely contributes to its invasion success, but no evidence exists to document this response to fire. Furthermore, increased post-fire nutrient effects may promote a positive feedback cycle (invasive plant-fire regime) in these ecosystems.

Although little research exists on the effects of fire in riparian ecosystems, several authors have suggested that fire may increase the ability of *A. donax* to invade natural riparian systems (Rieger and Kreager 1989, Scott 1994, Bell 1997). The large amount of

highly flammable biomass that *A. donax* produces and that accumulates during most of the year, as well as the ability of its rhizomes to respond quickly after fire, likely contribute to its invasion success by creating a invasive plant-fire regime cycle. DiTomaso (1998) suggests that *A. donax* invasion is changing riparian ecosystems from primarily flood-defined (Mount 1995) to fire-defined systems. The Simi/Verdale wildfire of October 2003 (Ventura County, CA) (Keeley and Fotheringham 2005) provided a unique opportunity to study the contribution of fire to invasion of riparian terrace ecosystems of the Santa Clara River by *A. donax*. In this study, I compared growth and recolonization of *A. donax* to that of native plant species in riparian ecosystems burned in a southern California wildfire. I hypothesized that high adjacent soil nutrient content, immediate post-fire resprouting phenology, and higher growth rate than native plants promote invasion of *A. donax* in riparian corridors of southern California.

METHODS

Study area

Study sites were located in the approximately 700-acres of riparian ecosystem of the Santa Clara River that was burned in the late October 2003 Simi/Verdale fire (Keeley and Fotheringham 2005) (Figure 16). The 187 km-long Santa Clara River and its tributaries drain a 4,185 km^2 watershed, the second largest coastal watershed in southern California. Hundreds of acres of *A. donax* infest floodplains and terraces along the Santa Clara River. Natural riparian vegetation on terraces consisted of large riparian trees, both black cottonwood (*Populus balsamifera* (L.) ssp. *trichocarpa* Torrey & A. Gray) and red willow (*Salix laevigata* Bebb) in the canopy layer. A mixture of smaller trees and shrubs

comprised the understory layer, including arroyo willow (*Salix lasiolepis* Benth.), sandbar willow (*Salix exigua* Nutt.), shining willow [*Salix lucida* Muhl. ssp. *lasiandra* (Benth.) E. Murray], mulefat [*Baccharis salicifolia* (Ruiz Lopez & Pavon) Pers.], and blue elderberry (*Sambucus mexicana* C. Presl.).

Study design

Six sites established in a previous study along the Santa Clara River (see Chapter 3) were burned during the 2003 wildfire. These study sites were all located on riparian terraces, and five out of six sites were adjacent to shrubland ecosystems. The wildfire crossed the river through one site located near the Los Angeles-Ventura County line and the other five sites were located near the town of Santa Paula. I compared pre-fire plant composition and soil nutrient data collected in summer 2003 at these six permanent monitoring sites to data collected in these sites during the year after the wildfire (2004). I established eight additional study sites along riparian terrace areas burned to the west of these sites in a river reach that did not contain previous study sites to make sure sites were well-distributed throughout the riparian areas burned and represented the range of environmental conditions found in the study area. I monitored recolonization of all sites from November 2003-October 2004 (Figure 16) (see Appendix 4-1 for study site locations and descriptions). The 14 study sites were approximately 600 m^2 (most sites were 30 m long x 20 m wide) and all but one was located next to open space land use types; the one exception was adjacent to a citrus orchard.

Study species

Arundo donax is a robust, perennial, bamboo-like member of the Poaceae family (grass family) that occurs throughout the floodplains and terraces of rivers in California and other warm, temperate climates worldwide (Crampton 1974, Hickman 1993). It has erect, stout yet hollow culms that are 1–4 cm in diameter and 2–8 m or more tall. Culms branch, forming ramets, typically at the end of the first year of growth or after a culm is damaged. Leaf blades are broad (2–6 cm wide), less than 1 m long, flat, clasping at the base, strongly scabrous along their margins, and evenly spaced along the culm (Faber and Holland 1992, Hickman 1993). *Arundo donax* reproduces vegetatively through a network of large thick rhizomes that grow horizontally just below the surface of the soil. Under some conditions it produces a large (3–6 dm), terminal, plume-like inflorescence (panicle) at the end of the growing season (Faber and Holland 1992, Hickman 1993); however, seeds of the inflorescence are primarily sterile in California (Johnson et al. 2006).

In addition to *A. donax*, I studied several native riparian plant species commonly found on terraces of rivers in southern California and in terraces that were burned in the fire: *Salix laevigata, S. lasiolepis*, *S. exigua*, *Populus balsamifera* ssp. *trichocarpa*, and *Baccharis salicifolia*. *Salix laevigata* is a riparian tree that reaches heights up to 15 m and is dominant in both floodplains and terraces along southern California rivers, and *Populus balsamifera* ssp. *trichocarpa* grows to a height of 30 m in alluvial plains and terraces along rivers in southern California (Faber et al. 1989, Faber and Holland 1992, Hickman 1993). *Salix lasiolepis* is a widely distributed plant that occurs as a small tree

in wetter areas and a spreading shrub in drier locations (Faber et al. 1989). *Salix exigua* is a shrub-sized willow that commonly grows on sandy substrates along active floodplains (Faber et al. 1989). *Baccharis salicifolia* is one of the most dominant shrubs found throughout floodplains and terraces of streams and rivers of southern California. A member of the Asteraceae, it usually grows to a height of less than 4 m.

Sampling methods

I took plant measurements monthly from November 2003 to October 2004 in all 14 study sites to examine the effects of fire on recolonization of riparian terraces. I determined change in plant abundance in burned areas by comparing pre- and post-fire (summer 2003 and July 2004) percent cover of *A. donax* and native woody plant species in the six long-term study locations. Ocular estimates of percent cover by species were taken within 1 m^2 quadrants place randomly throughout six permanent study sites during summer 2003 and all 14 study sites during each post-fire sampling period. Post-fire mean shoot density (stems m^{-2}) of *A. donax* and all native species were sampled monthly within six $1m^2$ quadrants (placed randomly each time) within all 14 study sites. I measured mean shoot length (cm) and basal diameter (mm) of 20 randomly selected *A. donax* and 20 native individuals of each dominant native woody species at each study site and post-fire sampling period. In addition, I measured shoot height and basal diameter for three permanently marked *A. donax* and native plant shoots (three of each species) at each sampling period. Basal diameter measurements were taken 10 cm above the surface of the soil. I calculated mean shoot elongation rate (cm d^{-1}) for each species using data from the permanently marked individuals.

I calculated the aboveground biomass, relative growth rates (RGRs), and productivity of plants within the study sites using the plant dimension data collected during the study. Non-destructive dimensional analyses were used to estimate aboveground biomass dry weight of plants in study sites with minimal interference to plant growth (Whittaker 1961, 1965, Whittaker and Marks 1975, Sharifi et al. 1982, Spencer et al. 2006). I created regression models for each species using basal diameter, shoot length, and aboveground biomass of culm/branch samples measured in the field experiment to predict biomass of each individual plant sampled in the study sites. Regression models for aboveground biomass were very highly significant for all species ($r^2 = 0.971$ to 0.990, $P < 0.001$) (see Chapter 2 for study design and Appendix 2-1 for equations). *Arundo donax* biomass was estimated based on both basal diameter and shoot length measurements taken at all study sites, and native species biomass estimates were based on basal stem diameter. All data were log transformed in regression models.

I calculated RGRs for all permanently marked individuals using the following differential equation, where W is the total aboveground biomass dry weight (g) of each shoot and t is time (day^{-1} post-fire).

$$\text{RGR} = \frac{dW}{dt}\frac{1}{W} = \frac{d(\ln W)}{dt}$$

Mean productivity (kg m^{-2} year^{-1}) for each species was calculated at approximately 1 year post-fire. I estimated biomass (kg) for the 20 randomly sampled culms/stems for each species measured during September 2004. For each species, mean biomass per shoot (kg shoot^{-1}) was multiplied by mean density (shoots m^{-2}) at each study

site and then divided by time (year). I averaged productivity calculations for each species across study sites.

Five soil subsamples were collected at each study site adjacent to *A. donax* and each native woody plant species immediately after fire (November through January). Subsamples were collected in the upper 20 cm of the soil where nutrient concentrations are greatest (Day 1983). For each species, soil samples were combined into a composite sample by thorough mixing in a stainless steel bowl. Each soil subsample was collected with an 8-cm diameter bucket auger. Soil samples taken before the fire (summer 2003) were taken adjacent to *A. donax* and *S. laevigata* according to the same sampling protocol.

Soil samples were air-dried and ground to a powder in preparation for nutrient content analyses at the DANR Analytical Laboratory in Davis, California. Soil samples were analyzed for total N (%), nitrate-N (NO_3-N - ppm), ammonia-N (NH_4-N - ppm), and orthophosphate (PO_4-P - ppm). Total N in the soil was determined by the combustion gas analyzer method (Method 972.43) (Hofer 2003, Knepel 2003). Concentrations of NO_3-N and NH_4-N in the soil were determined by equilibrium extraction of soil with potassium chloride and a flow-injection analyzer (Olsen and Sommers 1982, Prokopy 1995). Because the soils studied were neutral to alkaline, the Olsen-P method was used to estimate the relative availability of inorganic PO_4-P in the samples. Soil grain size was analyzed using a hydrometer to determine the particle size distribution of sand, silt, and clay in soil suspension (Sheldrick and Wang 1993).

Statistical analyses

One-way and two-way analysis of variance (ANOVA) tests were used to analyze effects of various combinations of factors (plant type and time) on plant performance and growth data (dependent or response variables) (Systat Statistical Program [Version 10]). Factors tested include plant type (*A. donax* and native plant species) and time (pre-fire vs. post-fire or months post-fire). Dependent variables included plant abundance (percent cover), density (stem m^{-2}), shoot length (cm), shoot elongation rate (cm d^{-1}), RGR (g $g^{-1}day^{-1}$), productivity (kg m^{-2} yr^{-1}), and soil nutrient concentrations (NH_4-N, NO_3-N, and phosphate in ppm).

I conducted a one-way ANOVA of productivity by species (*A. donax*, *B. salicifolia*, and *S. laevigata*) and two way-ANOVAs for all plant performance metrics by factors of plant type and time to determine differences in plant growth by species over time post-fire. Tukey's post-hoc test was used for pairwise comparisons of means in the one-way ANOVA. I performed ANOVA hypothesis tests to evaluate contrasts between means of grouping variables and levels in two-way ANOVA results. Probability plots were examined to test for normality of data and to identify any data that required transformation. All biomass, soil NH_4-N, and NO_3-N data were ln transformed. When means and standard errors were used to describe or present statistical differences, data were back-transformed and reported in original units.

RESULTS

Pre- versus post-fire plant abundance

In the two-way ANOVA (plant type x time period) of plant abundance, both main effects were significant (Table 12). Percent cover of *A. donax* was much higher than native plant cover both before and after the study sites were burned (Figure 17). Although both *A. donax* (65.0 ± SE 6.7% cover) and the native plants (21.7 ± SE 6.0% cover) were in greater abundance before the fire, less than a year after the fire *A. donax* (42.8 ± SE 4.3% cover) was the dominant plant species in these riparian ecosystems (Figure 17). Native species comprised 25.0% of the total vegetation before the fire and less than 1% (0.4 ± SE 0.2% cover) of the vegetation in burned riparian terraces only 9 months after the fire.

Post-fire density

The two-way ANOVA (plant type x time period) of plant density revealed a significant two-way interaction (Table 12). The mean density of *A. donax* (stems m^{-2}) was much greater than that of native plant species for all months sampled (March–September 2004) (Figure 18). Mean density of native plant species declined somewhat over time during the first year after the fire, although differences between sampling periods were not significant. However, mean density of *A. donax* shoots increased significantly over time. A year after the wildfire, *A. donax* density (26.3 ± SE 3.2 stems m^{-2}) was an order of magnitude greater than that of native species (1.4 ± SE 0.4 stems m^{-2}) within the burned riparian ecosystems sampled.

Post-fire shoot length

Post-fire resprout timing and shoot length over time differed significantly between *A. donax* and the native plants studied (Figure 19). *Arundo donax* began growing within days after being burned to the ground, whereas native plants did not start to appear (a few seedlings/resprouts at eight sites) sites until January (over two months after they burned). The two-way ANOVA of shoot length by plant type and time period resulted in a very highly significant two-way interaction (Table 12). Shoot length was 1.7–5.2 times greater (over 2.5 times greater on average) for *A. donax* than for natives during all months sampled (Figure 19).

Post-fire shoot elongation rate and RGR

Arundo donax shoots grew at a much faster rate than the native riparian plant species within the first year after fire (Figure 20 and Figure 21). The two-way ANOVA (plant type x month post-fire) for the shoot elongation rate revealed a significant two-way interaction due to variation in rate between species for each time period (Table 13). The highest *A. donax* shoot elongation rates were observed immediately post-fire (first two months) and in April 2004 at the beginning of the growing season. During the first 3 months post-fire, *A. donax* exhibited very high shoot elongation rates. Native plant species did not emerge until January 2004 and grew much more slowly than *A. donax*. Mean shoot elongation rates of *A. donax* were significantly higher than those of native plant species except during the winter (between January and March) when rates did not differ significantly. A series of heavy frosts occurred in late February 2004 (4 months post-fire), and they appeared to have lowered *A. donax* shoot elongation rates

substantially. In April, shoot elongation rates for both *A. donax* and native plant species increased from winter levels, corresponding with warmer spring growing conditions. From April 2004 until the end of the year, elongation rates decreased for all plants, with *A. donax* maintaining higher rates (up to two times higher) than native species until December 2004.

In the two-way ANOVA (plant type x month post-fire) of RGR, the two-way interaction was very highly significant (Table 13). The mean RGR of *A. donax* was much greater initially (first three months) than that of the native plant species (Figure 21). *Arundo donax* mean RGR was extremely high (0.094 ± SE 0.005 g $g^{-1}day^{-1}$) immediately after being burned, whereas the native plants did not emerge until the third month after the fire and then grew at a much more moderate rate. Mean RGR of native plants was highest five months after the fire and significantly higher than *A. donax* during the spring. As mentioned above, a series of very heavy frosts in February 2004 appeared to curtail *A. donax* growth but had little effect on the RGR of native plants. The mean RGR of both *A. donax* and native plants was very low at the end of the growing season, from mid-summer (July) to late fall (November).

Post-fire productivity

Approximately one year after the fire, *A. donax* productivity was much higher than that of any of the native species ($F_{(2,295)} = 43.291$; $P < 0.001$) (Figure 22). Productivity of *A. donax* was 14 times higher than that of *B. salicifolia* and 24 times higher than that of *S. laevigata* in burned areas. Due to initial low abundance and significant mortality during the year, *S. exigua*, *S. lasiolepis*, and *P. balsamifera* ssp.

trichocarpa were at such a low density in burned sites that their productivity was undetectable one year after the fire.

Soil nutrients

Mean pre- and post-fire soil nutrient levels surrounding *A. donax* compared to native plants differed significantly (Figure 23; Table 14). Mean soil nutrient levels (NH_4-N, NO_3-N, and PO_4-P) adjacent to *A. donax* plants increased substantially after the study sites burned. However, no significant differences in nutrient concentrations were observed between pre- and post-fire soil adjacent to native plant species. After the study sites burned, both NH_4-N and PO_4-P concentrations were more than twice as high in the soil adjacent to *A. donax* plants compared to native plant species.

DISCUSSION

In this study, I explored the role of fire in the *A. donax* invasion process in riparian ecosystems of southern California where wildfire is naturally prevalent in adjacent shrubland ecosystems. Burning through nearly 300 ha of *A. donax* infested riparian terraces, the October 2003 Verdale-Simi fire provided an opportunity to examine ecosystem-level effects of wildfire, namely the change in native versus invasive plant composition, and mechanisms responsible for invasion by *A. donax*. Comparisons of post-fire *A. donax* and native plant performance demonstrate several physiological and morphological characteristics that give *A. donax* an advantage over native species after fire. Elevated nutrient levels found surrounding *A. donax* compared to native plants, likely resulting from greater pre-fire biomass, may have maintain its immediate post-fire

growth. These findings indicate how fire promotes invasion of *A. donax* in riparian terraces adjacent to shrubland ecosystems and may help in establishing an invasive plant-fire regime cycle (Brooks et al. 2004).

Change in Plant Composition and Structure

Results of this study indicate a strong and potentially lasting effect of fire on plant composition in riparian areas burned along the Santa Clara River study area. Less than a year after the fire, *A. donax* was clearly increasing its dominance in these ecosystems. *Arundo donax* increased in abundance by almost 25% and comprised more than 99% of the vegetative cover in study sites a year after fire. The much higher biomass or productivity of *A. donax* a year after the fire compared to the two most abundant native species, *S. laevigata* and *B. salicifolia*, suggests that native riparian trees and shrubs might eventually be excluded by *A. donax* in fire-prone riparian ecosystems. Similar examples of post-fire competitive exclusion of native plant species by invasive grasses have been documented in many ecosystems in which fire is an unnatural or altered process (i.e., enhanced frequency) (D'Antonio and Vitousek 1992, D'Antonio 2000). Although smaller in stature, the invasive annual grass *Bromus tectorum* L. (cheatgrass) has caused an increase in wildfire occurrence followed by a decrease in native species abundance in sagebrush shrublands of the western United States (Whisenant 1990, Brooks and Pyke 2001). The dominant species in sagebrush shrublands, *Artemesia tridentata* (sagebrush), does not resprout after fire (Booth et al. 2003), whereas *B. tectorum* successfully germinates from seed and grows in harsh conditions in interspaces

between shrubs after fire (Brooks et al. 2004). Successive fire cycles and increased fire return intervals have lead to dominance by the invader.

Soil Nutrients Stimulate Growth

Elevated nutrient levels in surface soil provide high nutrient levels that increase or maintain plant growth immediately after fire in shrubland ecosystems (Rundel and Parsons 1980, Boerner 1982). Wildfires are known to alter nutrient budgets and cycling by volatilizing some nutrients and mobilizing the levels of others (Boerner 1982, D'Antonio and Vitousek 1992, D'Antonio 2000). Volatilization of nutrients depends on fire temperature but is thought to be high for nitrogen, carbon, and sulfur because of the low temperatures at which they become volatile (Rundel et al. 1983). Ammonium and phosphate levels in surface soils may increase rapidly after fire in shrubland ecosystems due to mineralization (Christensen 1973, Debano and Dunn 1982, Rundel et al. 1983), but post-fire nitrate levels are highly dependent on vegetation type and quantity (Romanya et al. 2001). Nitrogen losses in shrubland ecosystems may occur after fire due to leaching by rainfall and soil erosion (Debano and Conrad 1978, Romanya et al. 2001). Because of the low-lying nature of riparian ecosystems in the landscape, nutrient-rich ash may collect in these areas or nutrients in the ash may run off into these systems from surface erosion and soil leaching (Boerner 1982).

Mechanisms contributing to increased abundance of *A. donax* compared to native plant species in burned areas a year after fire were examined, including response to elevated nutrient levels, differing phenology, and high growth rates. A positive feedback cycle was observed, whereby *A. donax* contributes higher nutrient levels to soil post-fire

and these high levels promote rapid growth compared to native riparian species. Evidence suggests that large differences in pre- and post-fire soil nutrient levels may have stimulated and/or helped maintain high growth rates of *A. donax* following fire. Levels of ammonia, nitrate and phosphate in the soil surrounding *A. donax* were much higher in riparian study sites after the fire, whereas soil nutrient levels adjacent to the native plants species did not change. Higher soil nutrient levels found next to *A. donax* versus native plants were likely due to quality and quantity of fuel (vegetation) burned, fire intensity, and resulting ash deposited (Debano and Conrad 1978). Although not measured, these high post-fire levels were likely indicative of nutrient content contained in the pre-fire aboveground biomass of varying species, influencing nutrient content of ash (Christensen and Muller 1975, Debano and Conrad 1978). Variation in fire intensity between patches of *A. donax* (Bell 1997, D'Antonio 2000) and native plants mixed with *A. donax* observed may have also influenced nutrient content. In mature California chaparral, elevated post-fire soil nitrogen levels from addition of ammonium and phosphorus-rich ash (Christensen 1973) provide favorable nutrient conditions for plant growth (Christensen and Muller 1975, Rundel and Parsons 1980). The high proportion of nutrients, such as ammonium, in the ash remaining after fire is thought to mineralize rapidly, especially after the first rainfall, and become available to plants (Rundel and Parsons 1984), and be readily available to plants, if not lost from the system (Rundel et al. 1983). Higher soil ammonium and phosphate concentrations associated with *A. donax* compared to native plants post-fire may help explain higher initial growth rate of *A.*

donax compared to native species immediately after fire, but causation cannot be definitively determined from these results.

Mechanisms of Invasion

I found clear evidence of three mechanisms, response to nutrients, fire-adapted phenology, and high growth rate of *A. donax*, that promote its preemption of natives after fire. Fire appears to stimulate *A. donax* growth immediately, whereas native plant species recover much slower after burned. Native species did not begin resprouting or germinating until several months after the October 2003 wildfire. In areas containing high nitrogen levels, Decruyenaere & Holt (2005) found that *A. donax* exhibited no dormancy during the year, although recruitment of new shoots (from rhizomes) was higher in the summer than in winter months. Accordingly, high nutrient levels in soils surrounding *A. donax* post-fire may have led to high growth rates and maintenance of shoot growth after rhizomes burned. Conversely, native woody riparian species, such as *S. laevigata*, *P. balsamifera* spp. *trichocarpa* and *B. salicifolia*, are dormant in the winter months and are leafless (G. Coffman personal observation). Resprouting and germination of these species in southern California occurs between late winter and early spring, corresponding with declining river flows (Braatne et al. 1996, Stella et al. 2006). Resprouting and germination of native species after fire appeared similar to the natural phenology (no burn effect) of these species and nutrient levels did not appear to effect regrowth. In chaparral ecosystems, several sprouter non-seeder species (clonal growth form similar to *A. donax*) appear within weeks after fire (Hanes 1971, Naveh 1975, Zedler et al. 1983, Thomas and Davis 1989).

Growth rates and other measures of plant performance of *A. donax* were much higher than native species during the first year after fire, resulting in a higher aboveground biomass a year later. Mean monthly growth rates of *A. donax* were up to three times higher than native riparian plant species in the winter and twice as high in spring through summer. Most native species growth occurred in the spring and early summer and corresponds to phenology under non-burned conditions (Braatne et al. 1996). The pattern and mean RGRs of *A. donax* were similar to those measured for recruits that emerged in April in a Northern California study (Spencer et al. 2005) (see Chapter 3).

Riparian ecosystems infested by *A. donax* adjacent to fire-prone shrublands in southern California appear to be on a trajectory to an invasive plant-fire regime cycle (Brooks et al. 2004). Introduction the unique habit of *A. donax*, a clonal tall grass species, into an ecosystem naturally dominated by woody trees and shrubs has altered fuel types, layers, and loads (Scott 1994, DiTomaso 1998, Brooks et al. 2004). Decreased moisture content and increased surface to volume ratio of *A. donax* versus native vegetation may lead to an altered or increased length of fire susceptibility or increased probability of ignition in these systems, although no data currently exists to document this assertion. Addition of this novel fuel characteristic to the riparian ecosystem has increased vertical continuity (structure of fuel allows fire to spread from surface to crowns of shrubs and trees), which can in turn increase the frequency and extent of fires (Brooks et al. 2004). Due to its tall growth form, infestations of *A. donax* mixed with native species may spread fire vertically into the canopy of riparian trees

instead of mainly burning trunks of riparian species near the ground surface. As *A. donax* abundance increases in fire-prone areas due to increased nutrient levels, fire-adapted phenology and high growth rate of *A. donax*, increased fire return intervals may eventually lead to exclusion of native species in riparian ecosystems. Evidence of this positive-feedback cycle suggests that *A. donax* may create an invasive plant-fire regime cycle in streams and rivers of Mediterranean-type climates similar to this southern California example.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

That fire promotes invasion of riparian ecosystems by the large alien grass species, *Arundo donax* L., has long been speculated, but no data existed to support this premise. Although fire was once a natural part of shrubland ecosystems that characterize the coastal southern California landscape, large riparian ecosystems provided natural firebreaks because native vegetation retains foliar water that resists ignition (Hanes 1971, Naveh 1975, Bell 1997, Rundel 1998, Keeley and Fotheringham 2001). In October 2003, however, a wildfire burned more than 700 acres of vegetation on riparian terraces along the Santa Clara River. One year after the fire, *A. donax* dominated the vegetation in burned areas. This study illustrates how wildfire promotes invasion of this large alien grass species in riparian ecosystems of southern California.

Removal of *A. donax* from riparian ecosystems adjacent to fire-prone shrublands in Mediterreanean-type climates should be a key management priority. Negative effects on other ecosystem functions, such as wildlife habitat reduction (Knick et al. 2005), follow fire regime changes (Brooks et al. 2004) and associated plant invasions (Herrera

and Dudley 2003, Kisner 2004). Infestations of *A. donax* located on riparian terraces adjacent to towns or agricultural practices pose an increased risk of fire to people and property. Immediate post-fire removal of *A. donax* reduces future fire risk and greatly reduced the amount of biomass removal necessary. However, time of year is critical to selection and success of appropriate removal techniques. Active planting of removal areas with a diverse composition of native species may be required to prevent reinvasion by *A. donax* or other exotic species due to enhanced nutrient levels in these burned riparian ecosystems (Chapter 2).

TABLES

Table 12. Two-way ANOVA of plant abundance (% cover), density (stems m^{-2}), and shoot height (cm) by factors of plant type (*A. donax* and native plant species) and pre- and post-fire time periods.

Factors and interactions	Plant abundance	Density	Height (shoot elongation)
Plant type	$F_{(1,80)} = 59.123$; $P < 0.001$***	$F_{(1,852)} = 322.769$; $P < 0.001$***	$F_{(1,3231)} = 819.299$; $P < 0.001$***
Time period	$F_{(1,80)} = 15.166$; $P < 0.001$***	$F_{(5,852)} = 1.700$; $P = 0.132$	$F_{(8,3231)} = 442.074$; $P < 0.001$***
Plant type x time period	$F_{(1,80)} = 0.006$; $P = 0.937$	$F_{(5,852)} = 2.850$; $P = 0.015$*	$F_{(8,3231)} = 21.295$; $P < 0.001$***
r^2	0.626	0.287	0.591

* = $0.05 \geq P > 0.01$ = significant; ** = $0.01 \geq P > 0.001$ = highly significant; *** = $P \leq 0.001$ = very highly significant

Table 13. Two-way ANOVA of shoot elongation rate (cm d^{-1}) and relative growth rate (RGR; g $g^{-1}day^{-1}$) by factors of plant type (*A. donax* and native plant species) and month post-fire (12 months).

Factors and interactions	Shoot elongation rate	RGR
Plant type	$F_{(9,319)} = 16.178$; $P < 0.001$***	$F_{(9,315)} = 44.146$; $P < 0.001$***
Month post-fire	$F_{(1,319)} = 76.481$; $P < 0.001$***	$F_{(1,315)} = 81.154$; $P < 0.001$***
Plant type x month post-fire	$F_{(9,319)} = 6.845$; $P < 0.001$***	$F_{(9,315)} = 55.397$; $P < 0.001$***
r^2	0.556	0.762

Table 14. Two-way ANOVA of soil nutrients (NH_4-N, NO_3-N, and P) by factors of plant type (*A. donax* and native plant species) and pre- and post-fire time periods. Soil grain size (% silt + clay) was used as a covariate. NH_4-N and NO_3-N were ln transformed.

Factors and interactions	**NH_4-N (ppm)**	**NO_3-N (ppm)**	**P (ppm)**
Plant type	$F_{(2,44)} = 2.002$; $P = 0.164$	$F_{(2,44)} = 0.612$; $P = 0.438$	$F_{(2,44)} = 3.021$; $P = 0.089$
Time period	$F_{(1,44)} = 8.125$; $P = 0.001$***	$F_{(1,44)} = 2.670$; $P = 0.080$	$F_{(1,44)} = 6.002$; $P = 0.005$**
Plant type x time period	$F_{(2,44)} = 5.459$; $P = 0.008$**	$F_{(2,44)} = 2.268$; $P = 0.115$	$F_{(2,44)} = 2.224$; $P = 0.120$
Silt + clay	$F_{(1,44)} = 11.737$; $P = 0.001$***	$F_{(1,44)} = 2.710$; $P = 0.107$	$F_{(1,44)} = 5.803$; $P = 0.020$*
r^2	0.555	0.255	0.394

FIGURES

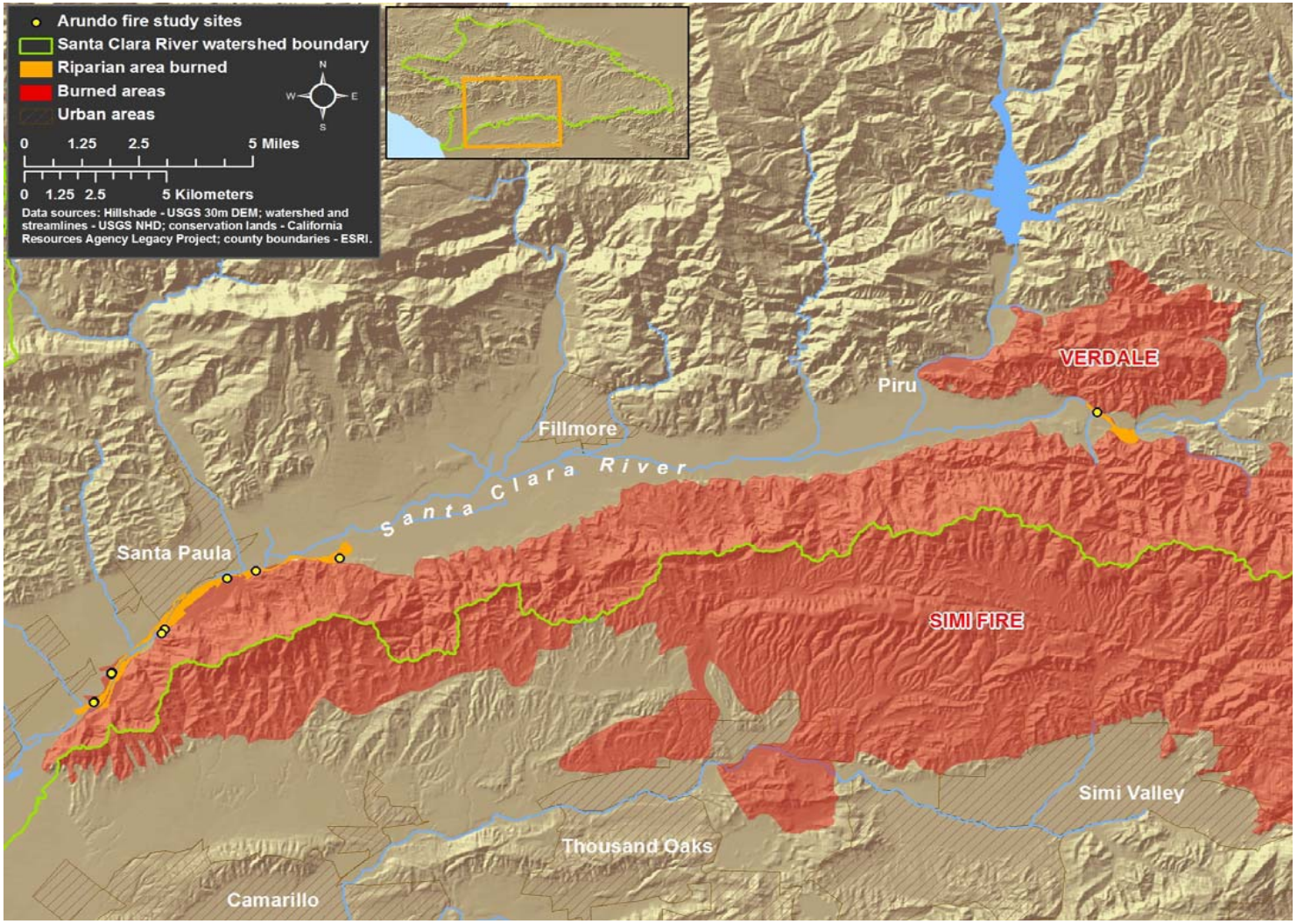

Figure 16. Location of study sites in riparian terraces of the Santa Clara River, Ventura County, California.

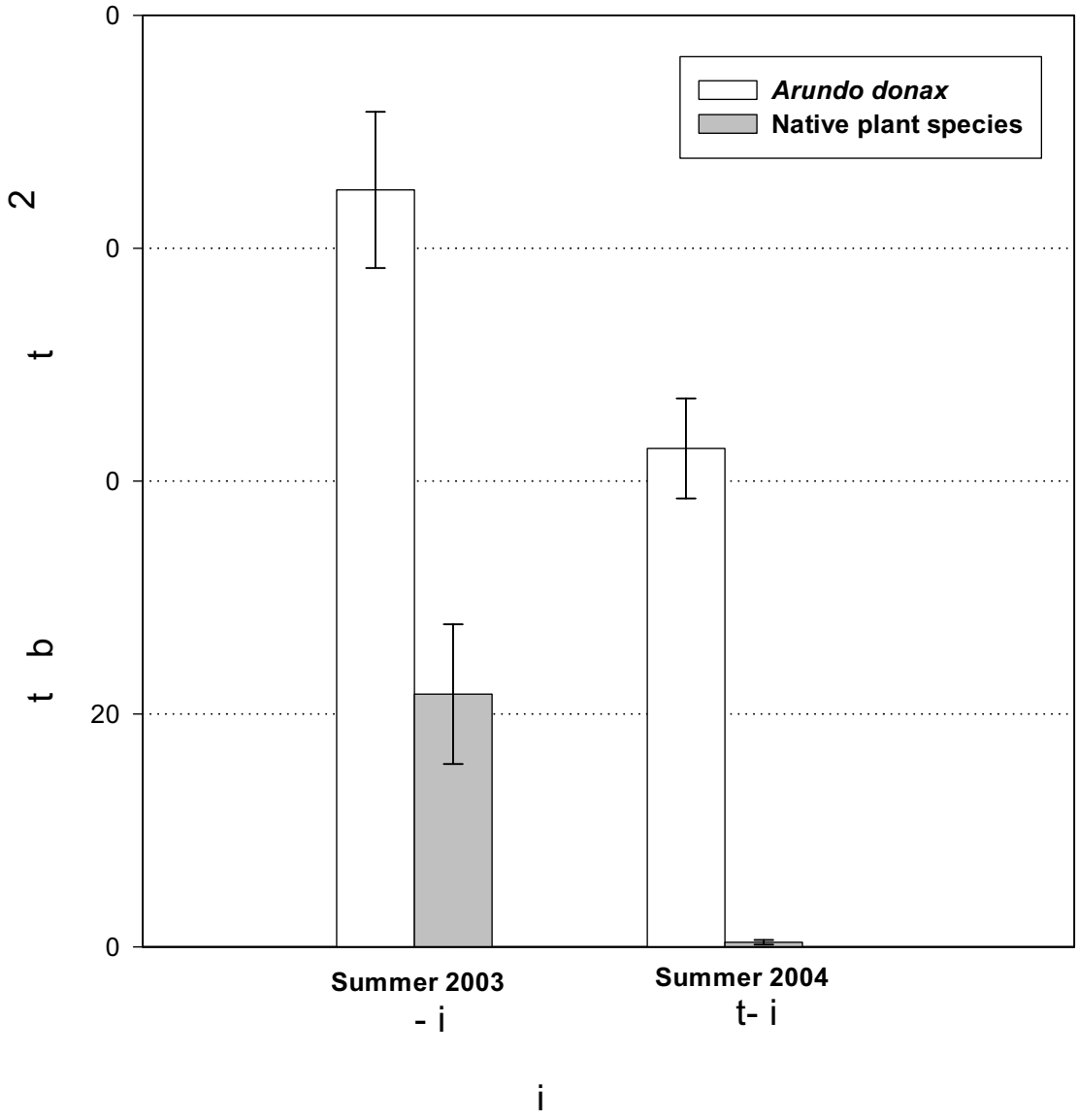

Figure 17. Abundance of *A. donax* compared to native riparian plant species before the October 2003 wildfire (summer 2003) and a year later. Letters denote results of post-hoc hypothesis tests (comparison of means) with significance recognized at $\alpha < 0.05$.

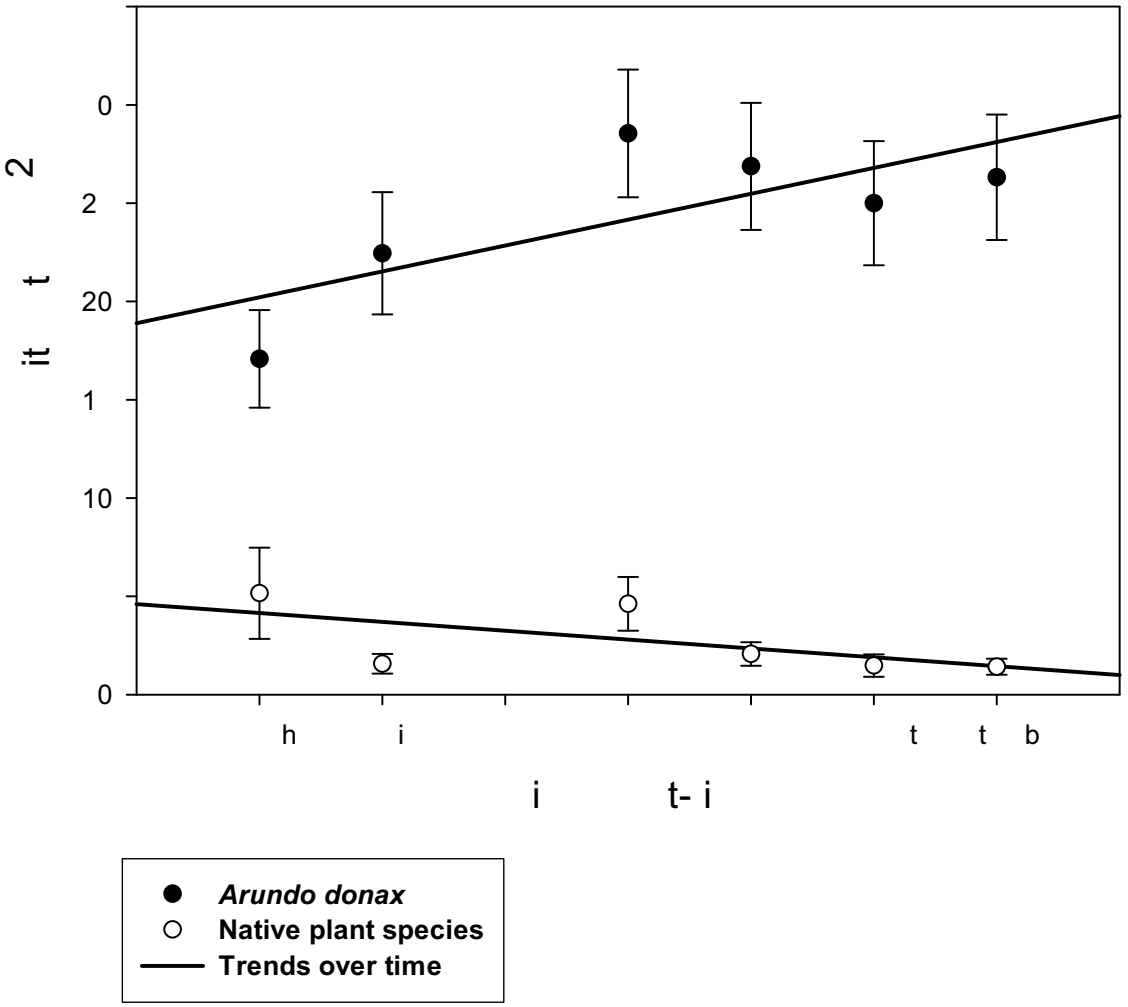

Figure 18. Mean density of *A. donax* versus native plants after the October 2003 wildfire. Regression lines illustrate trends over time. Letters denote results of post-hoc hypothesis tests (comparison of means) with significance recognized at $\alpha < 0.05$.

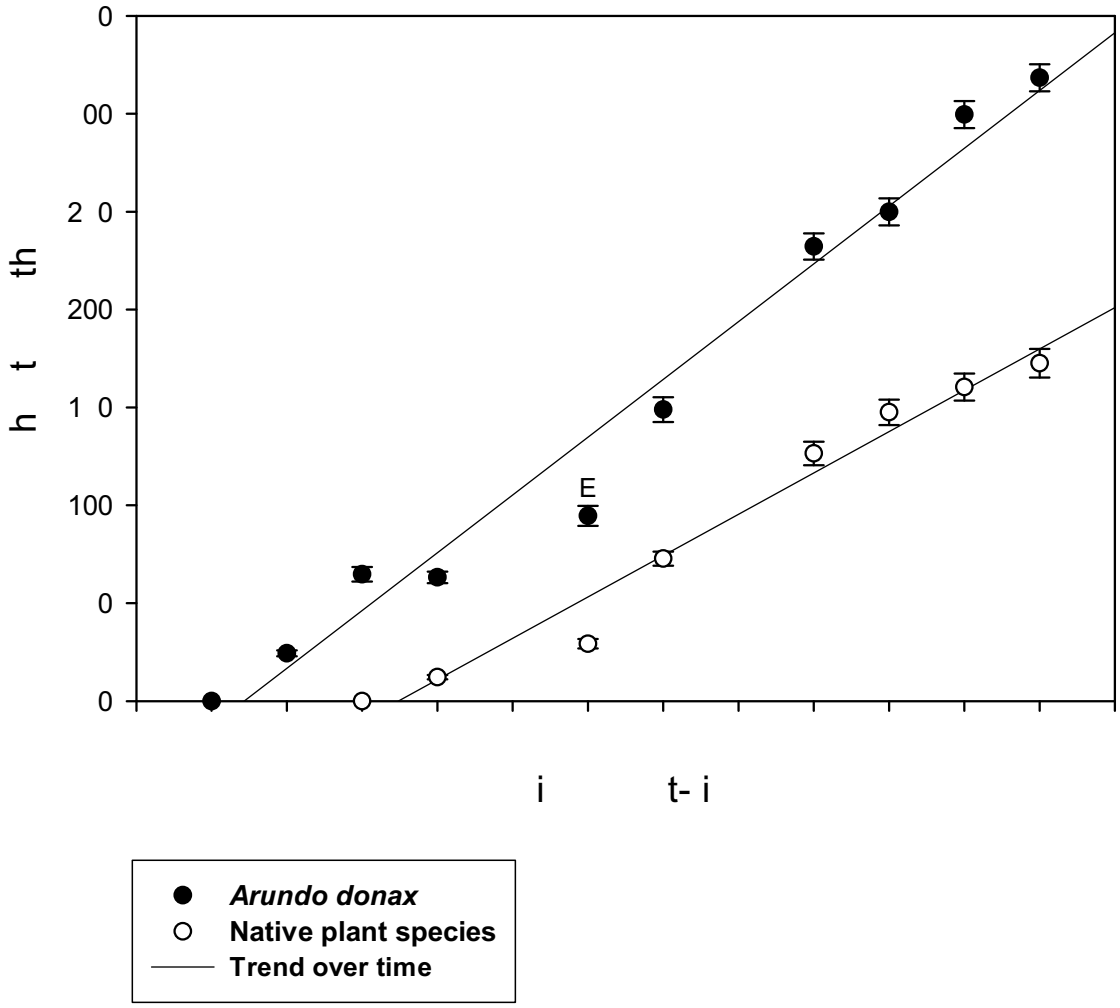

Figure 19. Monthly mean shoot length of *A. donax* compared to native plant species for a year following the October 2003 wildfires. Regression lines illustrate trends over time. Letters denote results of post-hoc hypothesis tests (comparison of means) with significance recognized at $\alpha < 0.05$.

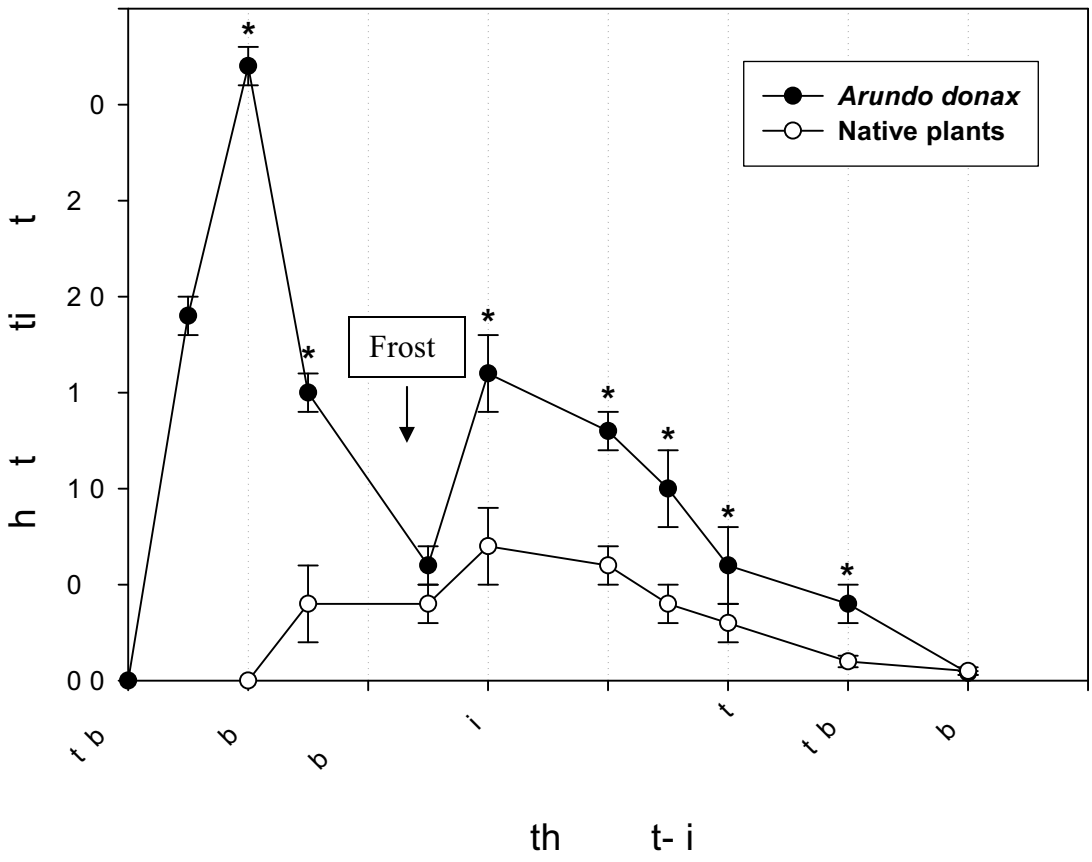

Figure 20. Mean monthly shoot elongation rates of *A. donax* compared to native plants after being burned in the October 25, 2003 wildfire. Asterisks denote significant differences in means between *A. donax* and native plants at each time period based on results of post-hoc hypothesis tests (comparison of means) with significance recognized at $\alpha < 0.05$.

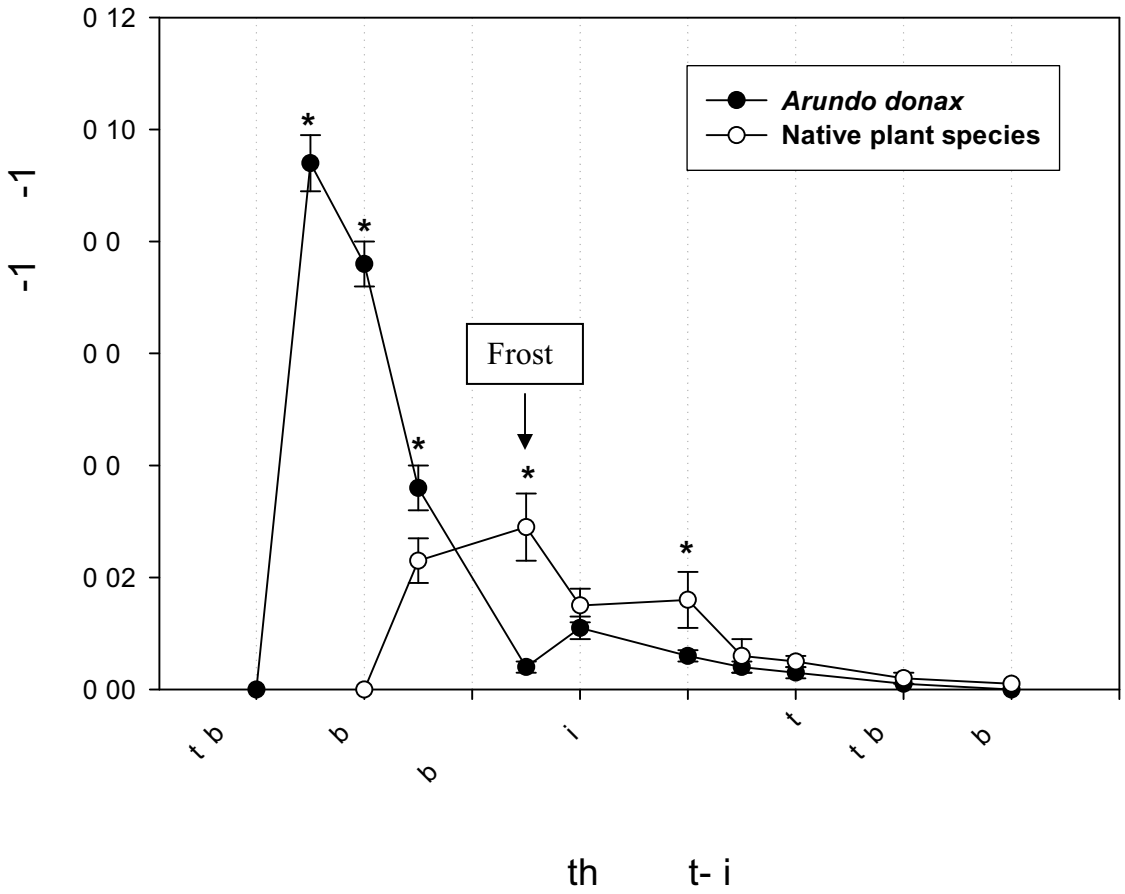

Figure 21. Relative growth rate of *A. donax* compared to native plant species. Asterisks denote significant differences in means between A. donax and native plants at each time period based on results of post-hoc hypothesis tests (comparison of means) with significance recognized at $\alpha < 0.05$.

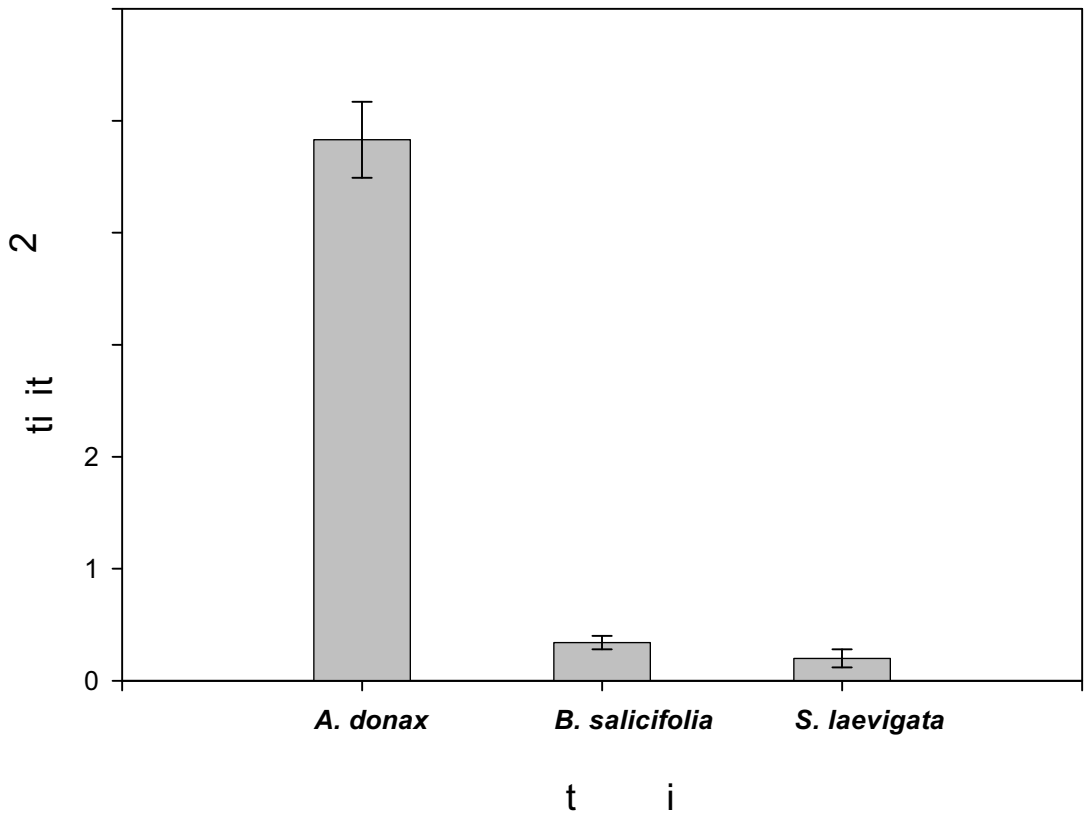

Figure 22. Mean productivity (kg/m^2/year) of *A. donax* compared to native plant species in burned sites. Letters denote results of post-hoc hypothesis tests (comparison of means) with significance recognized at $\alpha < 0.05$.

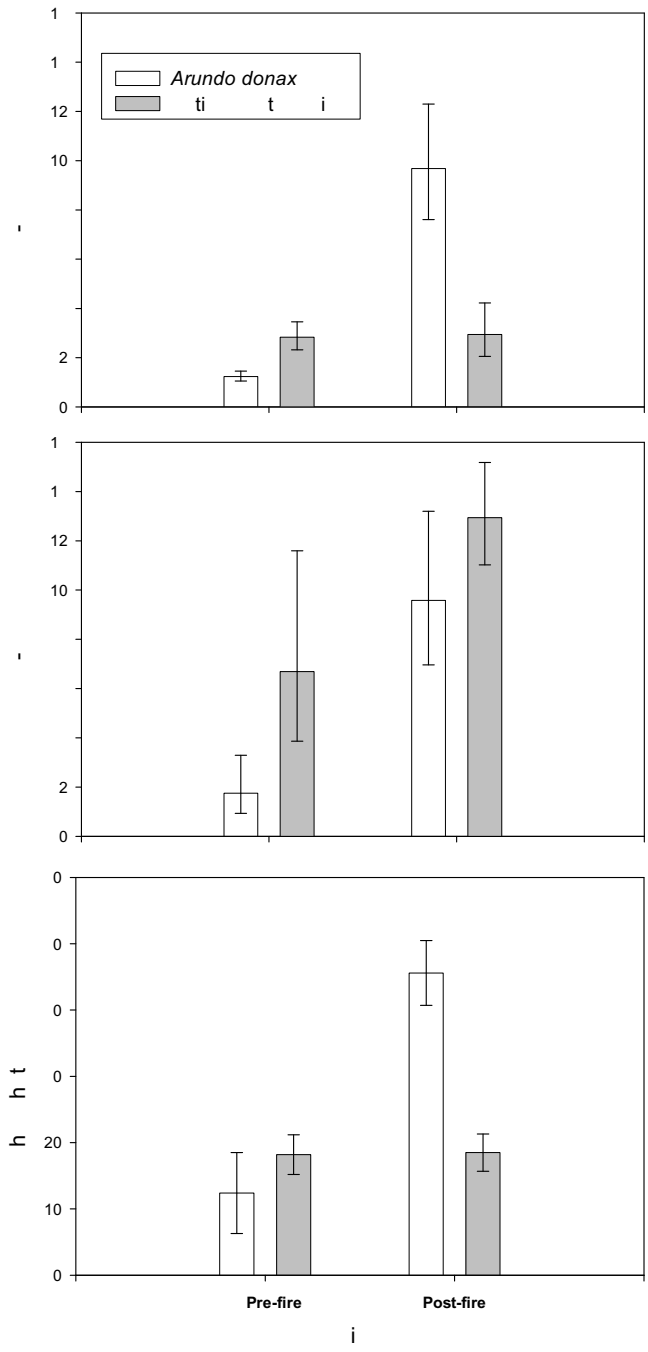

Figure 23. Pre- and post-fire mean nutrient levels of soil adjacent to *A. donax* compared to soil next to native plants. Letters denote results of post-hoc hypothesis tests (comparison of means) with significance recognized at $\alpha < 0.05$.

APPENDIX

APPENDIX 4-1

SAMPLING LOCATIONS

Site No.	Location Description	Latitude	Longitude	Pre-Fire Data Available
1	Near Piru, along Hwy 126 where fire spread to riparian corridor, on right bank of river terrace	34.41°	118.73°	Yes
2	East of Santa Paula and off of Peck Road, on left bank of river terrace	34.33°	119.08°	Yes
3	East of Santa Paula and off of Peck Road, on left bank of high river terrace	34.33°	119.08°	Yes
4	Just Downstream of 12th Street Bridge in Santa Paula, on left bank of river terrace under large coastal live oaks	34.35°	119.05°	Yes
5	Approximately 2 miles east of Santa Paula along South Mountain Road, on left bank of river terrace	34.35°	119.02°	Yes
6	Approximately 1 mile east of Santa Paula along South Mountain Road, on left bank of river terrace under mature willow trees	34.35°	119.04°	Yes
7	Southwest of Santa Paula, east of Mission Rock Road, on right bank of river terrace	34.31°	119.10°	No
8	Southwest of Santa Paula, east of Mission Rock Road, on right bank of river terrace	34.31°	119.10°	No
9	Southwest of Santa Paula, east of Mission Rock Road, on right bank of river terrace	34.31°	119.10°	No
10	Southwest of Santa Paula, east of Mission Rock Road, on right bank of river terrace	34.31°	119.10°	No
11	Southwest of Santa Paula, west of Mission Rock Road, on right bank of river terrace	34.30°	119.10°	No
12	Southwest of Santa Paula, west of Mission Rock Road, on right bank of river terrace	34.30°	119.10°	No
13	Southwest of Santa Paula, west of Mission Rock Road, on right bank of river terrace	34.30°	119.10°	No
14	Southwest of Santa Paula, west of Mission Rock Road, on right bank of river terrace	34.30°	119.10°	No

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CHAPTER 5 -

CONCLUSIONS

FACTORS INFLUENCING *ARUNDO DONAX* INVASION

I found that the role of all four factors that I investigated in my dissertation were critical to the *A. donax* invasion process, but varied in importance based on quantity and availability to plants. My results show that nutrient enrichment in riparian ecosystems due to increased urban and agricultural land use development plays an important role in *A. donax* expansion in the past half century. *Arundo donax* dominated experimental high soil moisture and nutrient treatments in full sun, indicating that the combination of elevated water quantity, decreased quality and light is key to its invasion success especially where disturbance levels are high. Fire appeared to have the greatest effect on *A. donax* invasion; it promotes rapid expansion of *A. donax* infestations near fire-prone shrublands and dominates the vegetation only months after burned.

Nutrient Availability

Anthropogenic nutrient enrichment has been linked to invasion of natural ecosystems worldwide (Kolb et al. 2002, Booth et al. 2003, Brooks 2003, Kolb and Alpert 2003, Suding et al. 2004), but little is known about the role of nutrients in promoting invasion in riparian ecosystems in Mediterranean-type climates (Wang 1998). I explored the influence of anthropogenic nutrient enrichment on the invasion of riparian ecosystems by *A. donax* in southern California. My field study results suggest that N

(nitrogen) limiting conditions may occur naturally in riparian ecosystems in this geologically young landscape but that anthropogenic nutrient inputs have elevated groundwater N:P ratios and may provide invasive species with an advantage where N enrichment of soils and groundwater occurs. In my study area, elevated levels of N in shallow groundwater and soils of floodplains were associated with adjacent land use and with watersheds with higher anthropogenic nutrient inputs. Floodplains with both large and small *A. donax* infestations contained higher soil NO_3-N concentrations than did non-infested areas. Higher N and K (potassium) leaf tissue content of *A. donax* in large and small infestations compared to those of native red willow (*Salix laevigata* Bebb.) collected from non-infested and reference sites suggests that these nutrients may be more available to *A. donax*. Unlike *S. laevigata*, *A. donax* may take advantage of anthropogenically enriched N levels in riparian ecosystems, as illustrated by its positive response to all forms of shallow groundwater N in floodplains and soil N on riparian terraces.

Interspecific competition between native and introduced species for nutrients, water, and light availability plays a critical role in plant invasion in many terrestrial ecosystems worldwide (D'Antonio and Vitousek 1992, Gordon and Rice 2000, Booth et al. 2003, Suding et al. 2004, White and Holt 2005, Richardson 2006). Experimental studies in river and wetland ecosystems have demonstrated superior resource competition by invasive plants for nutrients (Green and Galatowitsch 2002, Minchinton and Bertness 2003). My experimental findings suggest that higher nutrient levels may benefit *A. donax* more than native species, although response to competition for nutrients varies by

species groupings. *Arundo donax* exhibited a positive response to high nutrient additions, but primarily under high soil moisture and light levels, and these effects were much greater in monocultures of *A. donax* (see Chapter 2, Figure 6). Both *S. laevigata* and *B. salicifolia* responded positively to high nutrient treatments under similar conditions, but the effects were of much lower magnitude than those of *A. donax*. When *A. donax* was grown in competition with *P. balsamifera* spp. *trichocarpa*, responses to high nutrient treatments were greater for both species compared to the effects when they were grown in monoculture. However, when grown in competition with either *S. laevigata* and *B. salicifolia* effects of nutrient addition on *A. donax* were decreased; thus, competition from *B. salicifolia* and *S. laevigata* had a strong negative effect on *A. donax* biomass under high soil moisture, light, and nutrient conditions.

Water Availability

In this dissertation, I hypothesized that high soil moisture levels may promote invasion by *A. donax*. Although *A. donax* tolerates a wide variety of ecological conditions, it reportedly thrives in areas with high soil moisture, such as along canals, ditches, and stream banks (Perdue 1958, Rezk and Edany 1979). Preliminary data analyses (Stillwater Sciences, unpublished spatial data) indicate that a higher percentage of *A. donax* is associated with areas of rising groundwater, compared to other drier areas in riparian ecosystems along the Santa Clara River. In addition, increased water quantity in stream systems of Mediterranean-type climates caused by anthropogenic inputs may contribute to higher than natural soil moisture availability. My field experiment showed that *A. donax* produced the highest biomass under high soil moisture conditions,

especially when light and nutrient levels were also high (see Chapter 2; Figure 5). Although competition with *A. donax* did not suppress native plant species aboveground biomass under these high resource conditions during the time frame of the study, its biomass was much higher than those of all three native plant species studied.

Along naturally loosing stream reaches (i.e., river reaches that contribute water to the groundwater supply) in southern California or in riparian ecosystems with water tables lowered by groundwater extraction, invasion by *A. donax* appears to be diminished by lower water availability. However, growth of all native riparian species as well as *A. donax* appears to be lower than under higher water availability; all four species exhibited much lower biomass under low soil moisture versus high soil moisture conditions in my field experiment (see Chapter 2). The presence of sustained high soil moisture or near-surface shallow groundwater during the growing season may important for establishment of most riparian species (especially *Populus* spp. seedlings) (Braatne et al. 1996, Stella et al. 2006), although *A. donax* is known to establish under very low soil moisture conditions (Perdue 1958) and *B. salicifolia* grown from cuttings also had a high rate of survival in low soil moisture conditions in my field experiment (See Appendix 2-2). However, in years with prolonged wet winters all species may establish successfully, even in areas where soil type does not normally sustain high moisture levels. Once established, rooting depth, distribution, and structure relative to soil moisture and depth to groundwater likely play a larger role in growth of and competition between *A. donax* and native species (see Chapter 2, Figure 9). *Salix* spp., *Populus* spp., *B. salicifolia*, and other woody riparian species are phreatophytes with adaptations to low soil moisture

conditions; their roots follow the receding soil moisture during establishment and can use water from depths of up to 30 m (Robinson 1958). In contrast, *A. donax* is a perennial grass with roots that can only reach ~3 m below the soil surface based on my field observations. Evidence from my field experiment indicates that all plants grow much more slowly under low compared to high soil moisture conditions, but the higher biomass of *A. donax* under all conditions may only decrease the rate of expansion in drier riparian ecosystems.

Light Availability

Light availability influences plant invasion in many ecosystems, due to both vegetation removal and direct effects of shading by invasive species (Crawley 1987, D'Antonio and Vitousek 1992, Yamashita et al. 2000, Meekins and McCarthy 2001, Fargione and Tilman 2002). Reduction in light availability may act as a barrier to invasion in both disturbed and natural habitats (Richardson et al. 2000), because plant species vary greatly in the amount of light they require for colonization and optimal growth (Treshow 1970, Menges and Waller 1983). Light availability varies greatly according to time and space along rivers in Mediterranean-type climates; the natural dynamic disturbance regime within these rivers creates large open areas after flooding and mature riparian forests create light limiting environments on high terraces. I experimentally investigated the effects of varying light levels on *A. donax* growth (in combination with nutrients and soil moisture factors) and competition with three native plant species. Light availability did not affect initial plant establishment of woody species (or *A. donax*) in this experiment, as was documented by D'Antonio and Vitousek

(1992) for other invasive grass species (see Appendix 2-2). In general, biomass of *A. donax* and native plant species was lower under low light conditions when soil moisture was not limiting (see Chapter 3, Figure 5). However, *A. donax* biomass was much higher than that of native species in low light and low soil moisture conditions but similar in high soil moisture conditions. Only one negative effect of competition was observed under conditions of low light (and high soil moisture): *A. donax* biomass was significantly lower when grown with *P. balsamifera* spp. *trichocarpa* compared to monoculture. Thus, light reduction does not appear to be an effective barrier to initial *A. donax* invasion in riparian ecosystems in Mediterranean-type climates. Dudley (1998) suggested that monotypic stands of *A. donax* limit native riparian plant recruitment through light reduction. Further investigation is needed to determine the effects of *A. donax* infestations on recruitment of native plant species in later stages of the invasion process.

Occurrence of Fire

Although healthy riparian ecosystems function as natural barriers to wildfire (Radtke et al. 1981, Dudley 1998, Rundel 2000, 2003), the extensive wildfires in southern California in October 2003 burned large expanses of riparian ecosystems along the Santa Clara River and appeared to promote *A. donax* invasion. Due to its immediate regrowth after the fire and its high growth rate compared to that of native riparian plants, *A. donax* dominated these burned riparian ecosystems within a few months after the fire and comprised 99% of the vegetative cover a year later. *Arundo donax* grew an average of 3–4 times faster than native woody riparian plants – up to 2.62 cm/day (average 0.72

cm/day) – and reached up to 2.3 m in height less than 3 months after the fire. One year post-fire, *A. donax* density was nearly 20 times greater and productivity was 14–24 times higher than density and productivity of native plants. Elevated soil nutrient levels post-fire may have contributed to *A. donax*'s high post-fire growth rate, which was similar to post-fire growth observed for chaparral resprouters after fire (Zedler et al. 1983). The large amounts of *A. donax* biomass that replaced native woody species after the wildfire have increased the susceptibility of riparian ecosystems along the Santa Clara River to fire, creating an invasive plant-fire regime cycle similar to those described by D'Antonio and Vitousek (1992) and Brooks et al. (2004). Wildfire not only promotes dominance of *A. donax* in riparian ecosystems but also alters vital ecosystem processes and increases the risk that fire will spread to surrounding shrublands, towns, and agricultural areas.

***ARUNDO DONAX* INVASION ECOLOGY**

Based on my research findings and available literature, I propose three *A. donax* invasion scenarios and associated conceptual invasion trajectories. I extrapolated invasion scenarios and trajectories from my two-year field experiment based on results of my two field studies, other *A. donax* invasion research, and my personal field observations. Proposed conceptual invasion trajectories represent general degree of infestation (abundance of *A. donax*) over time depending on variation in amount and timing in factors (and levels) investigated in my research: water, nutrient, light, and fire. Invasion scenarios include: *A. donax* growing alone in monocultures (scenario1), *A. donax* growing with native plants from the onset of establishment (scenario 2), and *A. donax* growing under a mature riparian forest canopy (scenario 3).

Invasion Scenario 1

According to experimental results and field observations, *A. donax* expansion is most rapid where it grows alone in large monotypic stands (Figure 24). Results of my field experiment show that after two years, *A. donax* biomass was highest when it was grown by itself in monoculture then when grown with any other species (see Chapter 3, Figure 4). *Arundo donax* (and native riparian plant) biomass was relatively low under the low resource conditions (low water and nutrient availability) that naturally exist in the riparian ecosystems found in many floodplains as well as high terraces in Mediterranean-type climates (Figure 24). However, I predict that a rapid *A. donax* invasion trajectory will occur where naturally high soil moisture, nutrient, and light conditions prevail or are added to the system, such as in floodplains in highly urbanized watersheds or high terraces next to agricultural areas (see Chapters 2 and 3). Several studies have shown a similar increased response of invasive, clonal plant species to addition of nutrients and light in a variety of ecosystems (Aerts and Berendese 1988, Bobbink et al. 1988, Green and Galatowitsch 2002, Maurer and Zedler 2002). Maurer and Zedler (2002) reported that rapid expansion of *Phalaris arundinacea*, another clonal grass species, into wetlands throughout North America was likely due to clonal subsidy, morphological plasticity, and high nutrient availability. When fire burns through large, continuous *A. donax* infestations on riparian terraces where high resource conditions are prevalent, *A. donax* reinvades on an even steeper trajectory (Figure 24; also Coffman unpublished data and Chapter 4). Results of my fire study showed that *A. donax* dominated burned riparian ecosystems (i.e., via high regrowth from rhizomes) within a few months after a large fire

and reached 99% in aerial cover one year later (see Chapter 4). Regardless of resource level or combination of resources added, *A. donax* expansion is most rapid when it grows alone in monotypic stands.

Invasion Scenario 2

Where *A. donax* begins (at time 0) to grow with native plants on bare substrates after a large disturbance, a more gradual but similar invasion trajectory to Scenario 1 may be found regardless of resources added (Figure 24). Results of my field experiment show that in low resource conditions *A. donax* aboveground biomass was slightly lower when grown with *B. salicifolia* compared to in monoculture, possibly due to early shading by this native species (see Chapter 2; Figure 5). Although *A. donax* only suppressed one native species (*P. balsamifera* ssp. *trichocarpa*) under naturally low resource conditions, its biomass was 2–3 times higher than that of either native tree. Under high soil moisture, nutrient, and light conditions, competition from *B. salicifolia* and *S. laevigata* had negative effects on *A. donax* biomass. Despite some suppression by these native species, however, *A. donax* had a higher biomass than that of all native plant species examined. In a similar field competition experiment, Booth et al. (2003) showed that a native clonal perennial grass (*Elymus elymoides*) suppressed an annual invasive grass (*Bromus tectorum*) in high soil moisture and nutrient conditions, thereby facilitating recruitment of a native shrub (*Artemesia tridentata*). When fire is introduced to riparian terraces infested with *A. donax* and a mix of native riparian plants, fire intensity is likely decreased due to higher leaf water content of natives (Brooks et al. 2004). However, the invasion trajectory in this type of mixed community is probably only slightly lower than

that of large *A. donax* infestations (Scenario 1) due to immediate resprouting and much higher growth rates of *A. donax* compared to native plants after fire (Figure 24). However, this invasion trajectory will vary between Scenario 1 and 3 depending on length of time from establishment to fire.

Invasion Scenario 3

An invasion trajectory similar to Scenario 2 (low water and nutrient availability) occurs when *A. donax* establishes under a mature riparian canopy regardless of soil moisture or nutrient levels (Figure 24). In my field experiment, under low light but high water and nutrient availability conditions *A. donax* biomass was slightly lower than it was where all resource conditions were low, but the biomass of native plant species was slightly higher. Competition with *Populus balsamifera* ssp. *trichocarpa* saplings that establish concurrently may suppress *A. donax* growth, but only under high soil moisture and nutrient levels. Thus, the incline of the trajectory may be slightly lower when water and nutrients are added due to the different responses of *A. donax* and native plant species found under these experimental conditions. When fire enters riparian ecosystems containing a mature riparian canopy infested by an understory of *A. donax*, a crown fire may spread through these areas due to an unnatural ladder effect: *A. donax* provides a large quantity of flammable material that transfers fire vertically to large riparian trees under which it grows (Brooks et al. 2004). The post-fire invasion trajectory is initially gradual due to competition from resprouts, but most of these resprouts will eventually die (according to field observations; Coffman unpublished data), and the trajectory then increases in steepness.

MANAGEMENT IMPLICATIONS

Arundo donax ***removal effort priorities***

Millions of dollars have been spent to remove *A. donax* infestations of riparian ecosystems throughout California (Katagi et al. 2002). Due to the lack of understanding of *A. donax* ecology, however, decisions regarding prioritization of removal areas and removal techniques often have to be made in the absence of sufficient scientific information. After analyzing my own research results and the current body of literature available on *A. donax*, I propose the following management strategies, which incorporate the most current understanding of the *A. donax* invasion process, to most effectively and efficiently address this problem. I recommend that *A. donax* control efforts should be placed where ecological benefits are the greatest and associated removal effort the lowest.

1. Remove *A. donax* under mature riparian forests, especially adjacent to fire-prone shrublands. The highest priority location for *A. donax* control is within mature riparian forests adjacent to shrublands. My research suggests that removal in these areas creates the greatest environmental benefit, because these areas have the highest risk of further damage if removal is conducted and threat of reinfestation is lowest (i.e., where removal effort is long-lasting). *Arundo donax* may reinfest areas that are flooded occasionally but not completely scoured (e.g., higher terraces), especially where water and nutrient levels are high. In these locations, mature riparian forests may facilitate invasion by physically trapping propagules after flooding (Dudley pers. comm.). Although my research shows that *A. donax* does not grow as rapidly in low light

conditions compared to high light conditions when high levels of water and nutrients are present (see Chapter 2), my field observations suggest that the understory of mature riparian forests can be invaded by *A. donax* after large floods; the invasion trajectory just may be more protracted. When these mature riparian forests become heavily invaded, areas near fire-prone shrublands are highly susceptible to fire. The large, dry biomass produced by *A. donax* in these areas carries fires (i.e., ladder effect) through canopies of these once-natural firebreaks, burning across and along river systems. These areas should be targeted for high priority removal due to the subsequent threat of an invasive plant-fire cycle and the lasting damage caused, the complete loss of mature riparian forests.

2. Remove the largest *A. donax* propagule source. Another *A. donax* removal priority should be to target areas containing the largest source of propagules to curtail the distribution of *A. donax*, thereby working to control it in the initial phase of the invasion process. Due to its clonal growth form, dominant asexual reproduction, and flood-driven dispersal mechanisms, the largest *A. donax* infestations will produce the highest quantity of vegetative propagules. My research suggests that the largest infestations are most prevalent in riparian ecosystems that are within highly urbanized watersheds, located adjacent to agricultural and residential land uses, and in areas that have burned in both southern California and the Western Cape region of South Africa. Large infestations in areas most frequently scoured by winter flooding contain the largest potential source of propagules.

Prioritization of removal in riparian ecosystems with the lowest likelihood of reinfestation has been suggested (i.e., areas outside the flood zone) (Coffman et al. 2004).

In general, my research findings suggest that *A. donax* is least likely to invade open substrates or recently scoured areas in which resources levels are low (i.e., low soil moisture and nutrient availability) and where native plants have established at the same time. Further investigation of the relationship between frequency of rhizome establishment and *A. donax* abundance in various locations after flood events is necessary to validate this recommendation. Riparian ecosystems downstream of large propagule sources along active floodplains are most likely to be reinfested and removal in these areas should be given lowest priority. Results of my studies suggest that *A. donax* is most likely to invade open (i.e., very low native vegetation cover) or recently scoured areas in which resources levels area high (i.e., high soil moisture and nutrient availability). These areas often are found next to agricultural land uses and areas exposed to wastewater treatment discharge from residential land use (see Chapter 3) (Neely and Baker 1989).

I recommend that more effort should be placed where ecological benefits are the greatest and associated removal costs the lowest. Natural biological and physical processes in riparian ecosystems that are heavily invaded by *A. donax* are usually already degraded. Although removal efforts may slightly reduce propagule abundance, net ecological benefits from removing *A. donax* in these areas may be much lower than in areas less invaded. My research suggests that removal of *A. donax* in locations within riparian forests adjacent to fire-prone shrublands, watersheds with low nutrient inputs, and watersheds with little *A. donax* abundance will result in the greatest ecological benefit. Furthermore, a considerable amount of money and effort is involved in removal of large infestations.

3. Control *A. donax* on a watershed scale. Here I suggest several watershed-scale *A. donax* control strategies given the natural dynamic flood regime in streams of Mediterranean-type climate regions and the widespread anthropogenic resource inputs that are not easily altered. *Arundo donax* should be removed from low nutrient input watersheds where infestations are small or area of infestation is localized; the highest probability of eradication success at the lowest cost is possible in these locations. However, watershed-scale long-term control of *A. donax* in natural riparian ecosystems may require management of resource levels that promote invasion to reduce growth and competition. Manipulation of resource availability in favor of a given native (desired) species has been proposed to create a competitive advantage and a barrier to reinvasion (Blumenthal et al. 2003, Corbin and D'Antonio 2004, Suding et al. 2004, Prober et al. 2005, Perry and Galatowitsch 2006). Results of my studies suggest that reduction of nutrient inputs in urbanized watersheds may slow invasion of *A. donax* but likely will not alone prevent its eventual spread.

Several researchers suggest that *A. donax* should be removed from the most frequently inundated floodplains only using a top-down directional approach (Bell 1997, Coffman et al. 2004). Removal of *A. donax* on higher terraces may not necessarily need to proceed in this downstream manner because reinfestation is much less likely. However, one study suggests that layering (i.e., rooting from nodes) is an important *A. donax* invasion mechanism in streams of southern California and, thus, an inside-out approach is required (Boland 2006). I suggest that both approaches are necessary depending on the flooding dynamics of the stream, infestation size and distribution, and

fluvial geomorphic location of the infestation. Because removal of large areas of *A. donax* is very costly, the ideal time to remove it from a heavily infested watershed may be immediately after a very large flood event (i.e., 100-year flood) that removes most of the vegetation, resulting in much easier access to much reduced quantities of *A. donax* biomass.

4. Revegetation after removal may not help resist or suppress *A. donax*. The management literature recommends revegetation of riparian systems with native species after removal of invasive species, including *A. donax*, to resist further invasion (Sonoma Ecology Center 1999, County of Ventura Planning Division 2006). Resistance to invasion may be achieved if natives obtain a much higher biomass than *A. donax* and suppress it when competing for resources. However, results of my two-year competition field experiment suggest that this is rarely the case; *A. donax* had a significantly higher biomass than almost all native plant species under all resource levels and only minimal suppression by native plants was documented under a few conditions tested (see Chapter 2). Results of my competition field experiment indicate that *B. salicifolia* may increase in biomass when grown with *A. donax*, although it never obtained a significantly higher biomass than *A. donax* under any condition. Longer studies are needed to validate these findings, although it appears that revegetation will not resist reinvasion without implementation of appropriate *A. donax* maintenance. However, active revegetation after *A. donax* removal should help initiate restoration of riparian ecosystem functioning if *A. donax* removal is conducted in the appropriate location and diligent maintenance is implemented.

FIGURES

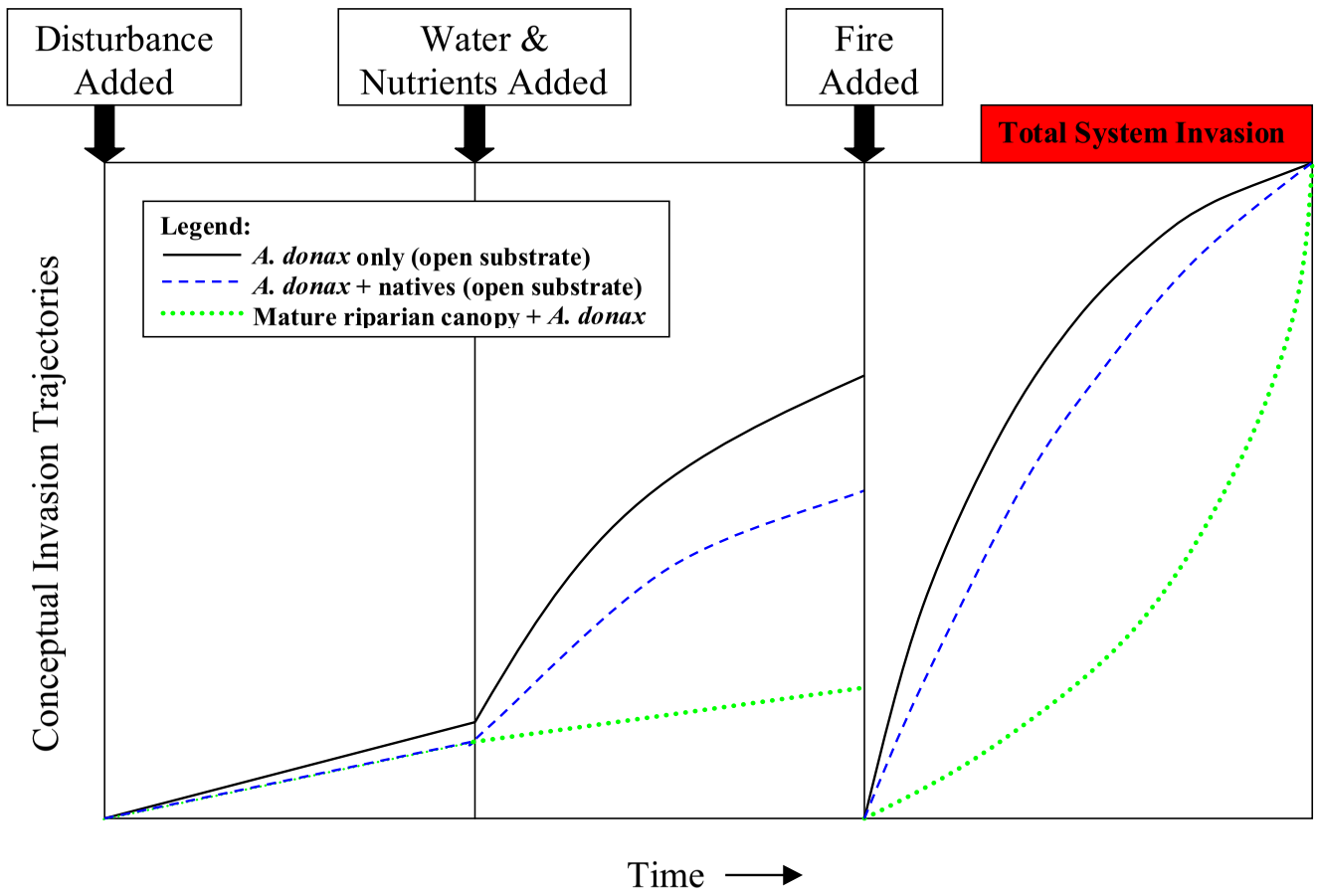

Figure 24. Conceptual *Arundo donax* invasion trajectories over time. Trajectories represent three invasion trends beginning after a large disturbance, including invasion where *A. donax* grows in monotypic stands, where it begins to grow at the same time as native riparian plants, and where it grows underneath a mature riparian forest canopy. The first panel shows invasion under low resource levels, conditions found throughout natural riparian ecosystems in California. When water and nutrients are added to riparian ecosystems, trajectories increase (panel 2). Panel 3 illustrates the steep invasion trajectories that occur when fire is introduced to riparian ecosystems where *A. donax* is already present.

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UNIVERSITY OF CALIFORNIA

Santa Barbara

Prioritizing Sites along the Santa Clara River for Conservation of Threatened and Endangered Species

A Group Project submitted in partial satisfaction of the requirements for the degree of Master's in Environmental Science and Management

for the

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Abstract

The Santa Clara River is one of the few rivers in southern California where continuous stretches of riparian habitat persist. Although the expansion of agriculture and urban development has reduced the extent of riparian habitat, these areas continue to support a number of threatened and endangered species. As a result of a 1994 oil spill, a trustee council was formed to appropriate a $7.1 million settlement for the acquisition and future restoration of land along the Santa Clara River. The Trustee Council requested our assistance in determining which parcels of land would be most appropriate for acquisition.

Combining a Geographic Information System (GIS) with a computer-aided site selection model, we evaluated parcels for the conservation of potential habitat for eight threatened and endangered species. All the parcels were within the 500-year floodplain of the Santa Clara River. Criteria used to assess these sites included the amount and contiguity of habitat, as well as the cost of land.

Based upon an analysis of the model results, we recommended 38 parcels, clustered in two areas of the river, for purchase. The area of these parcels totaled approximately 2000 acres. It is hoped that our results and recommendations will not only provide guidelines for the conservation of riparian habitat along the Santa Clara River, but will also provide a framework for others faced with the challenge of prioritizing land for acquisition.

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Executive Summary

As a result of a 1994 oil spill, a $7.1 million settlement was agreed upon as compensation for damages to natural resources along the Santa Clara River. A Trustee Council was formed to disburse the funds for habitat protection and/or restoration of areas within the Santa Clara River watershed that would benefit threatened and endangered species. The trustee council requested our assistance in identifying ecologically significant sites for acquisition. Our goal is to provide assistance to the Trustee Council in the form of recommendations for the purchase of sites along the Santa Clara River for the purpose of riparian ecosystem conservation. We determined which parcels of land would be most appropriate for these purposes based on the amount of habitat provided for threatened and/or endangered species, the contiguity of the selected sites, the cost of the parcels, and the compatibility with the surrounding landscape.

Riparian habitats are among the most ecologically productive and diverse environments, and have undergone serious decline during the last several decades due to water diversions and increased development within the floodplain. The Santa Clara River is one of the last remaining free-flowing rivers in Southern California. It flows for approximately 100 miles from Pacifico Mountain in the San Gabriel Mountains to the Pacific Ocean, and drains a total area of about 1,630 miles. Its watershed contains various native habitat types including chaparral, coastal sage scrub, and oak woodlands in the uplands, cottonwood/willow riparian forests on the upper terraces above the streambed, and riparian scrubs on the lower terraces of the streambed.

The distribution of native habitat along the Santa Clara River has been altered as a result of human disturbance. Population growth has led directly to an increased use of the floodplain, as well as an ever-increasing demand for water. Urban and suburban development, agriculture, and invasion by exotic plants have

reduced the extent of riparian vegetation and resulted in the fragmentation of remaining habitat areas. In these scattered patches, however, wildlife still flourishes. These habitats provide areas for nesting and foraging for a variety of sensitive, threatened and endangered animal species. Of the 35 sensitive species that inhabit the area, 14 are considered threatened or endangered by State and/or Federal agencies.

We defined our conservation goal as the maximization of potential habitat for eight threatened and endangered species: the least Bell's vireo, the southwestern willow flycatcher, the unarmored three-spine stickleback, the arroyo toad, the California red-legged frog, the tidewater goby, the western snowy plover, and the least tern. The cost of land was also considered since the amount of habitat to be purchased was limited by available funds. Thus, the distribution of species habitat and the cost of land parcels were combined in a Geographic Information System (GIS) and a computer-aided site selection model to prioritize parcels and highlight critical areas that should be protected.

We used land parcel boundaries as planning units for our analysis. The analysis was confined to parcels within the 500-year floodplain, where the distribution of riparian habitat is more abundant and the ecological value of the land for species conservation is greater. The study area was further limited by considering only those parcels in Ventura County.

We used the GIS database developed by the Santa Clara River Enhancement and Management Plan (SCREMP), which contained coverages such as parcel boundaries, floodplain boundaries, riparian habitat distribution and potential distribution for threatened and endangered species. The amount of species habitat in each parcel was quantified by overlapping the species distribution coverages with the parcel coverage. Aerial photos were used to interpret land use changes along the Santa Clara River. By overlaying the photos with the GIS coverages, we were able to assess the effects of increased agricultural development

on riparian habitat over the past 50 years. To estimate the cost of each parcel, we collected data on the assessed value for each parcel and the year in which the parcel was assessed from the Ventura County Assessor's Office. For each of seven land uses, we ran a regression of assessed land value per square foot versus the year of assessment. These results were used to estimate the price of each parcel in the year 2000.

Due to our time constraints and funding limitations, we chose to use an existing site-selection model to represent our objectives, rather than develop our own. We chose SITES, a site-selection model written by Ian Ball and Hugh Possingham for The Nature Conservancy. SITES uses a heuristic procedure, known as "simulated annealing", for making selections that attempt to meet stated, quantitative conservation goals as efficiently as possible. "Simulated annealing" is an iterative process in which entire reserve systems are evaluated and compared to identify a good solution. In this process, each reserve system is evaluated based on the constraints and the goals defined by the user. In our analysis, the goals were amounts of habitat for eight species. The constraints were the costs of land and the contiguity of the selected sites. Thus, we entered the following data into the model: the amounts of different types of habitat within each parcel, the costs of each parcel, and the connectivity of each parcel to other parcels. We also specified a cost threshold, which limited the number of sites chosen, and a boundary modifier, which determined the importance of contiguity in the selection process. As a comparison to the SITES model, we set up a simple linear maximization of habitat in Microsoft Excel.

Of the 1,067 parcels in our study area, 282 contained endangered species' habitat. SITES selected 44 parcels for $8 million and an additional 37 parcels for $16 million.. These results were corroborated by the linear maximization. Eighty percent of the parcels chosen by SITES for $8 million were also chosen by the linear maximization, and 90% of the parcels chosen by SITES for $16 million were

chosen by the linear maximization. Furthermore, 98% (44 out of 45) of the parcels chosen by the SITES $8 million scenario were also chosen by the linear maximization for $16 million. These results strongly support the selection of parcels made by SITES. Many of the selected parcels are adjacent to other selected parcels, creating a series of clusters. This natural clustering is driven by the distribution of habitat and cost values. Ten clusters and six lone parcels were identified. The parcels chosen using SITES provide a general picture of the possibilities for acquisition along the Santa Clara River. By using aerial photographs and the GIS database, the SITES results were further evaluated and verified within the context of surrounding land uses, levels of disturbance, and exotic species presence at both the parcel and landscape level. As a result, two areas were deemed priority sites for acquisition.

Of the 81 parcels identified by SITES, we recommended two areas for acquisition. The first area is located between the cities of Santa Paula and Fillmore and is significant for several reasons. Along this section of the river, agriculture is further back from the edge of the river and the presence of undeveloped upland areas allows for the formation of seasonal pools. It is the only cluster that contains habitat for five of the endangered species (stickleback, vireo, flycatcher, frog, and toad). Almost all (94%) of the red-legged frog habitat is in this cluster. Its proximity to the confluence of Sespe Creek offers an important connection to upland systems and a migration corridor for endangered species. The second area is located near the Ventura/ Los Angeles County line. It has a high percentage of riparian scrub and woodland habitats and low amounts of giant cane. The amount of potential endangered species' habitat is relatively high. The mountains to the south of this cluster are a source of ephemeral streams, which provide a connection to upland isolated environments.

The conservation of the recommended areas is only one step in what should be a multifaceted effort. If riparian conservation is to be effective, acquisition must

be coupled with restoration, management, long-term monitoring, and public education. We hope that our project will serve as a foundation for riparian conservation along the Santa Clara River.

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I Project Objectives and Significance

History of Project

On January 17, 1994, a magnitude 6.8 earthquake in the Los Angeles area caused an oil pipeline owned by the ARCO Pipe Line Company (APL) to rupture in at least eight locations. The ruptures resulted in the discharge of crude oil onto nearby lands and water. The largest spill, approximately 190,000 gallons of crude oil, occurred at APL's Newhall Pump Station near the city of Santa Clarita, CA. A portion of the oil flowed down a roadway, into an open drainage ditch, and eventually into the Santa Clara River. The oil continued to flow approximately sixteen miles downstream to Piru where a dam was constructed to halt further spread of the oil (United States and State of California v. ARCO Pipe Line Company 1997).

As required under the Oil Pollution Act (33 U.S.C. §§ 2701 et seq.), a Natural Resource Damage Assessment was performed in order to assess the injuries to natural resources. Approximately 100 acres of woody and herbaceous vegetation, as well as 150 acres of river sediments, were impacted by the spill and its subsequent cleanup operations. Cleanup operations included removing oiled vegetation along the riparian corridor, excavating soil and sediment, backfilling, and grading the riverbed (Memorandum of Understanding Between CDFG and USFWS 1997; United States and State of California v. ARCO Pipe Line Company 1997). The spill and the cleanup operations resulted in injury to fish, including the arroyo chub (*Gila orcutti*) and the federally endangered unarmored three-spine stickleback (*Gasterosteus aculeatus williamsoni*), as well as injury to a number of wildlife species and riparian vegetation, including critical habitat for the federally endangered least Bell's vireo (*Vireo bellii pusillus*) (Memorandum of Understanding Between CDFG and USFWS 1997; United States and State of California v. ARCO Pipe Line Company 1997).

The natural resource damage was translated into a monetary value that reflected an amount reasonable and necessary to restore the injured resources. The California Department of Fish and Game (CDFG) and the U.S. Fish and Wildlife Service (USFWS) reached a settlement with the APL in lieu of a trial. APL was instructed to pay the sum of $7.1 million in compensatory damages for the "natural resource damages related to the earthquake-related oil spills" (United States and State of California v. ARCO Pipe Line Company 1997).

After the settlement, a Trustee Council was formed, composed of representatives from USFWS and CDFG. The Trustee Council was required to use the settlement funds for habitat rehabilitation, revegetation, and/or protection of areas within the Santa Clara River watershed, and wildlife projects that will benefit the endangered and threatened species in and along the Santa Clara River (United States and State of California v. ARCO Pipe Line Company 1997). One of the Trustee Council's original focuses was on the purchase of land along the river, either outright or through conservation easements.

Objectives of Project

The goal of this project was to provide assistance to the Trustee Council in the form of recommendations for the purchase of sites along the Santa Clara River. We determined which parcels of land would be most appropriate for these purposes based on the amount of habitat for threatened and/or endangered species, the contiguity of the selected sites, the cost of the parcels, and the surrounding landscape. Specifically, we provided lists of land parcels along the Santa Clara River that offer the greatest potential conservation value subject to the monetary constraint of the settlement. We also provided a list of parcels that are prioritized in terms of their conservation value, regardless of cost. This allowed us to identify parcels that have a great deal of habitat, but may have been overlooked because of their estimated cost.

Significance

Riparian habitats are among the most ecologically productive and diverse environments. The strong land-water ecotone creates moisture gradients that lead to a diversity of physical environments. Dynamic river changes create a mosaic of habitats and microhabitats. Riparian zones are especially important in semi-arid regions where the availability of moisture and the associated microclimate give these habitats an ecological importance disproportionate to their areal extent (Kondolf et al 1996; Zaleweski et al. 1998). Avian densities and species richness in riparian systems demonstrate the importance of these habitats to birds (Franzreb 1987).

Riparian habitat in the southwestern United States has undergone serious decline during the last several decades (Kus 1998). The Santa Clara River is one of the last remaining free-flowing rivers in Southern California (SCR Project Steering Committee 1996). Urban and suburban development, agriculture, and invasion by exotic plants have all reduced the extent of riparian vegetation and its accompanying wildlife. This project is an important step towards protecting some of this critical environment.

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II Environmental Setting

Natural History

The Santa Clara River, from its headwaters at Pacifico Mountain in the San Gabriel Mountains to its mouth at the Pacific Ocean, drains a total area of about 1,630 square miles (ACOE 1973). The river flows in an east-west direction for approximately 100 miles and is fed by several streams flowing south out of the San Rafael Mountains. The main tributary streams include Santa Paula Creek, Sespe Creek, Hopper Creek, and Piru Creek in Ventura County, and Castaic Creek, Bouquet Canyon Creek, and San Francisquito Creek in Los Angeles County. Its watershed contains various native habitat types. These include chaparral, coastal sage scrub, and oak woodlands in the uplands, cottonwood/willow riparian forests on upper terraces above the streambed, riparian scrubs on the lower terraces of the streambed, freshwater marsh on undisturbed depressions along the banks, and foredune and alkali marsh near the coastal regions (SCR Project Steering Committee 1996).

The distribution of native habitat along the Santa Clara River has been altered as a result of human disturbance. Introduction of non-native species and encroachment into the floodplain have resulted in the loss of habitat and the fragmentation of remaining habitat areas. For centuries, the indigenous Chumash and Tataviam people lived along the river with very little impact on the riparian system. In the 1800s, the Spaniards brought increased agricultural activity and large-scale cattle ranching to the area. Since then, the expansion of agriculture and the establishment of oil enterprises have further put demands on the river. Population growth has led directly to an increased use of the floodplain, as well as an ever-increasing demand for water (SCR Project Steering Committee 1996). A comparison of aerial photos of the lower part of the river from 1927, 1941, 1969 and 1979 shows that much of the middle and upper terrace zones had already been

converted to agriculture by 1927 (Fairchild Aerial Photograph Collection, as cited in Faber et al. 1989). The distribution and extent of riparian woodlands have not diminished markedly over the last 50 years. However, activities such as off road vehicles, mining, floods and urban development have resulted in thinning and fragmentation of these woodlands.

The major difference in the nature of the river between 1927 and today is the current absence of riparian thickets on the floodplain. These thickets, consisting of mule fat *(Baccharis salicifolia*) and willow (*Salix* spp.) with a diverse understory of native vines such as poison oak (*Toxicodendron diversilobun*) and blackberry (*Rubus ursinus*), were once characteristic of the entire riverbed (Faber et al. 1989).

Flooding Characteristics and History

Three types of storms produce precipitation in the Santa Clara River watershed: general winter storms, thunderstorms, and tropical storms. The general winter storms usually occur from November through April and cause most of the major floods in the area. Thunderstorms can occur anytime and can cause high intensity precipitation within a short period of time (six hours or less). Tropical storms tend to occur in the late summer, but have not resulted in any major-recorded floods.

Streamflow in the Santa Clara River is negligible other than during and immediately after rains because climatic and basin characteristics are not conducive to continuous runoff (ACOE 1973). This is typical of the majority of southern California river basins. Additionally, streamflow is seasonal with the flow diminishing rapidly at the end of the winter rainy season.

Damaging floods have been recorded for the Santa Clara River for over 100 years. Records of river stage and discharge have been maintained since the U.S. Geological Survey began observations in 1911 by using a staff gage on Sespe Creek near the City of Fillmore (ACOE 1973). Based on stream-gage records,

newspaper accounts, and field investigations, the majority of the large floods in the Santa Clara River basin resulted in washed out bridges, roads and orchards.

Biological Resources

Between 95 and 97 percent of riparian habitat within floodplain areas has been lost in southern California (Faber et al. 1989). This is mainly due to channelization or damming of these riparian systems in order to allow development on the floodplain. Although these activities are minimal along the Santa Clara River, agriculture and urban development have fragmented the existing riparian areas. In these scattered patches, however, wildlife still flourish (SCR Project Steering Committee 1996). The following section briefly describes the vegetation and wildlife that currently exist on the river.

Vegetation

The riparian zone along the Santa Clara River can be divided into several distinct habitat types based on the dominant species within each habitat. These plant community names follow those proposed by Holland (1986). Mule fat scrub, southern willow scrub, southern willow riparian woodland, southern cottonwood/willow forest, arrow weed scrub, alluvial scrub, and big sagebrush scrub are the dominant riparian communities located on the upper and lower terraces of the active channel. Areas that are saturated for prolonged periods of time support valley freshwater marshes and ponds. Near the mouth of the river are alkali marsh and foredune habitats. Nonriparian communities adjacent to the Santa Clara River include coastal sage scrub, chamise chaparral, and coast live oak woodland. These habitats provide areas for nesting and foraging for a variety of sensitive, threatened and endangered animal species. See Appendix A for a list of the habitat types and their associated plant species (SCR Project Steering Committee 1996) and Appendix B for a description of the habitat types.

Wildlife

Many sensitive, threatened and endangered species are supported by the previously mentioned native habitats. Whether migratory or year round residents, all of them depend on riparian habitat for survival. Thus, conservation of these habitat types would help prevent further declines in native populations of riparian-dependent plants and animals.

We developed a table of the Santa Clara River's sensitive species based upon information provided by the U.S. Fish and Wildlife service and the Santa Clara River Enhancement and Management Plan Study (SCR Project Steering Committee 1996), in addition to a database search in the Natural Diversity Data Base (NDDB). Sensitive, in this document, refers to those species that are listed as endangered or threatened by state or federal agencies, species that are proposed for listing by state or federal agencies and/or species considered rare or of special concern by other agencies or organizations. A total of 5 fish, 2 amphibians, 4 reptiles, 17 birds, 3 mammals, and 4 plants were identified as sensitive and occurring or having the potential to occur within the study area. Potential habitat that exists along the Santa Clara River was also identified for these species (SCR Project Steering Committee 1996). See Appendix C for the list of sensitive species and their potential habitat.

One of the tasks for this study was to identify riparian habitat associated with threatened and endangered species. Of the 35 species identified as sensitive, 14 are considered threatened or endangered by State and/or Federal agencies. For reasons discussed in the Methods Section, eight out of the 14 species were utilized in our analysis. A literature search was conducted for each species, and the information was compiled and summarized in Appendix D. The following are brief descriptions of the eight species.

Tidewater goby – *Eucyclogius newberryi*

The tidewater goby is federally endangered. This species is discontinuously distributed throughout California, from Del Norte County to San Diego County. Before 1900, the tidewater goby occurred in at least 87 of California's coastal lagoons. Since then, it has disappeared from approximately 50 percent of formerly occupied lagoons (Brewer et al. 1994).

The tidewater goby is benthic, and is restricted mostly to coastal lagoons and near stream mouths in the uppermost brackish portions of larger bays (Lee 1980, as cited in SCR Project Steering Committee 1996). Mollusks, insects, and crustaceans are food sources for the tidewater goby (Brewer et al 1994).

Poor water quality and loss of habitat due to urbanization are the major threats to tidewater goby populations (SCR Project Steering Committee 1996). Sightings were reported in 1984 in the Santa Clara River, from the mouth to 3 miles upstream (SCR Project Steering Committee 1996).

Unarmored threespine stickleback – *Gasterosteus aculeatus williamsoni*

The unarmored threespine stickleback is a federal and state listed endangered species. Historically, it is believed that this species occurred in the drainages of the Santa Clara River, the Los Angeles River, the San Gabriel River, and the Santa Ana River (Haglund 1989, as cited in SCR Project Steering Committee 1996). This species is now restricted to the Santa Clara River above the confluence of Piru Creek.

The threespine stickleback prefers calm water, often living in weedy pools and backwaters, or among emergent plants at stream edges, or over bottoms of sand and mud. It is usually never found in water with temperatures over 23° Celsius. The stickleback avoids cloudy waters because they are visual feeders preferring bottom organisms that live on aquatic plants (Tamagni 1995).

Populations of the stickleback are threatened by stream channelization, urbanization, agricultural development, water diversions, groundwater pumping, introduction of predators and competitors, off-highway vehicle use, and oil spills (State of California 1992, as cited in SCR Project Steering Committee 1996).

Several sightings of the unarmored threespine stickleback have been reported along the Santa Clara River (see Appendix D). Potential habitat occurs in appropriate portions of the low-flow channel from the confluence of the river with Piru Creek to the Los Angeles aqueduct crossing upstream from Bouquet Canyon Road (SCR Project Steering Committee 1996).

Arroyo Toad - *Bufo microscaphus californicus*

The arroyo toad is a federally listed endangered species. It lives in rivers that have shallow, gravelly pools adjacent to sandy terraces. Both juveniles and adults are insectivores (Sweet 1992).

The arroyo toad was formerly found on rivers with near-perennial flow throughout southern California from San Luis Obispo County to San Diego County. Today, populations persist in Santa Barbara, Ventura, Los Angeles, Riverside, and San Diego Counties. Both Sespe and Piru Creeks, which drain into the Santa Clara River, contain populations of arroyo toad (Sweet 1992).

Virtually all remaining populations are small and face a variety of immediate threats to their continued viability. These threats include: short- and long-term changes in river hydrology due to construction of dams and water diversions; alteration of riparian wetland habitats by agriculture and urbanization; construction of roads; site-specific damage by off-highway vehicle use; development of campgrounds and other recreational activities; over-grazing; and mining activities.

Potential habitat for the arroyo toad occurs in the Sespe and Piru Creeks, the active channel and riparian woodlands/forest from the Los Angeles County line

east to Interstate 5, as well as the active channel and riparian woodlands/forest from the mouth of Soledad Canyon east to Acton (SCR Project Steering Committee 1996).

California red-legged frog – *Rana aurora draytonii*

The California red-legged frog is a federally threatened species. Its historical range extended from Marin and Shasta Counties in California, south to Baja California, Mexico. Today the red-legged frog has disappeared from over 90 percent of its original range (Jennings and Hayes 1994). It is known to occur in about 240 streams or drainages primarily in Monterey, Santa Barbara, and San Luis Obispo Counties.

Preferred habitat for adult frogs is characterized by dense, shrubby or emergent riparian vegetation closely associated with deep still- or slow-moving waters (Jennings and Hayes 1994). The most suitable habitat is commonly composed of arroyo willow, but cattails (*Typha* sp.) and bulrushes (*Scirpus* sp.) are also suitable (Jennings and Hayes, 1994).

The diet of California red-legged frogs is extremely variable. Adults eat invertebrates, small tree frogs and mammals, while larvae are thought to feed on algae (Jennings and Hayes 1994).

Current threats to red-legged frog survival include agriculture, urban development, reservoir construction, exotic predators, grazing, and drought. Clearing of creek-bed vegetation and the creation of concrete banks, as well as other forms of water-diversion associated with development, threaten the frog's breeding habitats.

Habitat for the red-legged frog along the Santa Clara River is scarce due to the lack of vegetation necessary to shade ponds and pools in the low flow channel. A few small freshwater marsh areas on the floodplain, as well as the river reach in

Soledad Canyon and east of Acton in Los Angeles County, may serve as potential habitat for the species (SCR Project Steering Committee 1996).

California Least Tern - *Sterna antillarum browni*

The California least tern is a federal and state listed endangered species. This species nests each spring and summer close to estuaries and coastal lagoons, and on sandy beaches and playas, from San Francisco Bay south into Baja California, Mexico (Palacios and Mellink 1996; Caffrey 1996). It winters along the coasts of western Mexico, south to northern South America (King 1981, as cited in García and Ceballos 1995). Least terns are opportunistic feeders known to capture more than 50 species of fish.

Numerous threats have affected the least tern populations. Predation is the major factor constraining the fledging of terns across California (Caffrey 1996). In addition, disturbance and degradation of nesting sites has led to its population decline (Palacios and Mellink 1996). Current conservation efforts should focus on the reduction of impacts from recreational activities and on the preservation of the coastal habitats on which the species depends (Palacios and Mellink 1996).

The Santa Clara River is an area in which terns have returned to breed after their absence for variable periods of time (Caffrey 1996). Potential habitat along the Santa Clara River occurs at the mouth.

Least Bell's Vireo – *Vireo bellii pusillus*

The least Bell's vireo, one of the four subspecies of Bell's vireo, is a federally and state listed endangered species and only occurs in coastal California. This subspecies arrives at its breeding grounds in southern California and northern Baja California, Mexico around mid-March to early-April, and departs by mid to late September to winter in southern Baja, California. Its preferred habitat is dense

willow dominated riparian areas with a lush understory. The least Bell's vireo is insectivorous (Steinitz et al. 1997).

Loss of riparian habitat and increased parasitism by the brown-headed cowbird (*Molothrus ater*) are two main reasons for the decline in numbers of the least Bell's vireo. Protection of riparian habitat, habitat creation and enhancement projects, and brown-headed cowbird removal has resulted in significant increase in the region's least Bell's vireo population (USFWS 1995, as cited in SCR Project Steering Committee 1996).

Recorded occurrences of the least Bell's vireo on the Santa Clara River stretch from Saticoy east to Santa Clarita (SCR Project Steering Committee 1996). Potential habitat occurs in areas that support southern willow scrub and southern willow riparian woodland (SCR Project Steering Committee 1996).

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Southwestern Willow Flycatcher – *Empidonax trailii extimus*

The southwestern willow flycatcher is a federally and state listed endangered species. This species is present in its breeding range, which includes southern California, southern Utah, Arizona, New Mexico and western Texas, from late April until August or September. It then migrates to its wintering grounds, most likely in Mexico, Central America and perhaps northern South America (SCR Project Steering Committee 1996). Historically, the southwestern willow flycatcher was present in all lowland riparian areas of the southern third of California. Today, approximately 10 nesting groups exist in California, all of which consist of six or fewer nesting pairs.

Habitat requirements for the southwestern willow flycatcher include riparian areas along rivers, streams and wetlands where dense growths of willows, arrowweed, buttonbush, tamarisk, Russian olive and a scattered overstory of cottonwood are present (Federal Register 1995a). The willow flycatcher is an insectivorous bird that forages within and above dense riparian vegetation.

The decline of the southwestern willow flycatcher has resulted from the loss or degradation of riparian habitats due to urban and agricultural development, water diversion and impoundment, channelization, invasion by non-native species, and livestock grazing. This degradation attracts brown-headed cowbirds, which parasitize willow flycatcher nests (Sogge et al. 1997).

No recorded instances of breeding by the southwestern willow flycatcher have been documented along the Santa Clara River (SCR Project Steering Committee 1996). However, potential breeding habitat for the species occurs in the mature willow woodlands and cottonwood/willow riparian forests, particularly in Los Angeles County (SCR Project Steering Committee 1996).

Western Snowy Plover - *Charadrius alexandrinus nivosus*

The western snowy plover is a federally threatened species. Sand spits, dune-backed beaches, unvegetated beach strands, open areas around estuaries, and beaches at river mouths are the preferred coastal habitats for nesting and for wintering (SCR Project Steering Committee 1996). The snowy plover uses a variety of sites for foraging and loafing, including mudflats of San Diego Bay and other coastal lagoons, and sandy beaches associated with river mouths and lagoons. It feeds almost exclusively on insects and crustaceans gleaned from the sand surface (SCR Project Steering Committee 1996).

The snowy plover nests through mid-March to mid-September (Federal Register 1995b). Eight areas, including the Oxnard lowland, support 78 percent of the California coastal breeding population. Some of these birds winter in the same areas used for breeding (Warriner et al. 1986), while others migrate north or south to wintering areas. The majority of birds winter south of Bodega Bay, California.

Habitat loss, predation, and other human activities have threatened snowy plover populations. Sightings of the western snowy plover have been reported at Ormond Beach, approximately 1.5 miles southwest of Port Hueneme, McGrath

Beach State Park, Point Magu, and the Santa Clara River mouth (State of California 1995, as cited in SCR Project Steering Committee 1996). Potential habitat for this species is located on the beach and southern foredune areas near the mouth of the river (SCR Project Steering Committee 1996).

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III Framework for Analysis

One of the most important steps in protecting endangered species is establishing legally designated protected areas. While land acquisition will not by itself ensure habitat preservation, it represents an important starting point. There are many facets to consider in order to identify sites in the landscape that are most important to protect. When nature reserves constitute a small fraction of an area and there are limited funds available for their expansion, it is critical to utilize conservation resources efficiently (Csuti et al. 1997). Prioritization of sites is the key to this efficiency.

The challenges of site prioritization have been faced by many others. The Cantara Trustee Council developed a plan for the Upper Sacramento River that included habitat acquisition among its goals (Cantara Trustee Council 1998). More locally, the National Park Service (NPS) developed the Santa Monica Mountains National Recreation Area Land Protection Plan, which identified land parcels with the most significant natural, cultural and recreational resources (NPS 1998). Other projects we investigated included a plan written by The Nature Conservancy to protect land in the Mississippi River Alluvial Plain ecosystem (Llewellyn et al. 1996) and a project to identify and purchase a riparian buffer zone in North Carolina (Xiang 1996). Based on these projects and others (Davis et al. 1999, Holmgren et al. 1993, Schaefer and Brown 1992), we developed a four-step methodology: 1) define the conservation goal, 2) establish site-specific criteria, 3) identify a preliminary group of sites, and 4) apply landscape level criteria to make final recommendations.

Conservation goal

Our conservation goal was to protect habitat for threatened and endangered species in an effort to ensure their persistence. Other projects have had similar

goals (Llewellyn et al. 1996, Schaefer and Brown 1992). More importantly, protecting endangered species habitat was one of the explicit requests of the Trustee Council.

Criteria

To move towards this goal, we established several criteria that could be applied to each planning unit. The most obvious criterion was the percentage of endangered species habitat in the planning unit; Schaefer and Brown (1992) used a similar criterion to select sites for protection. Because the amount of land to be purchased was limited by the available funds, the cost of each parcel was a second criterion. To obtain cost estimates, we followed an approach used in a project by Xiang (1996), who estimated land acquisition costs from the appraised land values at the County Tax Office. Our third criterion was the contiguity of the selected parcels. This is important because small, isolated habitats will not adequately protect species or processes (Schaefer and Brown 1992).

Preliminary Site Selection

To identify the sites that best met our criteria, we combined a Geographical Information System (GIS) with a computer-aided site selection model. The projects by the NPS for the Santa Monica Mountains (NPS 1998) and the Cantara Trustee Council for the Upper Sacramento River (Cantara Trustee Council 1998) have proven that a Geographic Information System (GIS) can be successful in accomplishing the task of prioritizing sites for resource protection. Both studies applied a set of criteria to the parcels in their study area and modeled each criterion as a layer in a GIS. Sites were prioritized based on how well they conformed to each criterion.

Final Recommendations

While criteria like amount of species habitat and cost apply to each individual planning unit, some aspects of the selected sites apply to the collection of sites as a whole. The configuration of the selected sites, for example, cannot be evaluated for each planning unit. There is a debate, known as "SLOSS" (single large or several small), whether species richness is maximized in one large nature reserve or several smaller ones (Diamond 1975; Simberloff and Abele 1982; Terborgh and Winter 1980). A single large reserve can support populations of big, wide-ranging species, encompass more species, minimize edge effects and contain greater habitat diversity (Schonewald-Cox 1983). On the other hand, a patchy distribution of reserves allows for recolonization, and offers protection from the negative effects of environmental stochasticity and catastrophes (Quinn and Harrison 1988). Both of these considerations were important for our final recommendations.

Besides the configuration of the selected sites, we also wanted to evaluate the surrounding land use (Cantara Trustee Council 1998) and any surrounding physical features that might enhance the value of the selected sites for endangered species protection.

These landscape level criteria were applied after the preliminary site selection. Thus, we used aerial photographs and the GIS to evaluate the results of the site-selection model. This evaluation led to our final recommendations. The implementation of this entire methodology is the subject of the next section.

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IV Methods

Based on the framework and goals discussed in the previous section, the methodology of the project was divided into six parts. First, we defined our study area. Next, we gathered current and historic information about the distribution of riparian habitat within the floodplain. We also gathered the necessary information to estimate the cost of land along the river. A computer model was then used to select the sites that offered the greatest potential habitat for a fixed cost. Next, the results of the models were verified using a linear maximization. Finally, the model results were analyzed critically in light of the historic riverine dynamics and landuses. The first five steps will be discussed in detail below, and the final step is discussed in Section VI.

Defining the Study Area

We confined our analysis to parcels within the 500-year floodplain, where the distribution of riparian habitat is more abundant and the ecological value of the land for species conservation is greater. The study area was further limited by considering only those parcels in Ventura County. The opportunities for conservation in Los Angeles County seemed to be fewer and more problematic.

We used parcel boundaries as the planning units for the analysis. Although these parcels do not generally reflect ecological realities, there were other compelling reasons for our decision to use them. Since the parcels were defined by the Ventura County Assessor's Office, we were able to estimate cost information from the assessed value of the land. More importantly, the parcels are the units in which land is bought and sold. Therefore, any acquisition of land will be done in terms of these divisions.

Biological and Landscape Information

The Santa Clara River Enhancement and Management Plan (SCREMP) developed a GIS describing the river and its associated natural resources. The mapping layers included flood control structures, land use, recreational areas, water resources and the distribution of flora and fauna. Kirk Waln, a wildlife biologist for the United States Forest Service and the primary contact for SCREMP, provided us with a copy of the GIS. Mapping layers, such as parcel boundaries, floodplain boundaries, riparian habitat distribution and potential distribution for threatened and endangered species, were the foundation for our analysis.

The information in the GIS was compiled by interacting subcommittees and groups. For example, the biological resources subcommittee of the Santa Clara River Enhancement and Management Plan generated data for the "bioreach", a layer which represented portions of the river within the 500-year floodplain that had similar habitat, channel and geomorphological characteristics. The consulting firm CH2MHill then used this information in conjunction with the vegetation layer to estimate the distribution of avifauna within several bioreaches. The most useful layers for our project were the habitat distributions, which were based on professional judgment using aerial photograph and field studies (Gautsch, pers. comm. 1999). A description of all of the coverages is provided in Appendix E.

Habitat Distribution

For our analysis we used eight threatened and endangered species: the least Bell's vireo, the southwestern willow flycatcher, the unarmored three-spine stickleback, the arroyo toad, the California red-legged frog, the tidewater goby, the western snowy plover, and the least tern. These eight species were chosen because their potential habitat was digitized and available to use in the GIS. Furthermore, the habitats used by these eight species are representative of most of the natural communities found along the Santa Clara River. Thus, conservation of these eight

species will provide an umbrella of protection for the other listed species found in these communities.

The amount of habitat for each of these species in each parcel was calculated in the following manner. We began by creating separate coverages for each of the targeted species using the potential habitat distributions delineated by the GIS. The actual amount of species habitat in each parcel was then quantified by overlapping the species distribution coverages with the parcel coverage. The species distribution polygons were essentially "clipped" by the boundaries of the individual parcels. This process created a number of polygons fragmented by the boundary of each parcel; these polygons could later be summarized for total area (Figure 4.1).

Figure 4.1: Using GIS to Calculate the Amount of Habitat

(a) (b) (c)

Figure 4.1. The blue line is the 500-year floodplain. The dark gray areas are parcels that lie within the floodplain (a). Figure (b) shows the distribution of habitat used by the least Bell's vireo. By "clipping" the species distribution coverage with the parcel boundaries, we created a separate coverage of species habitat delineated by the boundary of each parcel. This final coverage (c) gave us the amount of least Bell's vireo habitat in each parcel. The same operation was performed for each species.

Contiguity

As a result of the largely reduced and fragmented nature of riparian habitat along the Santa Clara River, contiguity became an important consideration. We addressed the contiguity issue by minimizing the perimeter to area ratio of any combination of parcels that would later be evaluated for potential selection. We

quantified the perimeter of each parcel and then used an AML (Arc Macro Language) to summarize the distances between them, allowing us to estimate the perimeter of any combination of parcels. The AML was written by David Stoms, manager of the Biogeography Lab at the University of California, Santa Barbara.

Historical Documentation

Aerial photos were used to interpret land use changes along the Santa Clara River after the early 1900s. We were primarily interested in the effects of land use changes on the distribution of riparian habitat over time. This information describing the historical extent of riparian vegetation was used to assess the restoration potential and the degree of anthropogenic disturbance to areas along the Santa Clara River. We also investigated the relationship between current and historic geomorphologic patterns and their effect on the landscape.

A series of aerial photos from 1947 and 1999 were provided by the Map and Imagery Lab at the University of California, Santa Barbara. The photos were geo-referenced using the ERDAS Imagine image registration software. By overlaying the photos with the GIS coverages, we were able to assess the effects of increased agricultural development on the extent of riparian habitat over the past 50 years. These data were gathered by comparing current land use activities with the 1947 image. The historic image provided a "snap shot" of the riparian vegetation that once existed along the banks of the river and in the upland areas of the floodplain. These previously existing patches were digitized and then compared to the current vegetation coverage. In order to assess the effects of flooding, we surveyed each photo for dramatic changes in the structure of the river and the distribution of riparian habitat.

Cost Data

An essential part of our analysis was a consideration of the costs of the parcels in the planning area. Ideally, we would have liked to know the price that the owners of the parcels were willing to accept for the purchase of their land, but political issues and physical impracticalities prevented us from gathering such information. So to estimate these prices, we collected data from the Ventura County Assessor's Office. We were able to get the assessed value and the year of assessment for 875 of the 1067 parcels in the planning area (See Appendix F).

Aside from the size of the parcel, the assessed value is also dependent on the year in which the assessment was made and the current land use status. A regression of the cost per area vs. time showed a steady increase until about 1990, after which there was no discernable trend. However, this ignored the different land uses along the river. Based on information in our GIS database, we divided the parcels into 7 land use types: residential, commercial, public, agricultural, mining/industrial, recreational, and vacant. For each of these 7 land uses, we ran a regression of assessed land value per square foot versus the year of assessment. The results (in Appendix G and summarized in Table 4.1) were only significant ($p<.01$) for some land use categories; these results were used to estimate the price of each parcel in the year 2000. When the p-value was not significant, the estimated costs for that land use were left equal to their assessed costs.

However, we could not do this for the 192 parcels for which we could not get information from the Assessor's Office. The costs of these remaining parcels were calculated based on the estimated prices of the other parcels for the year 2000. For each of the parcels without an assessed value, the cost per square foot was calculated as the average cost per square foot of all parcels of the same land use that were within two miles of the parcel. This approach was not practical for recreational parcels or industrial parcels because the study area only included eleven recreational parcels and nine industrial parcels. So in these cases, the

missing costs were calculated as the average cost per square foot of all the parcels of the same land use type in the entire study area.

Table 4.1:Results of Linear Regression of Price Per Area vs. Year of Assessment

Land Use Type	All Parcels	Parcels with Assessed Values	Regression Results (increase in $/square foot/year)	P-value
Residential	252	233	.40	<.001
Commercial	104	78	.08	.002
Public/Transportation	115	92	.14	.001
Agricultural	346	293	.01	.003
Vacant	230	164	.01	.294
Recreational	11	8	.22	.475
Industrial	9	7	.33	.002
All Parcels	1067	875	.33	<.001

One final adjustment to the estimated costs was made. Because unreasonably cheap or unreasonably expensive land would bias our results, we wanted to put a limit on the range of estimated costs. The county assessor for agriculture and vacant land informed us that the range of assessed values for these types of land was generally between $8000/acre and $40,000/acre. Therefore, as very conservative limits on the cost of land, we chose .08$/square foot ($3500/acre) and 5$/square foot ($215,000/acre). Any agricultural or vacant land that was above this range was set equal to the upper limit, and any agricultural or vacant land that was below this range was set equal to the lower limit.

SITES Model

Due to our time constraints and funding limitations, we chose to use an existing model to represent our objectives, rather than develop our own. We chose SITES, a simulated annealing site selection model written by Ian Ball and Hugh Possingham (Andelman et al 1999). The model was originally developed for The Nature Conservancy (TNC), a non-profit organization which recently adopted a

planning initiative with the aim of developing "portfolios" that would collectively conserve viable examples of all native species and plant communities within several eco-regions in the U.S., the Caribbean, and Latin America. SITES was developed as an iterative planning tool to assist TNC in identifying conservation areas.

SITES uses a heuristic procedure, known as "simulated annealing", for making selections that attempt to meet stated, quantitative conservation goals as efficiently (using as few sites) as possible. We will refer to a set of sites constituting a conservation area or potential reserve system as a "portfolio" in this report. The procedure begins with a random set. Then, at each iteration, the model swaps sites in and out of that set and measures the change in the function. If the change improves the set, the new set is carried forward to the next iteration. However, even changes that increase the function (that is, reduce the quality) of the set may be carried forward, so that one can examine a greater number of different site combinations to avoid getting stuck at a local minimum. The changes to the selected set can be large at first (even sites that contribute greatly to reducing cost can be removed) but then allowable changes are made progressively smaller as the function of the solution diminishes. Simulated annealing evaluates alternative complete reserve systems at each step, and compares a very large number of alternative reserve systems to identify a good solution.

In this process of comparing different portfolios, each reserve system is evaluated based on the constraints and the goals that the user has defined. For this project, the goals were amounts of habitat for the eight species in our analysis: the least Bell's vireo, the southwestern willow flycatcher, the three-spine stickleback, the arroyo toad, the California red-legged frog, the tidewater goby, the western snowy plover, and the least tern. The constraints were the costs of land and the contiguity of the selected sites. Thus, we entered the following data into the model: the amounts of different types of habitat in each parcel, the costs of each parcel,

and the connectivity of each parcel to the other parcels. We also specified a cost threshold, which limited the number of sites chosen. Although the original settlement was for $7.1 million, that amount has grown as a result of accrued interest, to nearly $8 million. Thus, $8 million was a logical threshold. However, it is very likely that more money will be available for purchasing land; this money could come from private organizations, or from future settlements for natural resource damage. To address this possibility, we also used a cost threshold of $16 million. We also specified a boundary modifier parameter, which determined the importance of contiguity in the selection process. Selection of the boundary modifier required exploration by trial and error to obtain a reasonable solution. However, this weight had little effect because the distribution of habitat was already strongly clustered. Using all of this information, SITES performed its simulated annealing process to find a portfolio. The details of how the SITES model does this are in Appendix H.

In our multi-species approach, we initially considered all species habitat equally valuable. All eight species have limited distributions, and are all considered endangered. However, as our exploration process continued, we began to believe that the importance of a species in our analysis should be determined by assessing the degree of protection already afforded to them, and by the limits of their current distribution. As a result, species with extremely limited or extensive potential distributions were treated differently, as described below.

The potential habitats of the tidewater goby, the snowy plover and the least tern are predominantly concentrated in one parcel at the mouth of the Santa Clara River. This parcel, known as McGrath State Beach, is already protected as an endangered species habitat preserve. Although the amount of habitat preserved on the State Beach may or may not be adequate to support populations, recommending McGrath State Beach for acquisition is unnecessary. As a result, McGrath State Beach was "locked in" to our conservation portfolios for all scenarios. This means

that McGrath State Beach is part of every portfolio, and cannot be removed. The habitat present at McGrath counts toward reaching our habitat goals, but the cost is set equal to zero to reflect the fact that it is, in a sense, already acquired.

We set the habitat goal for the unarmored three-spine stickleback equal to zero, as a result of its extensive potential distribution along the river. Its potential distribution spans the entire Santa Clara River, such that conservation of any endangered species' habitat would conserve stickleback habitat as well. Because of the nature of stickleback habitat, any clump of habitat anywhere adjacent to the river was contributing as much as any other clump to the preservation of stickleback habitat. In addition, the stickleback seems to be declining for reasons that are unrelated to parcel-scale activities. Thus, parcel level conservation would likely do little to speed its recovery. Setting the stickleback goal equal to zero means that SITES did not "try" to acquire stickleback habitat, but acquired it inadvertently while acquiring habitat for other species.

There are multiple parameters within these analyses that can be varied to represent different goals, and yield different results. We developed a series of scenarios by varying the boundary modifier, the species habitat goals, and the cost threshold. Scenario development was useful in exploring the role of the boundary modifier and the species habitat goals in our analysis. Often new scenarios were developed in response to information acquired through trial and error. However, the Results section refers only to the scenarios that provided insight into our research question. Scenarios whose purpose was related to parameterizing the SITES model are addressed in Appendix H.

Excel Models

As a comparison to the results of the SITES model, a simple linear maximization was performed using Microsoft Excel (Excel). Specifically, we maximized the total amount of habitat that could be purchased for $8 million and

for $16 million. Unlike the SITES model, this model did not differentiate between the different types of potential species' habitat.

We also used Excel to create a biological ranking of the parcels that was independent of the estimated costs of the parcels. This model ranked all of the parcels based on the percentage of the parcel with habitat. We will refer to this as the biological ranking of the parcels.

V Results

SITES Model

Out of the 1,067 parcels in our study area, 282 contained endangered species' habitat. SITES selected 44 parcels for the $8 million scenario and an additional 37 parcels for the $16 million scenario. Refer to Appendix I for a list of the 81 parcels and the Map 1 for their location. In addition, for more detail, see the five maps (Maps 2-6) located in the pocket at the end of the document.

Many of the selected parcels are adjacent to another selected parcel, creating a series of clusters (Map 1). A "cluster" in our report will refer to a group of adjacent parcels. These clusters generally fall within a particular bio-reach that is defined by similar habitat, channel, and geomorphological characteristics. Because of these similarities, the bio-reaches were used to structure our analysis of the model results. Table 5.1 lists the clusters with their associated bio-reaches. Cluster area, the percentage of the cluster with species habitat and the percentage of potential habitat in each cluster are also reported in Table 5.1. Note that there are "sub-clusters" (e.g., G1 and G2) in the $8 million scenario that are connected with the additional parcels selected in the $16 million scenario.

Table 5.1: SITES Results

Bio-reach	Cluster ID*	16 million				8 million			
		Total Cluster Area (acres)	Species	% of Cluster with Potential Habitat	% of Potential Habitat in Cluster	Total Cluster Area (acres)	Species	% of Cluster with Potential Habitat	% of Potential Habitat in Cluster
1	A	137	stickleback	43	2	85	stickleback	44	1
			flycatcher	30	6		flycatcher	33	4
			vireo	34	4		vireo	33	2
2	B	47	stickleback	21	0				
			vireo	25	1				
3	C	296	stickleback	48	4	181.45	stickleback	47	2
			flycatcher	16	7		flycatcher	25	7
			vireo	32	7		vireo	39	5

Bio-reach	Cluster ID*	16 million				8 million			
		Total Cluster Area (acres)	Species	% of Cluster with Potential Habitat	% of Potential Habitat in Cluster	Total Cluster Area (acres)	Species	% of Cluster with Potential Habitat	% of Potential Habitat in Cluster
3	D	98	stickleback	24	1	34	stickleback	56	0
			flycatcher	15	2		flycatcher	23	1
			vireo	22	2		vireo	41	1
	E	14	stickleback	94	0	11	stickleback	98	0
			vireo	36	0		vireo	37	0
	F	1215	stickleback	35	9	820	stickleback	24	7
			flycatcher	18	32		flycatcher	42	29
			vireo	25	23		vireo	28	17
			toad	35	17		toad	42	14
			frog	3	94		frog	4	94
4	G	384				G1=175	stickleback	72	2
			stickleback	55	6		vireo	17	2
			flycatcher	1	0		toad	72	3
			vireo	13	4	G2=24	stickleback	67	2
			toad	55	8		vireo	7	0
							toad	67	3
	H	1145				H1=113	stickleback	74	2
							vireo	2	0.20
							toad	74	3
			stickleback	63	19	H2=350	stickleback	74	7
			flycatcher	1	2		flycatcher	2	1
			vireo	5	5		vireo	9	2
			toad	63	29		toad	74	10
						H3=78	stickleback	42	1
							vireo	20	1
							toad	42	1
			vireo	23	8	J2=0.10	vireo	98	0.01
5	I		stickleback	85	0		stickleback	85	0
			toad	85	1		toad	85	1
6	J	469	toad	11	2	J1=119	flycatcher	15	3
			flycatcher	18	12		vireo	27	2
			vireo	23	8	J2=0.10	vireo	98	0.01

*Cluster ID: A cluster is defined by adjacency (see Map 1)

Excel Models

The linear maximization using Excel yielded results that were only slightly different from the SITES model. The $8 million and $16 million

constraints led to the selection of 41 and 74 parcels, respectively. Table 5.2 shows the total percentage of habitat acquired for each species from both the SITES and Excel models.

Table 5.2: Total Potential Species' Habitat Acquired by SITES and Excel Models

	SITES				*Excel*			
	$8 Million Scenario		**$16 Million Scenario**		**$8 Million Scenario**		**$16 Million Scenario**	
Species	**% Habitat**	**Total Area (acres)**	**% Habitat**	**Total Area (acres)**	**% Habitat**	**Total Area (acres)**	**% Habitat**	**Total Area (acres)**
Least Bell's Vireo	40	529	59	789	31	410	51	674
Willow Flycatcher	50	337	69	462	43	290	63	425
Stickleback	30	1144	47	1782	33	1258	53	2020
Arroyo Toad	37	917	59	1464	47	1165	74	1834
Red-Legged Frog	94	34	94	34	94	34	94	34

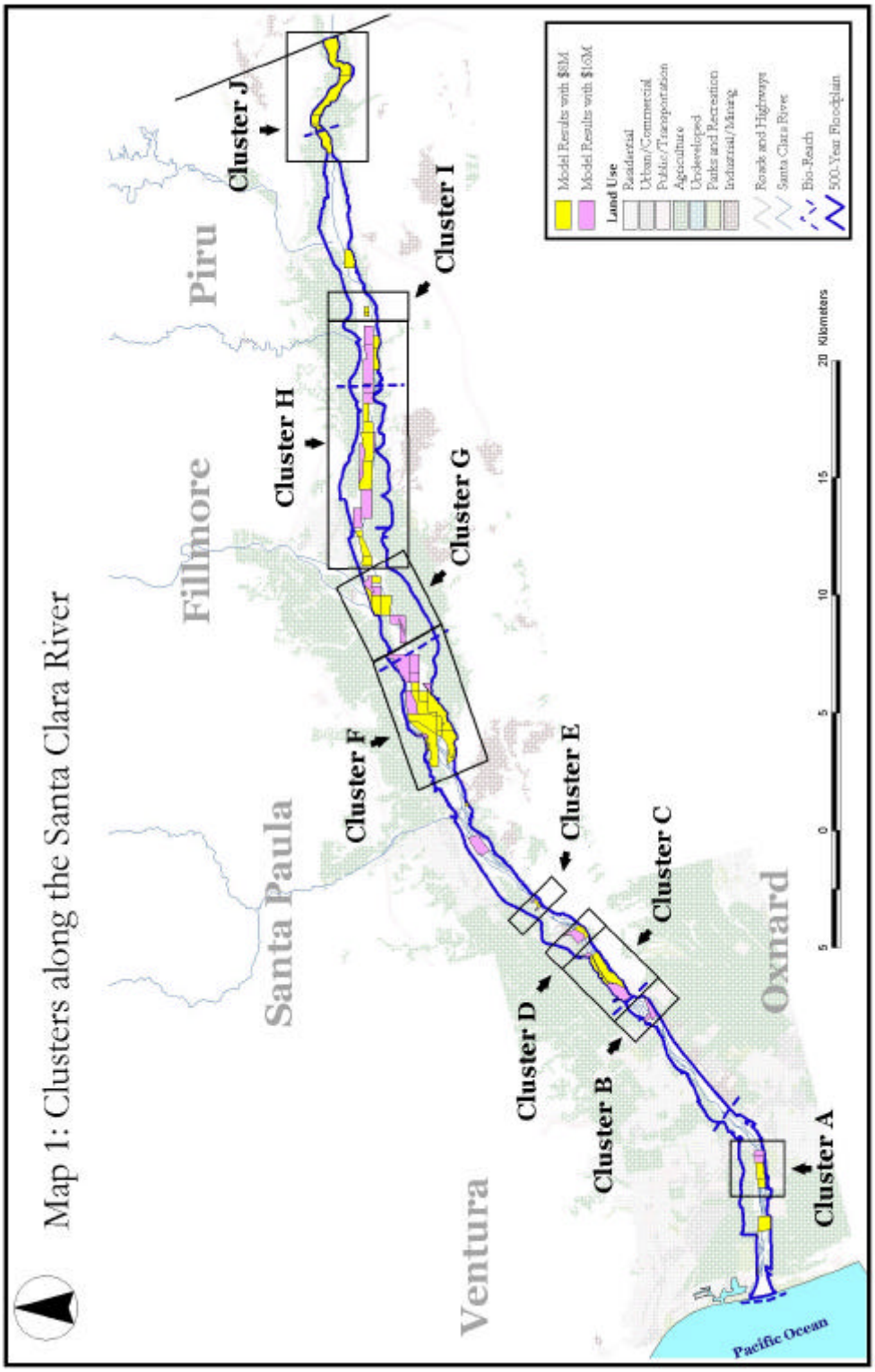
The second Excel model created a biological ranking of the parcels that was independent of the estimated costs. Table 5.3 lists the 20 parcels that scored the highest and that were also greater than 10 acres. The complete results are in Appendix J.

Table 5.3: Biological Ranks of Some Parcels with Areas > 10 Acres

Biological Rank	**APN**	**% Habitat**	**Area (Acres)**	**Estimated Cost/Acre**	**Land Use**	**SITES 8**	**SITES 16**
7	McGrath	174	91.7	0	3		
9	138005011	155	23.4	53735	1		
11	046023022	144	121.0	40182	2		
18	046023020	110	178.8	3485	4	Y	Y
19	046023008	107	100.3	3485	4	Y	Y
21	046023015	103	97.4	3485	5	Y	Y
22	046023025	101	23.3	3485	4	Y	Y
25	(no APN)	100	11.8	58313	7		
28	107001064	100	31.7	84950	2		
29	055026017	99	44.8	3485	4	Y	Y
33	046009002	97	83.5	3485	4	Y	Y
35	138019028	96	25.1	38264	4		
36	090018008	95	43.8	6787	5	Y	Y
38	055026005	95	125.3	3485	5	Y	Y

Biological Rank	APN	% Habitat	Area (Acres)	Estimated Cost/Acre	Land Use	SITES 8	SITES 16
40	055027028	94	31.9	3485	4	Y	Y
41	046023013	94	29.1	3485	5	Y	Y
42	179005004	93	24.7	12616	1		Y
45	107014037	91	39.3	46706	3		
46	046023009	90	38.9	3485	4	Y	Y
50	046023021	89	148.9	3485	5	Y	Y

% Habitat *refers to the percentage of endangered species' habitat in the parcel. It can be greater than one hundred because the habitat of all the species is added together (i.e. if a parcel were entirely covered with habitat for all 8 species, the % Habitat would be 800).*
Land Use *codes are as follows: 1=residential, 2=commercial, 3=public/transportation, 4=agriculture, 5=vacant/undeveloped, 6=parks and recreation, 7=industrial/mining.*
SITES 8 *and* ***SITES 16*** *refer to whether that parcel was chosen by either of the SITES scenarios.*


Map 1: Clusters along the Santa Clara River
Piru
Fillmore
Santa Paula
Ventura
Oxnard
Pacific Ocean
Cluster A
Cluster B
Cluster C
Cluster D
Cluster E
Cluster F
Cluster G
Cluster H
Cluster I
Cluster J
Model Results with $8M
Model Results with $16M
Land Use
Residential
Urban/Commercial
Public/Transportation
Agriculture
Undeveloped
Parks and Recreation
Industrial/Mining
Roads and Highways
Santa Clara River
Bio-Reach
500-Year Floodplain
5 0 5 10 15 20 Kilometers

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VI Discussion

This section is divided into three parts. First, we will discuss the results of the SITES model. Then, we will compare these results to the Excel model results. Finally, some limitations of our analysis will be evaluated.

SITES Results

The SITES model selected 44 parcels in the $8 million solution and 81 parcels in the $16 million solution. These parcels provide a general picture of the possibilities for acquisition along the Santa Clara River. The conservation portfolios that SITES selected were an attempt to represent a certain amount of habitat for each endangered species without spending more than a fixed amount of money. SITES did not evaluate solutions based on factors such as surrounding land uses, structure of vegetation, or level of disturbance. In the following section, the SITES results were evaluated and verified within the context of these attributes of the Santa Clara River at both the parcel and landscape level. This evaluation was based on our interpretation of the aerial photographs and the GIS database.

As shown in Maps 1 and 2, the areas chosen by SITES tend to be groups of parcels. That is, many of the selected parcels are adjacent to other selected parcels, creating a series of clusters. This natural clustering is driven by the distribution of habitat area.

Given the clumped nature of our solution, we have organized the discussion around clusters of parcels, located within unique bio-reaches of the river. Discussion of the attributes of clusters, which contain parcels with similar characteristics, is more practical than a discussion of each parcel individually. More importantly, groups of adjacent parcels containing endangered species' habitat foster more successful conservation because larger habitat areas support larger populations and contribute to the functioning of landscape level processes.

In addition, management of adjacent parcels is easier than management of parcels separated by land devoted to incompatible uses.

The bio-reach coverage, which was created by the SCREMP biological subcommittee, allowed us to segregate the selected parcels based on similarities in habitat and geomorphology within the 500-year floodplain (See Appendix E). Clusters were identified based on adjacency to other parcels within the solution and were given a letter as an identifier.

Table 5.1 and Map 1 identify ten clusters and six lone parcels. Of the clusters selected in the $16 million scenario, six contained more than 5% of the habitat of at least one species. Our discussion will focus on these clusters. These clusters were cluster A in bio-reach 1, cluster C in bio-reach 3, cluster F in bio-reach 3, cluster G in bio-reach 4, cluster H in bio-reach 4, and cluster J in bio-reach 6.

Cluster A

Sites within the first bio-reach are likely to be influenced by the coastal environment, as a result of their proximity to the Pacific Ocean. Unlike more upstream portions of the river, this stretch is supplemented by moisture moving off the coast during the dry seasons. Historically, these areas contained southern willow and mule fat scrub. However, agriculture now occupies the upland areas, and dense patches of giant cane often dominate remaining riparian habitats. The sites selected in this stretch are located within the active channel between two golf courses. Buena Ventura Golf Course is to the north and River Ridge Golf Course is to the south. Aerial photos from 1947 show that the golf courses were likely prone to large-scale flood events. In fact, it appears that the Santa Clara River once flowed through the site that is now River Ridge. In 1947, the floodplain extended to the south for an additional 0.5-km and contained at least 1.5 km^2 of additional riparian habitat. Flooding may currently occur at outer edges of Buena Ventura,

but a series of groins on the southern bank of the river has likely minimized the effects on River Ridge. Cluster A, located approximately 5 kilometers from the mouth of the Santa Clara River, is the only cluster of selected parcels within the first bio-reach.

Cluster A includes four parcels (See Map 3), three of which contain a significant amount of flycatcher habitat. Together, these parcels contain 6% of the flycatcher's habitat. Some vireo habitat (1.27%) is present in one of the parcels. The stickleback also exists in this cluster, although none of the parcels contain a significant percentage of its habitat. The current land use is vacant/undeveloped.

Clusters C and F

Two clusters were identified in the third bio-reach of the river, where a significant amount of riparian habitat remains in the upland and wetland portions of the braided channel (See Maps 3 and 4). In the cluster located between the city of Ventura and Santa Paula (Cluster C), the density of giant cane generally does not exceed more than 50% of the total area of each selected parcel. Most of the giant cane appears to be growing on the terraces of adjacent agricultural fields. Row crops and open fields appear to be more prevalent on the northern bank since the southern bank is largely protected by an undeveloped hillside.

Cluster C consists of five parcels. A significant percentage of vireo habitat is present in three of the five parcels in this cluster, two of which also contain a significant percentage of flycatcher habitat. This cluster contains about 7% of vireo habitat and 8% of flycatcher habitat. Two of the five parcels contain a significant percentage of stickleback habitat. Four of the parcels in cluster C are vacant/undeveloped, while the remaining parcel is in agricultural use (see Table 6.1).

A second cluster in the third bio-reach, Cluster F, lies approximately 2 miles east of Santa Paula. Within this section of the reach, agriculture is set further

back from the river and more than 2.5 km^2 of riparian habitat persists on the gradually sloping terraces. These gradients are likely to allow for frequent flooding and the subsequent formation of palustrine environments. Aerial photos provide evidence of recurring flooding and the formation of pools in upland areas adjacent to the selected sites. The dynamic landscape has also led to a braided channel where riparian vegetation dominates in several close patches.

Cluster F, with 25 parcels, contains a significant proportion of red-legged frog, arroyo toad, vireo and flycatcher habitat. Approximately 64% of frog habitat is present in one of these parcels (APN 046023023). The entire cluster contains 94% of frog habitat.

Clusters G and H

Two clusters, G and H, are located within the fourth bio-reach surrounding the City of Fillmore and are important for conservation purposes as a result of the large amounts of alluvial scrub within and adjacent to each parcel (See Map 5). The proximity to Sespe Creek also increases its significance, since Sespe Creek is one of the last wild rivers in southern California and could act as a migration corridor for endangered species such as the arroyo toad. The area directly upstream of the Sespe confluence is heavily used for agriculture and residential development. Agricultural activities have been present in Fillmore since the 1920s and flood control facilities have also been built at the northern edge of the channel. Such long-term disturbances have led to the removal of much of the riparian habitat in this stretch of the river. However, increased scouring of the riverbed has also decreased the distribution of giant cane in this area. In many of the selected sites, the density of giant cane is relatively low. Cluster H is located in the area east of Fillmore within bio-reach 4. Compared to many parts of the river, this area has small proportions of riparian habitat (less than 10% of the total area of the selected parcels in this cluster have riparian or alluvial scrub habitat).

The larger cluster, Cluster H, consists of 17 parcels. The cluster contains 29% of toad habitat, 5% of vireo habitat, 19% of stickleback habitat and 2% of flycatcher habitat. Cluster G is considerably smaller than H but contains a comparable amount of vireo habitat (4%). It also contains 8% of toad habitat and 6% of stickleback habitat. The current land use designation for the parcels in both these clusters is agriculture or vacant/undeveloped.

Cluster J

The last cluster is located within the sixth bio-reach near the Ventura/Los Angeles County line. Mountains rise at each side of the river and limit the spread and intensity of agriculture. A number of canyons filled with plunge pools and ephemeral streams empty into the Santa Clara River and could act as migration corridors for several aquatic species (Sweet, pers. comm. 2000). Riparian scrub and riparian woodland dominate the cluster, and the density of giant cane is low. Palustrine environments exist in the upland habitats of both sides of the river and likely occur from the dynamic structure and processes within this reach. Historic air photos reveal similar physical patterns as seen in the river today.

Cluster J contains five parcels, three of which have significant proportions of vireo, flycatcher and/or toad habitat. Together, these parcels contain 8% of vireo habitat, 12 % of flycatcher habitat, and 2% of toad habitat. Agriculture is the main land use on these parcels.

Excel Results

Linear Maximization

As a comparison to the results of the SITES model, a simple linear maximization was performed using Microsoft Excel (see Table 6.1). This table shows that 80% of the parcels chosen by SITES for $8 million were also chosen by the linear maximization, and 90% of the parcels chosen by SITES for $16 million

were chosen by the linear maximization. Furthermore, 98% (44 out of 45) of the parcels chosen by the SITES $8 million scenario were also chosen by the linear maximization for $16 million. These results strongly support the selection of parcels made by SITES.

Table 6.1: Comparison of SITES to Linear Maximization

	Number of Parcels Chosen		
Constraint	**SITES Model**	**Linear Maximization**	**Common Parcels**
$8 million	45	41	36
$16 million	82	74	64

Biological Ranking

The biological ranking created in Excel was useful because the results were independent of the estimated costs. The estimated costs of the parcels selected by SITES are fairly uniform. Under the constraint of $8 million, all 45 of the parcels had estimated costs between $3,500 per acre and $7,000 per acre. Only 5 of these 45 parcels had estimated costs over $5,000 per acre. Under the constraint of $16 million, 78 of the 82 parcels selected had estimated costs between $3,500 per acre and $7,000 per acre. Of the 4 parcels that were not in this range, only one of them (APN # 179005004) had an area greater than 2 acres, and its estimated cost was about $12,500 per acre. Thus, the cost estimations do not favor any of the clusters over other ones.

Since SITES selected less expensive parcels, it may have overlooked parcels that are superior from a conservation viewpoint because they were more expensive. The biological ranking that we created tested this hypothesis. This ranking was based solely on the amount of habitat and not on the cost of the parcel. This model ranked all of the parcels based on the percentage of the parcel with habitat. The results are in Appendix J. Of the first 100 parcels in the biological ranking, 40 of them were larger than 30 acres. Of these 40 parcels, 33 were chosen

by the SITES $16 million scenario. So, with only a few exceptions, SITES has selected those large parcels that contain greater amounts of habitat. This further supports the results of the SITES model. However, it also identifies other parcels that should be considered.

In particular, the biological ranking identified parcels that had a great deal of habitat but were not chosen by the SITES model because they were too expensive. Given the uncertainty of the cost estimates, these parcels may be reasonable selections for purchase. They are listed in Table 6.2.

Table 6.2: Habitat-Rich Parcels not selected by SITES

APN	Biological Rank	Acres	Estimated Cost/acre	Location (Cluster)
046023022	11	121	$40,182	Adjacent to F
107001064	28	32	$84,950	near F
107014037	45	39	$46,706	Between E and F
055029016	52	266	$6562	Between I and J
107001076	63	82	$102,057	Between E and F
138006055	94	142	$93,754	Adjacent to A
099009009	95	81	$39,451	Between D and E

Limitations

Both of the Excel models support the results of the SITES model. Thus, our results seem to be fairly robust. However, the data used to reach these results, both the species' habitat areas and the cost estimates, have some uncertainty associated with them. Another possible limitation is the fact that the clusters identified in our results only contain habitat for 5 of the 8 species that we used for our analysis. We will discuss each of these concerns below.

GIS data

We acquired our GIS database from the USFWS, who contracted several consulting firms to develop it. This data is at least 8 years old, and we are relying

on the judgement of others for the habitat information that is the basis of our analysis. Although we believe the quality of this information is good, our results might improve if this information was updated and verified.

Cost Data

Our cost data was obtained from the Ventura County Assessor's Office, which keeps a list of land value statistics for each parcel. The value estimates from the Assessor may or may not reflect the actual selling prices. Also, Proposition 13, which states that property may only be assessed at its purchase value, not at its current market value, meant that many of the land values from the Assessor were over a few decades old. Although regressions were run to try to correct for this, a regression is still a fairly crude tool. Even some of the recently assessed parcels have cost per area values that seem ridiculously high or ridiculously low. Finally, some of the Assessor's parcel numbers did not have values associated with them. As a result of all of these factors, the cost data required a high level of manipulation, and the numbers we arrived at are fairly uncertain. This does not, however, threaten the integrity of our results because the biological ranking (Appendix J) that was created independent of the cost estimates, verified the results of the SITES model.

Coastal Species

None of the clusters we have discussed contain habitat for the western snowy plover, the least tern or the tidewater goby. These coastal species occur significantly in only two parcels near the mouth of the river. One of these is McGrath State Beach and the other is 23 acres of Assessor's Parcel # 31960735. We are not recommending either of these parcels for purchase because the first one already offers some degree of habitat protection and the second one has an estimated cost of about $1,000,000. However, a conservation strategy for these

species should consider the activities in both of these parcels, and the possible acquisition of the second one.

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VII Recommendations for Acquisition

Based on the model results and in light of the limitations, we will now conclude with a discussion of our recommendations and some ideas about how to implement them. Of the six clusters discussed earlier, two clusters deserve special attention because of their amounts of potential habitat, diversity of habitats and possibilities for management and conservation (See Map 7). Cluster F, between Santa Paula and Fillmore, is unique for several reasons. Along this section of the river, agriculture is further back from the edge of the river and the presence of undeveloped upland areas allows for the formation of seasonal pools. It is the only cluster that contains habitat for five of the endangered species (stickleback, vireo, flycatcher, frog, and toad). Almost all (94%) of the red-legged frog habitat is in this cluster. Its proximity to cluster G is also an advantage because the confluence of Sespe Creek in cluster G offers an important connection to upland systems and a migration corridor for endangered species.

The other cluster that stands out is cluster J. It has a high percentage of riparian scrub and woodland habitats and low amounts of giant cane. The amount of potential endangered species' habitat is relatively high. The mountains to the south of this cluster are a source of ephemeral streams, which provide a connection to upland isolated environments.

Clusters A, C, and H are all less advantageous for several reasons. Clusters A and C are both smaller clusters and contain less potential habitat than the others. Additionally, cluster A, surrounded by golf courses, is in a more urbanized and less natural part of the river. Because of long-term agricultural use of the surrounding area, cluster H has less riparian habitat than some other parts of the river.

Given all of the above considerations, acquisition should focus on parcels in cluster F (with a possible connection to cluster G) and cluster J. Photos of these areas appear in Appendix K. One objective of our analysis was to recommend

parcels to be purchased for $8 million. If all of the parcels in these three clusters were purchased, the estimated cost is remarkably close to $8 million (See Table 7.1). Is this too good to be true? Probably. The estimated costs are clearly uncertain. However, there are several ways to proceed in the face of this uncertainty.

Table 7.1: Our Recommendations

Cluster	Number of Parcels	Total Area	Estimated Cost
F	25	1215	$4.5 Million
G	8	384	$1.4 Million
J	5	469	$1.9 Million
Totals:	38	2068	$7.8 Million

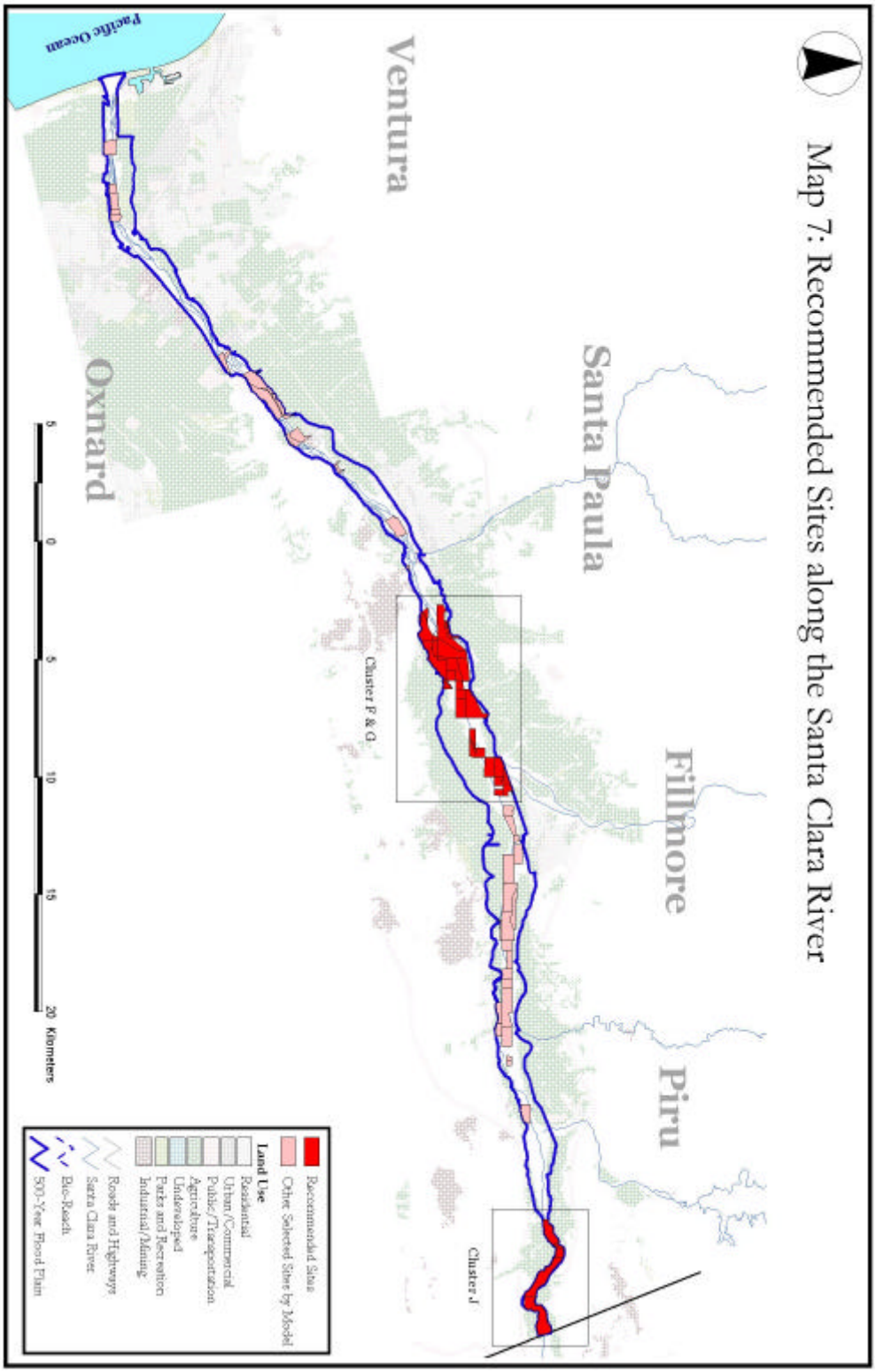
The purchase of any of these parcels presents the difficulties of whether the owner is willing to sell the parcel and, if so, at what price. The price may or may not be close to our estimate. One solution to these problems would be to focus acquisition activities on more parcels than will be bought so that there will be some flexibility in what is purchased. Our results offer this flexibility.

Another solution would be to hold a type of land auction. The Trustee Council could solicit bids from different landowners for the part of their land that is within the 500-year floodplain. Any landowner who was interested could offer her land for sale at any price. These bids could be ranked based on our biological ranking (in Appendix J) and the amount of the bid. A simple way to do this for each parcel would be to take our '% habitat' score multiplied by the area of the parcel, divided by the amount of the bid. The highest scoring bids could then be purchased until the $8 million was used up. This, in theory, would lead to the most efficient use of the money. A similar ranking system is used by the Department of Agriculture for their Conservation Reserve Program.

An alternative to acquisition is the purchase of conservation easements. A conservation easement is a legal agreement between a landowner and a qualified

conservation organization (e.g., land trust) or government agency that permanently limits a property's use in order to protect its conservation values. The easement, a legal document, guides future uses of a property regardless of ownership. While the land's conservation values are protected by the organization, the landowner retains title to the property and can live on it, use it, sell it, or pass it on to heirs. For example, it might be that that the landowner retains the right to create future building lots, but, with the easement, limits the number allowed to be built under local zoning. One of the benefits of an easement is that it can provide income tax and property tax reductions by eliminating unwanted development value (Natural Lands Trust 1997). Some landowners who are unwilling to sell their land may be interested in the advantages of putting their land in a conservation easement.

Regardless of how the land is acquired, the conservation of the recommended areas is only one step in what should be a multifaceted effort. If riparian conservation is to be effective, acquisition must be coupled with restoration, management, long-term monitoring, and public education. We hope that our project will serve as a foundation for riparian conservation along the Santa Clara River.


Map 7: Recommended Sites along the Santa Clara River
Fillmore
Piru
Santa Paula
Ventura
Oxnard
Pacific Ocean
Cluster J
Cluster F & G
Recommended Sites
Other Selected Sites by Model
Land Use
Residential
Urban/Commercial
Public/Transportation
Agriculture
Undeveloped
Parks and Recreation
Industrial/Mining
Roads and Highways
Santa Clara River
Bio-Reach
500-Year Flood Plain
5
0
5
10
15
20 Kilometers

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Appendix A

Dominant Plant Species of the Santa Clara River

The following table lists the dominant plant species for each habitat type (as defined by Holland 1986) found along the Santa Clara River. This information was taken from the *Santa Clara River Enhancement and Management Plan Study, Biological Resources, Volume I* (Santa Clara River Project Steering Committee, June, 1996).

Habitat Type	Plant Species	Native/ Introduced
Alkali Marsh	alkali heath (*Frankenia salina*)	N
	jaumea (*Jaumea carnosa*)	N
	pickleweed (*Salicornia virginica*)	N
	salt grass (*Distichlis spicata*)	N
Southern Foredune	sand verbena (*Abronia maritima*)	N
	beach-bur (*Ambrosia chamissonis*)	N
	Beach evening-primrose(*Camissonia cheiranthifolia*)	N
	salt grass (*Distichlis spicata*)	N
	sea rocket (*Cakile maritima*)	I
Mule Fat Scrub	mule fat (*Baccharis salicifolia*)	N
	narrow-leaved willow (*Salix exigua*)	N
Southern Willow Scrub	arroyo willow (*Salix lasiolepis*)	N
	red willow (*Salix laevigata*)	N
	mule fat (*Baccharis salicifolia*)	N
	narrow-leaved willow (*Salix exigua*)	N
Southern Willow Riparian Woodland	arroyo willow (*Salix lasiolepis*)	N

Habitat Type	Plant Species	Native/ Introduced
Southern Willow Riparian Woodland	red willow (*Salix laevigata*)	N
	fremont cottonwood (*Populus fremontii*)	N
	black cottonwood (*P. balsamifera* ssp. *trichocarpa*)	N
	mule fat (*Baccharis salicifolia*)	N
	narrow-leaved willow (*Salix exigua)*	N
	western sycamore (*Platanus racemosa*)	N
Southern Cottonwood-willow Riparian Forest	fremont cottonwood (*Populus fremontii*)	N
	black cottonwood (*P. balsamifera* ssp. *trichocarpa*)	N
	red willow (*Salix laevigata*)	N
	mule fat (*Baccharis salicifolia*)	N
	arroyo willow (*Salix lasiolepis*)	N
	arrow weed (*Pluchea sericea*)	N
	wild grape (*Vitis girdiana*)	N
	blackberry (*Rubus ursinus)*	N
	California bay (*Umbellularia californica*)	N
	hoary nettle (*Urtica dioica ssp. holosericea*)	N
	mugwort (*Artemisia douglasiana*)	N
Arrow Weed Scrub	arrow weed (*Pluchea sericea*)	N
	big saltbush (*Atriplex lentiformis*)	N
	mule fat (*Baccharis salicifolia*)	N
Alluvial Scrub	scalebroom (*Lepidospartum squamatum*)	N
	big sagebrush (*Artemisia tridentata*)	N
	California buckwheat (*Eriogonum fasciculatum*)	N

Habitat Type	Plant Species	Native/ Introduced
Alluvial Scrub	chaparral broom (*Baccharis sarathroides*)	N
	interior goldenbush (*Ericameria linearifolia*)	N
Big Sagebrush Scrub	big sagebrush (*Artemisia tridentata*)	N
	fourwing saltbrush (*Atriplex canescens*)	N
	hairy yerba santa (*Eriodictyon trichocalyx*)	N
	Palmer's goldenbush (*Ericameria palmeri*)	N
	California buckwheat (*Eriogonum fasciculatum*)	N
Valley Freshwater Marsh	broad-leaved cattail (*Typha latifolia*)	N
	bulrush (*Scirpus* sp.)	N
	sedge (*Carex* sp.)	N
	rush (*Juncus* sp.)	N
	yerba mansa (*Anemopsis californica*)	N
	dwarf and hoary nettle (*Urtica urens; U. dioica* ssp. *Holosericea*)	I;N
	cocklebur (*Xanthium strumarium*)	N
	celery (*Apium graveolens*)	I
Coastal Sage Scrub	California sagebrush (*Artemisia californica)*	N
	California buckwheat (*Eriogonum fasciculatum*)	N
	purple sage (*Salvia leucophylla*)	N
	black sage (*Salvia mellifera*)	N
	common encelia (*Encelia californica)*	N
	California broom (*Lotus scoparius*)	N
Chamise Chaparral	chamise (*Adenostoma fasciculatum*)	N
Coast Live Oak Woodland	coast live oak (*Quercus agrifolia)*	N
Disturbed Areas	giant cane (*Arundo donax*)	I

Habitat Type	Plant Species	Native/ Introduced
	castor bean (*Ricinus communis)*	I
	tamarisk (*Tamarix sp.)*	I
Disturbed Areas	tree tobacco (*Nicotiana glauca*)	I
	black mustard (*Brassica nigra*)	I
	Russian thistle (*Salsola tragus*)	I

Appendix B

Vegetation Descriptions

The following is a description of the plant community types located along the Santa Clara River. The plant community names follow those proposed by Holland (1986). The plant species nomenclature follows the Jepson Manual (Hickman 1993).

Mule Fat Scrub

Mule fat (*Baccharis salicifolia*) is commonly the sole or dominant canopy species in the mule fat scrub plant community, forming a continuous canopy with sparse ground layer. It occupies habitats that are seasonally flooded or saturated, usually along canyon bottoms, irrigation ditches, or stream channels (Sawyer and Keeler-Wolf 1995). This habitat type can be found along the Santa Clara River within the active channel following floods, along the banks, and on the low floodplain terraces (SCR Project Steering Committee 1996). Mule fat scrub is an early stage of the successional development of riparian woodlands often maintained by moderate to high frequency disturbance (Warner and Hendrix 1984, as cited in SCR Project Steering Committee 1996). Because this community occupies seasonally flooded or saturated areas, the mule fat shrubs tend to be relatively young and do not reach the typical height of 5 to 8 feet for mature stands. Many birds, including the least Bell's vireo (*Vireo bellii pusillus*), may utilize mule fat scrub for foraging.

Southern Willow Scrub

Southern willow scrub habitat is characterized by dense, broadleaf, winter-deciduous riparian thickets that are dominated by several willow species (*Salix* spp.) (Holland 1986). Understory development tends to be sparse due to thick vegetation cover. Southern willow scrub is found along the Santa Clara River on first and second terraces of the floodplain (SCR Project Steering Committee 1996). Moderate flooding frequency in these areas prevents the community from developing into a riparian woodland. Thus the willow scrub is the middle stage of riparian woodland succession. This habitat supports a variety of birds, including least Bell's vireo and southwestern willow flycatcher (*Empidonax trailii extimus*), which tend to nest in dense willow-dominated thickets. Foraging raptors and small mammals are also found in these habitats.

Southern Willow Riparian Woodland

Southern willow riparian woodland is characterized by a dense to open stand of broadleaf, winter-deciduous trees that are dominated by several willow species (Holland 1986). This habitat type represents a mature riparian habitat. The understory is composed of shrubby willows and mule fat with a limited herbaceous layer. Scattered cottonwoods and sycamore trees (*Platanus* spp.) may also be present. Red willow (*Salix laevigata*) and arroyo willow (*Salix lasiolepis*) dominate this habitat along the Santa Clara River. Willow riparian woodland provides habitat for a variety of small birds (e.g., least Bell's vireo and southwestern willow flycatcher), small foraging mammals, and amphibians, including the red-legged frog (*Rana aurora draytonii*) and the arroyo toad (*Bufo microscaphus californicus*).

Southern Cottonwood/Willow Riparian Forest

Southern cottonwood/willow riparian forest habitat consist of a tall, open, broadleafed winter-deciduous riparian forest dominated by cottonwoods (*Populus* spp.) and various tree willow species (Holland 1986). The understory is composed of shrubby willows and mule fat with an herbaceous layer. Because this habitat type is best represented on the mid to outer floodplain, disturbance from floods is less frequent and mature riparian forest is allowed to develop. Many birds, including the southwestern willow flycatcher, the least Bell's vireo, and the western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), may utilize this habitat for nesting and foraging. This habitat supports foraging raptors and small mammals as well.

Arrow Weed Scrub

Arrow weed scrub is characterized by moderate to dense streamside thickets strongly dominated by arrow weed shrubs *(Pluchea sericea)* (Holland 1986). It occurs in streambanks, ditches, and washes with gravelly or sandy channels. Along the Santa Clara River, this plant community is located on the upper floodplain and terraces at the edges of woodlands, forests, and along the manufactured slopes of Highway 126 (SCR Project Steering Committee 1996). This disturbance-maintained community appears to be increasing in extent at the expense of willow, cottonwood, and cotton-sycamore riparian forest types as a result of grazing and groundwater pumping (Holland 1986). Birds and insects are the primary users of this habitat type, but reptiles may also forage in these areas. The southwestern willow flycatcher has been noted to occur where arrow weed is present.

Alluvial Scrub

Alluvial scrub habitat is characterized by a mixture of shrubs that colonize alluvial materials within intermittent creeks, arroyos, and the drier terraces within large washes (Holland 1986). The widely scattered shrubs are intermixed with grasses and herbs as understory. Reptiles, including the silvery legless lizard *(Anniella pulchra pulchra)* and the San Diego horned lizard *(Phrynosoma coronatum blainvillii)*, utilize this habitat for foraging or burrowing. Plant species such as the endangered slender-horned spineflower *(Dodecahema leptoceras)* and the endangered Nevin's barberry *(Berberis nevinii)* are found in this habitat as well. Alluvial scrub is also utilized by foraging birds, small mammals, and insects.

Big Sagebrush Scrub

Big sagebrush scrub is characterized by soft-woody shrubs, 0.5 to 2 meters tall, usually with bare ground underneath and between shrubs (Holland 1986). Big sagebrush (*Artemisia tridentata*) is the dominant species in this community. It can occur on a wide variety of soils and terrain, from rocky, well-drained slopes to fine-textured valley soils with a high water table. This habitat occurs on the drier floodplain terraces adjacent to the Santa Clara River, especially in the eastern portion of the river in Los Angeles County (SCR Project Steering Committee 1996). Flooding frequency is low to moderate. This habitat is similar to alluvial scrub in that it provides habitat for birds, small mammals, insects, and reptiles on the drier portions of the riparian system.

Valley Freshwater Marshes and Ponds

Valley freshwater marshes and ponds are wetland habitats characterized by prolonged inundation which allows for the accumulation of deep, peaty soils (Holland 1986). These areas are dominated by perennial, emergent monocots four to five meters tall (e.g. broad-leaved cattail (*Typha latifolia*) and bulrush (*Scirpus sp*.)). Freshwater marsh is found in portions of the Santa Clara River channel where water accumulates and along small tributary streams, or in depressions in the scrubs, woodlands, and forests of the floodplain terraces (SCR Project Steering Committee 1996). This habitat supports amphibians such as the red-legged frog, reptiles such as the southwestern pond turtle *(Clemmys marmorata pallida),* and foraging and/or nesting birds.

Southern Foredunes

Southern foredunes are areas of sand accumulation along the coast (Holland 1986). Vegetation is sparse due to winds, salt spray and shifting sand. Fordune habitat is utilized by coastal

birds like the snowy plover *(Charadrius alexandrinus nivosus)* and the California least tern *(Sterna antillarum browni)*, and by small mammals. Insects like the sandy beach tiger beetle *(Cicindela hirticollis gravida)* also utilize this habitat.

Alkali Marsh

Small pockets of alkali marsh habitat have formed adjacent to the mouth of the river beyond the foredune habitat (SCR Project Steering Committee 1996). These low-lying marsh areas are saturated for long periods during the wet season but are dry during the summer. The frequency of flooding is moderate to high (i.e., floods one or more times a year). This community provides habitat for many coastal birds including the California least tern, the Belding's savannah sparrow *(Ammodramus sandwichensis beldingi)*, and the western least bittern *(Ixobrychus exilis hesperis)*. Salt marsh bird's beak *(Cordylanthus maritimus* ssp. *maritimus)* and ventura marsh milkvetch *(Astragalus pycnostachyus* var. *lanosissimus)* are two plant species also found in this habitat.

Non-Native Vegetation

Many of the native communities described above have been disturbed by urbanization, mining, agriculture and other human activities. This disturbance allows for the development of a suite of non-native weeds. These species (particularly giant cane (*Arundo donax)*) will compete with native vegetation for water and nutrients and can ultimately dominate the native communities and reduce the habitat quality for native wildlife species. See Appendix A for a list of non-native species along the Santa Clara River.

Appendix C

Sensitive Plant and Animal Species

The following table identifies the sensitive species that occur or have the potential to occur on the Santa Clara River (primarily within the 500-year floodplain). Sensitive species, as used in this report, refers to those taxa that belong to one of the following categories: taxa listed as endangered or threatened by state or federal resource agencies; taxa that are proposed for listing by state or federal agencies (including former federal category 2 candidate species); taxa considered rare or species of special concern by other local public and private resource agencies. The following list was generated from information provided by the USFWS, the Santa Clara River Enhancement and Management Plan Study, in addition to a database search using the California Natural Diversity Data Base (NDDB).

Given the known habitat requirements of each of the species listed below, potential habitat occurring on the Santa Clara River that could support these species was also identified (SCR Project Steering Committee 1996).

Code Designations

FT = Federally listed Threatened
FE = Federally listed Endangered
ST = State listed Threatened
SE = State listed Endangered
FPD= Federally proposed (Delisting)
sc = State species of special concern
C1 = Federal category 1 candidate for listing
C2 (former) = Federal category 2 candidate for listing (category eliminated in 1995)
CNPS 1B = California Native Plant Society listing
CFP = California fully protected

*Distribution of potential habitat was utilized in the site selection analysis.

Species	Status	Habitat Requirements	Potential Habitat on SCR
Insects			
Sandy beach tiger beetle *(Cicindela hirticollis gravida)*	Former C2	clean, dry, light-colored sand: occur in bright sunlight in open sandy areas on sandy beaches and on open paths or lanes	southern foredune, alluvial scrub

Species	Status	Habitat Requirements	Potential Habitat on SCR
Fish			
Tidewater goby* (*Eucyclogius newberryi)*	FE (94) FPD (99) sc	benthic, restricted mostly to shallow water (< 1meter) in small coastal lagoons and near stream mouths in the uppermost brackish portions of larger bays	active channel near mouth of river
Unarmored threespine stickleback* *(Gasterosteus aculeatus williamsoni)*	FE (70) SE (71)	weedy pools and backwaters or among emergent plants along the edges of streams where the water stays below 23 degrees Centigrade; prefer bottoms of sand or mud	active channel from east of the confluence of Piru Creek and the Santa Clara River to Los Angeles County aqueduct crossing
Southern steelhead trout *(Oncorhynchus mykiss iridius)*	FE (97)	salt water; spawning occurs in fall/winter in the headwaters of freshwater coastal streams with gravel bottoms	active channel from mouth of river to Piru Creek (including Sespe and Santa Paula creeks)
Santa Ana sucker *(Catostomus santaanae)*	Former C2 sc	clear, cool, rocky, and gravely streams	active channel from Santa Paula east to Acton
Arroyo chub *(gila orcuttii)*	Former C2 sc	sand and mud bottomed flowing pools and runs of headwaters, creeks, and small to medium rivers; it occasionally can be found in intermittent streams	active channel from mouth of river to Los Angeles County aqueduct crossing
Amphibians and Reptiles			
California red-legged frog* *(Rana aurora draytonii)*	FT (96) sc	dense, shrubby or emergent riparian vegetation closely associated with deep still or slow moving waters; prefers areas with arroyo willow, cattails, and rushes which cover a large portion of the water's surface; water at least 0.7 m deep required	freshwater marsh; active channel and riparian scrubs, woodlands, and forests from mouth of Soledad Canyon east to Acton
Arroyo toad* *(Bufo microscaphus californicus)*	FE (95) sc	Restricted to rivers with shallow, gravelly pools adjacent to sandy terraces	active channel in Sespe and Piru creeks; active channel and riparian woodlands and forests from LA county line east to I-5 and from mouth of Soledad Canyon to Acton

Species	Status	Habitat Requirements	Potential Habitat on SCR
San Diego horned lizard *(Phrynosoma coronatum blainvillii)*	Former C2 sc	Associated with coastal sage scrub and riparian woodlands, especially areas of level to gently sloping ground with well-drained, loose or sandy soil	alluvial scrub, coastal sage scrub, riparian woodlands and forests
Two-striped garter snake *(Thamnophis hammondii hammondii)*	Former C2	highly aquatic; most commonly found in or near permanent water; occasionally found in small and intermittent streams with rocky beds	riparian scrubs, woodlands, forests; freshwater marsh
Southwestern pond turtle *(Clemmys marmorata pallida)*	Former C2 sc	ponds, small lakes, reservoirs, and slow-moving streams, where it may be seen basking on logs or mud banks	active channel, freshwater marsh, and in man-made ponds (e.g., water cress ponds, duck ponds) within the floodplain of the river
Silvery legless lizard *(Anniella pulchra pulchra)*	Former C2 sc	Herbaceous layers with loose soil in coastal scrub, chaparral, and open riparian habitats; sand of washes and beach dunes are preferred for burrowing , and logs and leaf litter are used for cover and feeding	southern foredune, alluvial scrub, cottonwood/willow forest
Birds			
Least Bell's vireo* *(Vireo bellii pusillus)*	FE (86) SE (80)	dense willow dominated riparian areas with a lush understory in a 5-10 year old succession stage; dense, low growing thickets of willows, mule fat, blackberry and mugwort are an essential part of habitat; often with an overstory of tall willows, cottonwoods and sycamores	mule fat scrub, willow scrub, willow riparian woodlands from near river mouth to Bouquet Canyon Road
Southwestern willow flycatcher* *(Empidonax trailii extimus)*	FE (95) SE (88)	riparian habitats along river, streams, or other wetlands where stands of willows, mule fat, arrow weed, tamarisk, or other riparian plants are present; often with an overstory of cottonwood	willow riparian woodland, cottonwood/willow riparian forest

Species	Status	Habitat Requirements	Potential Habitat on SCR
Western snowy plover* *(Charadrius alexandrinus nivosus)*	FT (93) sc	sand spits, dune-backed beaches, mud flats, unvegetated beach strands, open areas around estuaries, and beaches at river mouths are the preferred	beach, southern foredune
California least tern* *(Sterna antillarum browni)*	FE (70) SE (71)	barren to sparsely vegetated sandbars along rivers, sand and gravel pits, or lake and reservoir shoreline; nests only in open sandy places or mud flats with little or no vegetation	beach, southern foredune, alkali marsh, active channel areas near the river mouth
Western yellow-billed cuckoo *(Coccyzus americanus occidentalis)*	SE (88)	restricted to dense riparian woodland during breeding	willow riparian woodland, cottonwood/willow riparian forest
Bank swallow *(Riparia riparia)*	ST (89)	riparian areas with vertical cliffs and banks with fine-textured or sandy soil	vertical banks; cliffs adjacent to the river
Belding's savannah sparrow *(Ammodramus sandwichensis beldingi)*	SE (74)	mud flats, beaches, rocks, and low tide coastal strand vegetation; nests low to the ground under a pickleweed canopy; build their nest in the upper littoral zone	alkali marsh near mouth of river
Western least bittern *(Ixobrychus exilis hesperis)*	Former C2 sc	nest in dense emergent wetland vegetation of cattails and tules	Alkali marsh, freshwater marsh
Elegant tern *(Sterna elegans)*	Former C2 sc	inshore coastal waters, bays, estuaries, and harbors	beach, southern foredune, alkali marsh, active channel areas near the river mouth
Long-billed curlew *(Numenius americanus)*	Former C2 sc	large coastal estuaries, salt marshes, tidal flats, upland herbaceous areas, and croplands	active channel near river mouth
White-faced ibis *(Plegadis chihi)*	Former C2 sc	fresh emergent wetland vegetation, shallow lacustrine waters, and the muddy ground of wet meadows and irrigated, or flooded pastures/croplands	alkali marsh, active channel near river mouth
Yellow warbler *(Dendroica petechia brewsteri)*	sc	require riparian woodland for breeding; utilize various trees during migration	riparian scrubs, woodlands, and forests

Species	Status	Habitat Requirements	Potential Habitat on SCR
Yellow-breasted chat *(Icteria virens)*	sc	dense riparian woodlands in the coastal lowlands	riparian scrubs, woodlands, and forests
Loggerhead shrike *(Lanius ludovicianus)*	sc	inhabits grasslands, agriculture, chaparral, and desert scrub	riparian scrubs, woodlands, and forests
Cooper's hawk *(Accipiter cooperii)*	sc	breeds in oak woodland habitats and southern cottonwood-willow riparian woodland	riparian scrubs, woodlands, and forests
Black-shouldered kite *(Elanus caeruleus)*	CFP sc	nests in riparian woodlands, particularly those comprised of live oaks and sycamores, and forage over open areas and grasslands	riparian scrubs, woodlands, and forests
Northern harrier (Circus cyaneus)	sc	prairie, wet meadow, and marsh habitats; hunts over grassland, agricultural fields, and coastal and freshwater marshes	riparian scrubs, woodlands, and forests up to mouth of Soledad Canyon
Mammals			
Mountain lion *(Felis concolor)*	CFP	riparian and brushland habitat	riverwide, except areas of urban development
Townsend's big-eared bat *(Plecotus townsendii)*	sc	mesic habitats; roost in caves, mines, tunnels, and buildings	may forage in riparian woodlands and scrubs along entire river
Western mastiff bat *(Eumops perotis)*	sc	riparian and brushland habitats; roosts in crevices in cliff faces, high buildings, trees, and tunnels	may forage in riparian woodlands and scrubs along entire river
Plants			
Slender-horned spineflower *(Dodecahema leptoceras)*	FE (87) SE CNPS 1B	restricted to older, stable sandy river terraces and washes in alluvial scrub and chaparral; at elevations between 200-700 meters.	alluvial scrub from Santa Paula east to Soledad Canyon
Salt marsh bird's beak *(Cordylanthus maritimus* ssp. *maritimus)*	FE (78) SE (79)	higher reaches of salt marshes where inundation with salt water occurs only at the higher tides	alkali marsh near mouth of river
Nevin's barberry *(Berberis nevinii)*	C1 CNPS 1B	sandy and gravelly places in chaparral, cismontane woodlands, coastal sage scrub, and riparian scrub	alluvial scrub from Santa Paula east to Bouquet Canyon Road
Ventura marsh milkvetch *(Astragalus pycnostachyus* var. *lanosissimus)*	T	coastal salt marshes and coastal seeps below 100 feet elevation	alkali marsh near mouth of river

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Appendix D

Species Descriptions

The following text describes in detail the distribution, habitat requirements, life history, and current threats to the eight species utilized in our analysis.

Tidewater goby – *Eucyclogius newberryi*

The tidewater goby is federally endangered. This species is discontinuously distributed throughout California, ranging from Tillas Slough (mouth of the Smith River) in Del Norte County south to Agua Hedionda Lagoon in San Diego County. The goby is apparently absent from three sections of the coast between: 1) Humboldt Bay and Ten Mile River, 2) Point Arena and Salmon Creek, and 3) Monterey Bay and Arroyo del Oso (Brewer et al. 1994).

Before 1900, the tidewater goby occurred in at least 87 of California's coastal lagoons. Since then, it has disappeared from approximately 50 percent of formerly occupied lagoons. A rangewide status survey conducted in 1984 found that 22 historic populations of tidewater goby had been extirpated. Only 5 years later, a status survey documented the disappearance of an additional 21 populations. In the San Francisco Bay area, 9 of 10 previously identified populations have disappeared. Losses in the southern part of the state have been the greatest, including 74 percent of the coastal lagoons south of Morro Bay. Three populations currently remain south of Ventura County (Brewer et al. 1994). Water quality and degradation, as well as the loss of habitat due to urbanization, are the major threats to tidewater goby populations (SCR Project Steering Committee 1996).

The tidewater goby occurs in loose aggregations of a few to several hundred individuals in shallow water less than 1 meter deep. All life stages of the tidewater goby are found at the upper end of lagoons in salinities less than 10 parts per thousand (ppt). Although its closest relatives are marine species, the tidewater goby does not have a marine life history phase (Brewer et al. 1994).

Nesting activities commence in late April and early May, when male gobies dig a vertical nesting burrow 10 to 20 centimeters (4 to 8 inches) deep in clean, coarse sand. Suitable water temperatures for nesting are 18 to 22 °C (75.6 to 79.6 °F) with salinities of 5 to 10 ppt (Brewer et al. 1994). Mollusks, insects, and crustaceans are food sources for the tidewater goby (Wang 1986).

Sightings of the tidewater goby were reported in 1984 in the Santa Clara River, from the mouth to 3 miles upstream (SCR Project Steering Committee 1996). This area coincides with potential habitat for this species (SCR Project Steering Committee 1996).

Unarmored threespine stickleback – *Gasterosteus aculeatus williamsoni*

The unarmored threespine stickleback is a federal and state listed endangered species. Historically, it is believed that the unarmored threespine stickleback occurred in the Santa Clara River, the Los Angeles River, the San Gabriel River, and the Santa Ana River drainages (Haglund 1989, as cited in SCR Project Steering Committee 1996). This species is now restricted to the Santa Clara River above the confluence of Piru Creek. Three zones have been proposed for critical habitat by the USFWS along the Santa Clara River drainage system: San Francisquito, Soledad Canyon, and Del Valle zones. The threespine stickleback prefers quiet water, often living in weedy pools and backwaters, or among emergent plants at stream edges, or over bottoms of sand and mud. It is usually never found in temperatures over 23 °C or in cloudy waters because they are primarily visual feeders evidenced by their large eyes (Tamagni 1995).

Spawning takes place in fresh water during the warm summer months, usually in June or July, but the breeding season varies with locality from April to September.

This species of stickleback feeds primarily on bottom organisms that live on aquatic plants (Moyle 1976, as cited in SCR Project Steering Committee 1996). The unarmored threespine stickleback may compete with another more common subspecies of threespine stickleback (*Gasterosteus aculeatus microcephalus*) for food.

Populations of this species are threatened by stream channelization, urbanization, agricultural development, water diversions, groundwater pumping, introduction of predators and competitors, off-highway vehicle use, and oil spills (State of California 1992, as cited in SCR Project Steering Committee 1996).

Sightings of the unarmored threespine stickleback in the Santa Clara River have been reported from the junction of San Martinez Grande Canyon east to Interstate 5, in San Francisquito Creek from its confluence to approximately 10 kilometers upstream, the downstream portion of the Santa Clara River from McBean Parkway through the proposed Del Valle critical habitat area (State of California 1995, as cited in SCR Project Steering Committee 1996), and the easternmost segment of the river in Aliso Canyon (Bautista, pers. comm. 1996, as cited in SCR Project Steering Committee 1996).

Potential habitat occurs in appropriate portions of the low-flow channel east of the confluence of the river with Piru Creek, east to the Los Angeles aqueduct crossing upstream from Bouquet Canyon Road (SCR Project Steering Committee 1996).

Arroyo Toad - *Bufo microscaphus californicus*

The arroyo toad is a federally listed endangered species. Its habitat requirements include rivers that have shallow, gravelly pools adjacent to sandy terraces. Breeding occurs in large streams with persistent water from late March until mid-June (Sweet 1992). Eggs are deposited and larvae develop in shallow pools with minimal current and little or no emergent vegetation. After metamorphosis (June or July), the juvenile toads remain on the bordering gravel bars until the pool no longer persists (3 to 8 weeks, depending on site and year) (Sweet 1992). Juveniles and adults forage for insects on sandy stream terraces that have nearly complete closure of cottonwoods, oaks, or willows, and almost no grass and herbaceous cover at ground level. Adult toads excavate shallow burrows on the terraces where they shelter during the day when the surface is damp or during longer intervals in the dry season (Sweet 1992).

The arroyo toad was formerly found on rivers with near-perennial flow throughout southern California from San Luis Obispo County to San Diego County. It is believed to be extirpated in San Luis Obispo County (Sweet, pers. comm. 1998), however, populations still persist in Santa Barbara, Ventura, Los Angeles, Riverside, and San Diego Counties. The majority of the remaining populations in Santa Barbara and Ventura Counties are located on the Los Padres National Forest. Both Sespe and Piru Creeks which drain into the Santa Clara River contain populations of arroyo toad (Sweet 1992). The Sespe Creek population is the largest known within the current range.

Due to the isolation and the small sizes, almost all populations are at great risk of extinction. Virtually all remaining populations are small and face a variety of immediate threats to their continued viability. These threats include: short- and long-term changes in river hydrology due to construction of dams and water diversions; alteration of riparian wetland habitats by agriculture and urbanization; construction of roads; site-specific damage by off-highway vehicle use; development of campgrounds and other recreational activities; over-grazing; and mining activities.

Potential habitat for the arroyo toad occurs in the Sespe and Piru Creeks, the active channel and riparian woodlands/forest from the Los Angeles County line east to Interstate 5, as well as the active channel and riparian woodlands/forest from the mouth of Soledad Canyon east to Acton (SCR Project Steering Committee 1996).

California red-legged frog – *Rana aurora draytonii*

The California red-legged frog is a federally threatened species. Its historical range extended from Point Reyes National Seashore, Marin County, California, and from Redding, Shasta County, California, south to northwestern Baja California, Mexico. Today the red-legged frog has disappeared from over 90 percent of its original range, and many of the remaining populations appear to be declining rapidly (Jennings and Hayes 1994). It is known to occur in about 240 streams or drainages primarily in the central coastal area of California, mostly in Monterey, Santa Barbara, and San Luis Obispo Counties.

Preferred habitat for adult frogs is characterized by dense, shrubby or emergent riparian vegetation closely associated with deep still- or slow-moving waters (Jennings and Hayes 1994). During winter, well-vegetated areas along these river corridors are needed for shelter. The red-legged frog disappears for some parts of the year when the creeks dry up, hiding in dense vegetation and small animal burrows as far as 300 feet from the creek, only to emerge when the creek is replenished (Defenders of Wildlife 1999). The most suitable habitat is commonly composed of arroyo willow, but cattails (*Typha* sp.) and bulrushes (*Scirpus* sp.) are also suitable (Jennings and Hayes, 1994).

The California red-legged frog breeds early in the year, from late November to late April. Males appear at breeding sites typically 2 to 4 weeks ahead of females, and call in small mobile groups of between 3 and 7 to attract females (Jennings and Hayes, 1994). Egg masses containing between 2,000 and 5,000 small (0.1 inches in diameter), dark, reddish-brown eggs are attached to vegetation, such as bulrushes or cattails, in or near the water. Biologists call this kind of plant "emergent vegetation". Emergent vegetation and streamside shrubs such as willows that root in creeks are so important to red-legged frogs that the frogs will usually disappear from an area when these plants are cleared (Defenders of Wildlife 1999).

The diet of California red-legged frogs is extremely variable. Adults eat invertebrates, small tree frogs, and mammals, while larvae are thought to feed on algae (Jennings and Hayes 1994).

The California red-legged frog was harvested for food in the San Francisco Bay area and the Central Valley during the late 1800s and early 1900s. About 80,000 frogs were harvested annually between 1890 and 1900 (Jennings and Hayes 1994). The market eventually dwindled as red-legged frogs became more rare, but the species continued to decline as agricultural and urban development eliminated its habitat. It has disappeared from over 99 percent of its former range in the Central Valley (Jennings and Hayes 1994). Remaining populations in the Sierra foothills were

fragmented and later eliminated by reservoir construction, exotic predators, grazing, and drought. Bullfrogs have also had substantial negative impacts on red-legged frog populations. Introduced to supply frog legs for restaurants in the face of declining numbers of the California red-legged frog, bullfrogs eat red-legged frog eggs, and replace them in their habitat. Clearing of creek-bed vegetation and the creation of concrete banks threaten the frog's breeding habitats, as well as other forms of water-diversion associated with development. The results have been fragmented habitat, isolated populations, and degraded streams.

Habitat for the red-legged frog is scarce due to the lack of vegetation necessary to shade ponds and pools in the low flow channel. Although the likelihood is low, a few small freshwater marsh areas on the floodplain may serve as potential habitat for the species as well as the river reach in Soledad Canyon and east of Acton in Los Angeles County (SCR Project Steering Committee 1996).

California Least Tern - *Sterna antillarum browni*

The California least tern is a federal and state listed endangered species. This species nests each spring and summer close to estuaries and coastal lagoons, and on sandy beaches and playas, from San Francisco Bay south into Baja California, Mexico (Palacios and Mellink 1996; Caffrey 1996). It winters along the coasts of western Mexico, south to northern South America (King 1981, as cited in García and Ceballos 1995). Habitat requirements during the nesting season include barren to sparsely vegetated sandbars along rivers, sand and gravel pits, or lake and reservoir shoreline.

There were approximately 4,017 pairs nested at 38 sites along the coast of California in 1997. This represented a 19 percent increase from 1996 pair estimates and 55 percent increase from 1995 pair estimates (Keane 1997). The birds usually live in colonies of 30-50 nesting pairs. The California Least Tern has evolved an ability to rapidly colonize new and appropriate nesting areas (García and Ceballos 1995). Some sites are actually clusters of alternative nesting sites, and the selection and use of a particular site of the cluster depends on its suitability during that particular breeding season (Massey and Fancher 1989, as cited in Palacios and Mellink 1996). Nests are usually in a shallow hole scraped in an open sandy area, gravelly patch, or exposed flat (Caffrey 1996). These birds have been found nesting on artificial islands and other areas created by construction activities (e.g., dredged sand and construction pads). Thus creation of new sites may aid in the management of these species (SCR Project Steering Committee 1996).

Least Terns are opportunistic feeders known to capture more than 50 species of fish. The terns hover over and dive into relatively shallow, near shore waters and coastal freshwater ponds, channels, and lakes to catch the fish (Thelander 1994).

Numerous threats have affected the least tern populations. Predation is the major factor constraining the fledging of terns across California (Caffrey 1996). In addition, disturbance and degradation of nesting sites has led to its population decline (Palacios and Mellink 1996). Current conservation efforts should focus on the reduction of impacts from recreational activities and on the preservation of the coastal habitats on which the species depends (Palacios and Mellink 1996). Protection of nesting sites with fencing and signage has effectively limited human disturbance at most nesting sites (Keane 1997). Enhancement of well-established, incipient, and potential sites remains a priority.

The Santa Clara River is an area in which terns have returned to breed after not being used for variable periods of time (Caffrey 1996). Potential habitat along the Santa Clara River occurs at the mouth.

Least Bell's Vireo – *Vireo bellii pusillus*

A federally and state listed endangered species, the least Bell's vireo, one of the four subspecies of Bell's vireo, only occurs in coastal California. This subspecies arrives on its breeding grounds in Southern California and northern Baja California, Mexico around mid-March to early-April, and departs by mid to late September to winter in southern Baja California. Its preferred habitat is dense willow dominated riparian areas with a lush understory in a 5-10 year old succession stage (Steinitz et al. 1997). Dense, low growing thickets of willows, mule fat, blackberry and mugwort are an essential part of its habitat, as well as an overstory composed of tall willows, cottonwoods and sycamores. Few vireos are found where open ground or low amounts of aquatic or herbaceous cover are present.

Nesting territories range in size from about one to four acres, and are defended by the males. These territories are established in riparian habitat, usually in dense willow-dominated thickets. A low growing dense shrub layer and a large degree of vertical stratification are preferred. Most nest sites are located near the edge of thickets (Steinitz et al. 1997) and the average nest height is approximately 3 feet from the ground (USFWS 1996).

The least Bell's vireo is insectivorous. Most foraging takes place below twelve feet (USFWS 1996) in the vicinity of the nest site in predominantly willow habitat (Steinitz et al. 1997). The vireo will travel up to 15 meters to forage in both high and low shrub layers.

Loss of riparian habitat and increased parasitism by the brown-headed cowbird (*Molothrus ater*) are two main reasons for the decline in numbers of the least Bell's vireo. Over the past century riparian habitat has decreased dramatically in California. Estimations show that more than 90 percent of riparian woodland habitat in the Central Valley has been cleared for development (Katibah 1984, as cited in SCR Project Steering Committee 1996). Nest parasitism by brown-headed cowbirds has also negatively impacted vireo populations. Development of agricultural and livestock activities near riparian habitats, where cowbirds tend to thrive, has increased nest parasitism by brown-headed cowbirds in southern California. Protection of riparian habitat, habitat creation and enhancement projects, and brown-headed cowbird removal has resulted in significant increase in the region's least Bell's vireo population (USFWS 1995, as cited in SCR Project Steering Committee 1996).

Recorded occurrences of the least Bell's vireo on the Santa Clara River stretch from Saticoy east to Santa Clarita (SCR Project Steering Committee 1996). Potential habitat occurs in these areas as well as the areas that support southern willow scrub and southern willow riparian woodland (SCR Project Steering Committee 1996).

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Southwestern Willow Flycatcher – *Empidonax trailii extimus*

The Southwestern willow flycatcher is a federal and state listed endangered species. From late April until August or September, this species is present in its breeding range including southern California, southern Utah, Arizona, New Mexico and western Texas. It then migrates to its wintering grounds, most likely in Mexico, Central America and perhaps northern South America (SCR Project Steering Committee 1996). Historically, the southwestern willow flycatcher was present in all lowland riparian areas of the southern third of California. Today, approximately 10 nesting groups exist in California, all of which consist of six or fewer nesting pairs. The total population is estimated to be 70 pairs and 8 singles in California (Federal Register 1995a).

The southwestern willow flycatcher occurs in riparian habitats along rivers, streams and wetlands where dense growths of willows, arrowweed, buttonbush, tamarisk, Russian Olive and a scattered overstory of cottonwood are present (Federal Register 1995a). Coyote willow, seepwillow (Johnson et al. 1999), cattail, horsetail (Sogge et al. 1997) and dogwoods (Harris 1991) are also suitable. An abundance of willow flycatchers is correlated with willow abundance, density and coverage. This species is most abundant in structurally complex, willow-dominated areas close to surface water, and are intolerant of changes in vegetation structure (Sanders and Edge 1998). A new hypothesis states that they may not attempt to breed in the absence of flowing water, especially in May and June (Johnson et al. 1999).

The willow flycatcher is an insectivorous bird that forages within and above dense riparian vegetation. It also forages in adjacent areas which may be more open (Federal Register 1995a).

The decline in the populations of the southwestern willow flycatcher has resulted from the loss or degradation of riparian habitats due to urban and agricultural development, water diversion and impoundment, channelization, invasion by non-native species, and livestock grazing. This degradation can attract brown-headed cowbirds, which parasitize willow flycatcher nests. Studies have shown that the cowbirds, which feed in heavily grazed pastures and stubblefields, parasitize nests that are located closer to the edge of the flycatcher habitat. To reach the nests, cowbirds can travel up to 20 km from where they feed (Sogge et al. 1997). Fragmentation and disturbance are associated with higher parasitism rates. Loss of wintering grounds to tropical deforestation is another factor affecting the abundance of the southwestern willow flycatcher.

No recorded instances of breeding by the southwestern willow flycatcher have been documented along the Santa Clara River (SCR Project Steering Committee 1996). However, potential breeding habitat for the species occurs in the mature willow woodlands and cottonwood/willow riparian forests, particularly in Los Angeles County (SCR Project Steering Committee 1996).

Western Snowy Plover - *Charadrius alexandrinus nivosus*

The western snowy plover is a federally threatened species. Sand spits, dune-backed beaches, unvegetated beach strands, open areas around estuaries, and beaches at river mouths are the preferred coastal habitats for nesting and for wintering (SCR Project Steering Committee 1996).

The snowy plover nests through mid-March to mid-September (Federal Register 1995b). It builds its nests in shallow depressions in sand lined with small pieces of shell (SCR Project Steering Committee 1996). The Pacific coast population breeds in loose colonies primarily on coastal beaches from southern Washington to southern Baja California, Mexico (Federal Register 1995b). Based on the most recent surveys, a total of 28 snowy plover breeding sites or areas currently occur on the Pacific Coast of the United States. A total of 20 plover breeding areas currently occur in coastal California (Page et al. 1991). Eight areas support 78 percent of the California coastal breeding population including the Oxnard lowland. Some birds winter in the same areas used for breeding (Warriner et al. 1986). Other birds migrate north or south to wintering areas. The majority of birds winter south of Bodega Bay, California. Wintering plovers occur in widely scattered locations on both coasts of Baja California and significant numbers have been observed on the mainland coast of Mexico. Many interior birds west of the Rocky Mountains winter on the pacific coast (Page et al. 1986).

The snowy plover uses a variety of sites for foraging and loafing, including mudflats of San Diego Bay and other coastal lagoons, and sandy beaches associated with river mouths and lagoons. It feeds almost exclusively on insects and crustaceans gleaned from the sand surface (SCR Project Steering Committee 1996).

Habitat loss, predation and other human activities have threatened snowy plover populations. The most important form of habitat loss to coastal breeding snowy plovers has been encroachment of European beachgrass (*Ammophila arenaria*) (Federal Register 1995b). This non-native plant was introduced to the west coast around 1898 to stabilize dunes. Cost effective methods to control or eradicate European beachgrass have not been found. Human activity (e.g. walking, jogging, running pets, horseback riding, off-road vehicle use, and beach raking) is also a key factor in the ongoing decline in snowy plover coastal breeding sites and breeding populations in California. Predation by birds and mammals (especially American crows (*Corvus brachyrhynchos*), common ravens (*Corvus corax*), and red fox (*Vulpes vulpes*)) predators is a major concern at a number of nesting sites (Federal Register 1995b). Accumulation of trash at beaches attracts these as well as other predators.

Sightings of the western snowy plover have been reported at Ormond Beach, approximately 1.5 miles southwest of Port Hueneme, McGrath Beach State Park, Point Magu, and the Santa Clara River mouth (State of California 1995, as cited in SCR Project Steering Committee 1996). Potential habitat for this species is located on the beach and southern foredune areas near the mouth of the river (SCR Project Steering Committee 1996).

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Appendix E

Metadata

The Santa Clara River Enhancement and Management Plan (SCREMP) developed the GIS database utilized by this project. The Ventura County Flood Control Department and the consulting firms of CH2MHill, Psomas & Associates, and RECON provided the following coverage information.

Coverage Name	Data Source*	Coverage Description
agg	Unknown	Aggregate mining areas for Ventura and Los Angeles (L.A.) Counties
agrilu	SCAG	Agricultural Land Use
agrilud	SCAG	Agricultural Land Use
arundo	BSC	Areas containing *Arundo donax (Giant Reed)*
bioreach	BSC	Biological Segments: This layer represents the 500-year floodplain with upstream and downstream reach boundaries. The reaches indicate portions of the river with similar habitat, channel, and geomorphological characteristics. They were used to make generalized recommendations as to the conservation priorities along the river.
countyln	unknown	Boundary between L.A. and Ventura Counties
dsfpb	LAC	L.A. County flood plain boundary
dsfwb	LAC	L.A. County floodway boundary
dvrsns	WRSC	Public and private water diversion locations
enhance	BSC	Areas of Vegetation Enhancement: This layer is indicative of some level of *Arundo donax* mixed in with native vegetation. Removal of *Arundo donax* in these areas would enhance the habitat value for native vegetation and wildlife.
excav	VCFCD	Streambed Excavation Areas: These areas, mapped by CH2MHill, contain large amounts of sediment deposition (Proposal to allow removal of these materials by aggregate minors)
fcfacl	LAC	L.A. County flood control facilities (levees, groins, dikes, etc.)
fcfacv	VCFCD	Ventura County flood control facilities (levees, groins, dikes, etc.)
fcplain2	VCFCD/LA	Flood Plain Boundaries: Coverage which outlines the boundaries for the floodway, 100-yr and 500-yr flood plains
floodway	VCFCD	Floodway for Ventura County
fp100	VCFCD	100 Year Flood Plain
fp500	VCFCD	500 Year Flood Plain
gwbasin	WRSC	Groundwater Basins for Ventura and L.A. Counties

Coverage Name	Data Source*	Coverage Description
if25	VCFCD	25 Year Interim Flood Plain (Proposed 25 year protection and encroachment limits in which property owners have the ability to protect their property up to this boundary)
landuse	SCAG	Landuse: SCAG landuse data from 1993 for Los Angeles and Ventura Counties (see code descriptions below)
map_ndx	CH2MHill	Map index boundary coverage for map series.
mrz	ASC	Aggregate Mineral Resource Zones: Derived from State of California mineral resource zone maps.
mrz2	ASC	Aggregate Mineral Resource Zone 2
ocean	unknown	Pacific Ocean
ospace	SCAG	Designated openspace areas
parcell	LAC	Los Angeles County Parcels
parcelv	VCFCD	Ventura County Parcels
prkreclu	RSC	Parks and recreation land use
prks_rec	RSC	Parks and recreation areas for Ventura and L.A. Counties
rail	unknown	Rail roads
reach	VCFCD	River reaches: Reach boundaries based on various factors including landmarks, flood control facilities, ground water basins and/or biology
restore	BSC	Vegetation Restoration Areas: This layer indicates pure stands of *Arundo donax*, agricultural areas within the floodplain, or disturbed areas within the floodplain but not the active channel. These areas have the potential to be restored to native riparian habitats.
risewat	WRSC	Areas of rising groundwater
scriver	unknown	The entire Santa Clara River system (including tributaries) for Ventura and L.A. Counties
species	BSC	Threatened and Endangered Species: This layer contains value fields of potential habitat for a selected set of threatened and endangered species based on the vegetation polygons as well as the "best professional judgment" of biologists based on aerial photo interpretation and field assessment.
sprdbsn	UWCD	Spreading basins (e.g., Saticoy spreading, Piru spreading grounds)
tiger	unknown	?
topo_l	LAC	Elevation contours for L.A. County
topo_v	VCFCD	Elevation contours for Ventura County
trails	RSC	Existing and proposed trails for Ventura and L.A. Counties
transcor	WRSC	Transportation corridor for water release from reservoirs
translin	WRSC	Transportation corridor to Freeman Diversion
Valu	BSC	Biological Habitat Valuation

Coverage Name	Data Source*	Coverage Description
Veg	BSC	Existing Vegetation: The distribution of the riparian habitat types along the Santa Clara River in the 500-year floodplain was mapped using topographic maps, color aerial photographs (flown in 1993), and field surveys conducted in March and April, 1995.
Vegera	BSC	Vegetation Eradication
Vegerac	BSC	Vegetation Eradication Class
wwtp	WRSC	Wastewater reclamation plants

***Data Source Descriptions:**

ASC = Aggregate Subcommittee
BSC = Biological Subcommittee
LAC = Los Angeles County
RSC = Recreation Subcommittee
SCAG = Southern California Association of Governments
UWCD = United Water Conservation District
VCFCD = Ventura County Flood Control District
WRSC = Water Resources Subcommittee

Land Use Code(LUCODE)	LUCODE Description
1000	Urban or Built-Up
1100	Residential
1110	Single Family Residential
1111	High Density Single Family Residential
1112	Low Density Single Family Residential
1120	Multi-Family Residential
1121	Mixed Multi-Family Residential
1122	Duplexes and Triplexes
1123	Low-Rise Apartments; Condominiums; & Townhouses
1124	Medium-Rise Apartments and Condominiums
1125	High-Rise Apartments and Condominiums
1130	Mobile Homes and Trailer Parks
1131	Trailer Parks and Mobile Home Courts; High Density
1132	Mobile Home Courts and Subdivisions; Low Density
1140	Mixed Residential
1150	Rural Residential
1151	Rural Residential High Density
1152	Rural Residential Low Density
1200	Commercial and Services
1210	General Office Use
1211	Low and Medium-Rise Major Office Use
1212	High-Rise Major Office Use
1213	Skyscrapers
1220	Retail Stores and Commercial Services
1221	Regional Shopping Mall
1222	Retail Centers (Non-Strip With Contiguous Interconnected Off-Street Parking)
1223	Modern Strip Development
1224	Older Strip Development
1230	Other Commercial
1231	Commercial Storage
1232	Commercial Recreation
1233	Hotels and Motels

Land Use Code(LUCODE)	LUCODE Description
1234	Attended Pay Public Parking Facilities
1240	Public Facilities
1241	Government Offices
1242	Police and Sheriff Stations
1243	Fire Stations
1244	Major Medical Health Care Facilities
1245	Religious Facilities
1246	Other Public Facilities
1247	Non-Attended Public Parking Facilities
1250	Special Use Facilities
1251	Correctional Facilities
1252	Special Care Facilities
1253	Other Special Use Facilities
1260	Educational Institutions
1261	Pre-Schools/Day Care Centers
1262	Elementary Schools
1263	Junior or Intermediate High Schools
1264	Senior High Schools
1265	Colleges and Universities
1266	Trade Schools
1270	Military Installations
1271	Base (Built-up Area)
1272	Vacant Area
1273	Air Field
1300	Industrial
1310	Light Industrial
1311	Manufacturing and Assembly
1312	Motion Picture
1313	Packing Houses and Grain Elevators
1314	Research and Development
1315	Winery
1320	Heavy Industrial
1321	Manufacturing
1322	Petroleum Refining and Processing
1323	Open Storage
1324	Major Metal Processing
1325	Chemical Processing
1330	Extraction
1331	Mineral Extraction - Other Than Oil and Gas
1332	Mineral Extraction - Oil and Gas
1340	Wholesaling and Warehousing
1400	Transportation; Communications; and Utilities
1410	Transportation
1411	Airports
1412	Railroads
1413	Freeways and Major Roads
1414	Park and Ride Lots
1415	Bus Terminals and Yards
1416	Truck Terminals
1417	Harbor Facilities
1418	Navigation Aids
1420	Communication Facilities
1430	Utility Facilities
1431	Electrical Power Facilities
1432	Solid Waste Disposal Facilities
1433	Liquid Waste Disposal Facilities
1434	Water Storage Facilities
1435	Natural Gas and Petroleum Facilities
1436	Water Transfer Facilities

Land Use Code(LUCODE)	LUCODE Description
1437	Improved Flood Waterways and Structures
1438	Mixed Wind Energy Generation and Percolation Basin
1439	Caretaker Residence for Water Transfer Facility
1440	Maintenance Yards
1450	Mixed Transportation
1460	Mixed Transportation and Utility
1500	Mixed Commercial and Industrial
1600	Mixed Urban
1700	Under Construction
1800	Open Space and Recreation
1810	Golf Courses
1820	Local Parks and Recreation
1830	Regional Parks and Recreation
1840	Cemeteries
1850	Wildlife Preserves and Sanctuaries
1860	Specimen Gardens and Arboreta
1870	Beach Parks
1880	Other Open Space and Recreation
1900	Urban Vacant
2000	Agriculture
2100	Cropland and Improved Pasture Land
2110	Irrigated Cropland and Improved Pasture Land
2120	Non-Irrigated Cropland and Improved Pasture Land
2200	Orchards and Vineyards
2300	Nurseries
2400	Dairy and Intensive Livestock; and Associated Facilities
2500	Poultry Operations
2600	Other Agriculture
2700	Horse Ranches
3000	Vacant
3100	Vacant Undifferentiated
3200	Abandoned Orchards and Vineyards
3300	Vacant With Limited Improvements
4000	Water
4100	Water; Undifferentiated
4200	Harbor Water Facilities
4300	Marina Water Facilities
4400	Water Within a Military Installation
4500	Area of Inundation

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Appendix F

Assessor's Information

The following information was collected from the Ventura County Assessor's Office.

APN Number	Land Value	Year Assessed
041026001	100000	91
041026012	107695	75
041026016	11652	86
041026017	1392865	75
041026019	36085	75
041026021	75874	75
041026025	4676	75
041026028	12175	75
041026029	10796	99
041026030	274681	85
041026032	417426	99
041026038	3033	83
041026039	368721	81
041026041	305133	86
041026042	338433	83
041026043	86196	75
041026045	5137	78
041026046	9555	76
041026047	12510	78
041026050	327	83
041026051	327	83
041026053	362796	90
041026055	206524	85
041029001	112079	87
041029003	17181	75
041029004	194512	89
041029005	62642	75
041029006	624	75
041029007	38850	82
041029011	16013	75
041029012	768	75
041029013	1242	75
041029015	7871	75
041029019	221171	84
041029023	43683	77

APN Number	Land Value	Year Assessed
041029024	452	75
041029025	15473	75
041029026	503315	80
041029028	181969	75
041029029	87950	75
041029034	260	75
041029035	524807	81
041029038	254624	95
041029039	250931	96
041029040	402679	86
041029041	375000	89
041029042	401556	78
041029043	662315	97
041029046	13355	77
041029047	57782	75
041029049	20304	75
041029050	281	76
041029051	87870	83
041029057	480000	87
041029058	14213	82
041030007	64674	99
046005001	82530	89
046005002	294000	99
046005007	219996	99
046006005	71000	87
046006010	168942	86
046006011	140532	81
046006012	8679	86
046007012	3880	75
046007013	10707	86
046008002	635000	93
046008007	443609	98
046008007	450464	98
046008011	176031	94
046008012	338786	94

APN Number	Land Value	Year Assessed
046009001	100087	89
046009002	26772	89
046010001	21972	89
046010007	232361	92
046010009	9519	86
046010010	7170	75
046010011	226059	75
046010012	4756	86
046010013	72254	75
046010014	1260	75
046010015	48589	77
046010017	36020	76
046011001	714533	98
046011003	306987	97
046011004	96947	75
046011006	245021	86
046011008	84512	99
046011009	97985	78
046011012	48468	75
046011013	47680	75
046011017	31001	75
046011018	95379	76
046011021	156994	98
046011027	73526	75
046011028	708545	98
046012202	80850	75
046012205	88335	75
046012206	6247	75
046012208	99616	75
046012209	102608	80
046013201	243179	75
046013203	406209	97
046013204	169076	97
046014203	427723	91
046014204	113112	89
046014205	55057	89
046014206	414741	91
046014207	406636	91
046014208	513363	93
046015009	635934	75
046015014	271618	93
046015017	398930	81
046015018	366322	81

APN Number	Land Value	Year Assessed
046015019	291	75
046015020	3714	75
046015021	16988	80
046015022	62429	80
046015027	149395	75
046015032	248005	94
046015033	2660	94
046015034	695654	97
046015037	532960	91
046015039	543124	92
046015040	481764	98
046015041	549340	91
046016002	292987	79
046016003	230389	77
046016007	11427	98
046016009	10502	93
046016023	36989	75
046016024	371926	98
046016030	1342861	75
046016033	1362	87
046016035	210795	75
046016037	98793	84
046016039	357749	95
046016041	436991	82
046016045	482994	90
046016046	646077	90
046017101	169547	75
046017102	90283	75
046017108	361979	75
046017109	249089	75
046017110	42609	75
046017201	120864	75
046017202	180098	85
046017203	61757	75
046017204	765	75
046017205	13240	77
046018101	454354	75
046018102	103547	75
046018103	39243	75
046018104	76872	81
046018202	69368	81
046018207	86353	75
046018208	48521	75

APN Number	Land Value	Year Assessed
046018302	23500	91
046018303	73332	81
046018304	111014	75
046018308	79288	85
046018309	166500	91
046018310	150174	88
046018401	108299	77
046019103	79592	75
046019104	795	75
046019201	168835	83
046019202	26781	75
046019203	180021	93
046019204	523947	92
046019205	123509	80
046019301	195806	80
046019303	122091	88
046019304	317995	96
046019306	80000	99
046019307	165000	99
046019308	46361	79
046019401	113485	75
046019402	59885	75
046019403	170000	94
046019405	161524	95
046019406	459	79
046019502	9359	75
046019503	153445	98
046019506	170375	85
046019509	19590	75
046019510	20373	75
046019512	36373	75
046019601	66450	75
046020101	97878	75
046023001	10737	81
046023002	76131	75
046023003	12812	75
046023004	1541	75
046023005	237	75
046023007	175421	80
046023008	117650	75
046023009	6234	75
046023013	36142	89
046023015	168612	75

APN Number	Land Value	Year Assessed
046023016	22640	95
046023020	174162	89
046023021	225036	89
046023022	223839	89
046023023	41891	89
046023025	9065	75
046025002	82868	75
046025005	109507	95
046025007	470	75
046025008	493062	75
046027001	205278	77
046027002	128271	75
046027003	21879	75
046027004	70361	75
046027009	163	75
046027010	442	75
052017001	29307	75
052017012	56800	99
052017013	33562	86
052017014	33562	86
052017015	38227	86
052017016	52400	98
052017017	53000	96
052017018	38227	86
052017019	52400	88
052017020	52400	88
052017021	38227	86
052017031	52400	89
052017032	38227	86
052017033	49200	91
052017034	33562	86
052017035	38227	86
052017036	52400	89
052017037	48532	96
052017038	33562	86
052017039	38227	86
052017052	49200	87
052017053	52400	92
052017054	40311	87
052017055	52400	97
052017056	52400	92
052017057	49200	94
052017058	43999	99

APN Number	Land Value	Year Assessed
052017071	28562	88
052017072	25968	88
052017073	47600	90
052017074	44904	96
052017075	25968	86
052017076	47600	97
052017077	47600	93
052017078	47600	92
052017079	47600	96
052017080	47600	93
052017081	47600	93
052018006	298887	87
052018035	43582	87
052018036	70000	91
052018044	63236	84
052019001	70948	75
052019002	70948	75
052020001	11711	75
052020002	22089	77
052020003	8641	75
052020005	73676	77
052020006	35571	75
052020009	40007	87
052021007	15626	75
052021009	9359	75
052021010	143605	79
052021011	7797	75
052021012	13881	79
052021013	7797	75
052021014	420000	99
052021015	1540000	99
053014002	26019	76
053014015	441916	89
055016027	154	98
055016028	1170402	98
055018007	83331	79
055018008	53820	79
055018009	25559	92
055018016	153765	80
055018017	244966	75
055018018	296	79
055018023	165671	79
055018028	277173	99

APN Number	Land Value	Year Assessed
055018029	200000	90
055018030	165671	79
055018034	243680	84
055021013	1440397	75
055024002	69256	93
055024006	111421	85
055024007	2135237	75
055025002	99761	85
055025003	737622	75
055026003	156548	90
055026004	129559	90
055026005	17633	75
055026006	14848	75
055026013	136715	90
055026014	75324	84
055026015	17372	75
055026017	26422	84
055026018	68714	84
055026020	139477	87
055026021	6234	75
055026022	6234	75
055026023	112543	81
055026024	146922	77
055026025	241423	82
055026026	3725	75
055026031	100434	84
055026033	434883	75
055026033	523241	75
055026039	54177	84
055026044	30555	98
055026047	223345	84
055026051	200608	75
055026053	197039	81
055026054	193005	99
055026057	399502	87
055026059	175748	80
055027009	1292	79
055027010	31354	75
055027012	1554	75
055027018	6763	93
055027019	1554	75
055027026	193000	99
055027028	52698	98

APN Number	Land Value	Year Assessed
055027029	233647	76
055027032	98670	98
055027038	105421	75
055027039	629000	99
055029013	1559500	90
055029014	54880	88
055029015	950000	90
055030002	319951	75
055031001	200185	75
057001014	113603	75
057002009	104575	75
057002010	684532	93
057002011	67813	75
057003011	302563	84
057003012	118712	75
057003013	301069	83
057003014	394899	84
057003016	287151	97
057004001	217233	96
057004003	136743	88
057004004	342309	95
057004006	31101	75
057004010	111421	85
057004011	162215	85
057005005	8825	75
057005008	6242	75
057005010	275979	85
057006001	316973	92
057006003	120227	92
057006003	123675	92
057007013	172741	75
057007015	429779	76
057007018	151695	77
057007019	62193	91
057008007	436338	91
057008009	514000	91
090011003	513422	98
090011004	1919	75
090011021	311853	84
090016004	634512	87
090017205	31338	86
090018007	34424	86
090018008	3071495	86

APN Number	Land Value	Year Assessed
090019014	87190	75
090019016	440825	96
090019020	7210	79
090019024	249000	99
090019026	22054	75
090019028	363615	97
090019029	39178	75
090019031	370169	75
090019032	152253	78
090019033	171648	75
090019035	4667	75
090019044	4856	75
090019049	87561	75
090019051	7985	75
090019053	7985	75
090019054	6220	89
090019058	4446	75
099003034	241137	88
099003056	56276	75
099003057	120477	75
099003063	31334	79
099003064	75606	75
099004053	180145	97
099004054	40511	75
099004055	39072	75
099004057	30933	78
099004058	87615	83
099004060	28129	75
099004061	15626	75
099004063	115579	79
099005006	440187	75
099005007	26455	74
099005011	4085	74
099005022	23434	75
099006004	6718	94
099006009	122457	75
099006016	1276355	90
099006017	22006	94
099006025	110585	75
099006026	218161	75
099006027	738	75
099006029	86731	94
099006033	254000	99

APN Number	Land Value	Year Assessed
099006034	332872	82
099006038	225000	90
099006039	140000	95
099006040	220000	84
099006044	229276	75
099006046	62428	75
099006047	58	75
099007004	247037	80
099007005	78171	75
099007006	7176	89
099007008	110664	75
099007009	77000	99
099007010	10106	94
099007012	31652	82
099007014	397015	75
099007016	218548	88
099007018	1192	89
099007020	473884	82
099007022	1551	75
099007023	150000	92
099007024	71135	75
099008003	240062	80
099008010	77726	80
099008011	141017	88
099008012	425	75
099008014	10577	87
099008015	300	75
099008016	20123	81
099008018	211935	97
099008019	209218	87
099008020	69335	79
099008021	143387	75
099008023	602562	97
099009004	809382	93
099009009	201094	89
099011001	328499	96
099011004	587626	99
099011005	17342	94
099011006	32739	94
099011007	149	75
099011008	602500	99
099011009	780007	95
099011010	148371	75

APN Number	Land Value	Year Assessed
104006114	30000	90
104006115	10143	75
104006116	7803	75
104006139	32386	85
104006140	9364	75
104006145	51945	97
104006148	21000	90
104006149	54000	90
104006505	65829	89
104006506	54139	92
104006507	8533	75
104006508	9364	75
104006509	73320	92
104006510	81480	99
104006511	4710	75
104006512	9364	77
104006513	42386	97
104007101	13609	82
104007102	45832	99
104007103	8582	75
104007104	8238	77
104007105	55000	90
104007106	21557	83
104007112	66214	99
104007116	35000	90
104007117	35000	90
104007118	36000	96
104007119	35647	99
104007120	37497	95
104007121	35000	90
104007122	83112	97
104007123	35000	91
104007124	35000	91
104007125	35648	98
104007126	35000	99
104007127	35000	99
104007128	101728	97
104008009	71297	98
104008010	45832	99
104008011	15626	75
104008033	7498	77
104008034	12490	75
104008035	10927	75

APN Number	Land Value	Year Assessed
104008036	10927	75
104008049	20612	76
104008056	55000	95
104008059	41984	78
104008061	8576	75
104008063	54452	82
104008064	64285	95
104008065	61069	95
104009106	70000	99
104009107	21236	80
104009118	11862	78
104009119	34314	75
104009120	7803	76
104009121	7803	75
104009221	26952	83
104009223	9574	75
104010503	8582	75
104010504	3134	75
104010505	8582	75
104010506	8582	75
104010508	3138	75
104010509	25904	86
104010510	8582	75
104010511	26422	85
104010512	54452	82
104010514	39639	84
104010516	8582	75
104010704	10921	75
104010705	68567	98
104010706	6234	75
104010707	6472	85
104010708	28321	80
104010709	676792	92
104010710	29946	82
104010713	7803	75
104010714	7803	75
104010715	7803	75
104010716	4775	80
104014308	203329	93
104014309	24257	77
104014312	83112	98
104014313	57156	86
104014314	81482	98

APN Number	Land Value	Year Assessed
104014315	90072	97
104014317	12490	75
104014318	77735	86
104014320	103890	98
104014321	68878	97
104014322	46249	84
104014504	47940	87
104014505	55200	98
104014506	10084	75
104014507	14724	78
104014508	10001	77
104014509	54800	91
104014510	52770	97
104014511	10138	75
104014512	56800	97
104014513	10138	75
104014514	10138	75
104014515	33654	86
104014516	39447	85
104014517	11474	76
104014518	50925	99
104014520	390953	75
104014521	84773	96
104014522	162130	96
104014523	100000	99
104014524	86731	94
104014525	13276	75
104014526	11706	75
104014527	10943	75
104014528	10143	75
104014529	28321	80
104014530	10143	75
104014535	64285	95
104014536	99623	87
104014542	64200	91
104014543	10138	75
104014545	28400	91
104014545	71000	91
104014546	28400	91
104014547	28400	91
104014548	32400	91
104014549	28400	91
104014550	28400	91

APN Number	Land Value	Year Assessed
104014551	32400	91
104014552	190741	96
104014601	234182	94
104014603	180000	90
104014604	92156	95
104014606	168052	99
104015101	55600	92
104015102	63200	99
104015103	28298	83
104015104	54800	90
104015105	55600	88
104015106	10138	75
104015107	38845	84
104015108	54800	95
104015109	14724	78
104015110	54800	95
104015111	54800	97
104015112	54800	93
104015113	55600	96
104015114	10138	75
104015115	54800	98
104015123	59226	95
104015206	10153	75
104015207	10138	75
104015208	54800	98
104015209	10218	75
104015210	39770	85
104015211	55600	89
104015212	14724	78
104015213	10157	75
104015214	23707	80
104015215	47898	87
104015216	45563	86
104015217	14724	78
104015218	55600	89
104015219	11491	76
104015220	62200	98
104015221	55600	89
104015222	10138	75
104015223	54800	94
104015224	10138	75
104015225	10218	75
104015226	10138	75

APN Number	Land Value	Year Assessed
104015227	54800	91
104015228	10138	75
104015229	56400	97
104015230	55600	88
104015231	47940	87
104015232	56000	99
104015233	10138	75
104015238	10138	75
104015241	11491	75
104015305	10138	75
104015306	54800	97
104015307	56017	99
104015308	37459	84
104015309	10138	75
104015310	54800	98
104015311	54641	95
104015312	15020	77
104015313	54800	96
104015314	10138	75
104015315	55600	94
104015316	15020	77
104015317	10153	75
104015318	14844	78
104015319	10138	75
104015320	55200	95
104015321	55200	98
104015322	55200	90
104015323	52963	88
104015324	10227	75
104015325	55200	97
104015326	18908	79
104015327	53200	97
104015328	44452	87
104015329	36998	84
104015330	58400	93
104015331	14724	78
104015332	10138	75
104015337	53600	92
104015338	61411	90
104015401	48832	88
104015402	43582	87
104015403	67528	98
104015405	10227	75

APN Number	Land Value	Year Assessed
104015406	10138	79
104015407	58200	88
104015408	56800	87
104015409	59000	96
104017024	24257	79
104017025	364	79
104017032	1728168	80
104017033	186805	87
104017037	187817	79
104017039	158951	96
104017040	84307	75
104017041	175101	75
104017042	91943	79
104017043	152478	82
104017044	51728	82
104017045	254051	87
104017046	768786	98
104017047	46900	75
104017048	47938	93
104017049	1294	75
104018101	331005	75
104018102	107053	92
104019301	3956	80
104019306	57174	82
104019401	31931	81
104019402	24901	88
104020020	2473	90
104022001	296	75
104022002	31262	75
104022003	245779	96
104022005	68878	96
104022006	9120	76
104022008	1869	98
104022009	149	75
104022019	56942	99
104022020	164081	99
104022021	441477	99
104023002	11024	84
104023003	11024	84
104023004	11008	84
104023005	11008	84
104023006	11056	93
104023007	11008	84

APN Number	Land Value	Year Assessed
104023008	42000	99
104023009	11008	84
104023010	11008	84
104023011	40000	91
104023012	42777	99
104023013	11008	84
104023014	11008	84
104023015	39027	94
104023016	11024	84
104023017	11008	84
104023018	11024	84
104023019	43633	98
104023020	11024	84
104023021	11008	84
104023022	11008	84
104023023	11008	84
104023024	43633	98
104023025	11008	84
104023026	11008	84
104023027	11008	84
104023028	11008	84
104023029	11008	84
104023030	11008	84
104023033	14438	79
104023034	14438	79
107001114	100426	84
107004303	945248	75
107004304	609	75
107004305	18804	75
107004307	439903	89
107005002	870	77
107005042	265958	97
107006201	73332	99
107006204	20241	83
107006213	66450	79
107008001	183752	89
107008003	179037	93
107012001	254380	86
107014015	31725	94
107014032	760	75
107014033	340922	75
107014037	55640	92
107014037	55640	92

APN Number	Land Value	Year Assessed
107014038	1462	75
107014039	22581	88
107014040	311228	88
107015002	17098	75
107015004	168393	94
107015008	149	75
107015009	30933	75
107015010	162625	94
107016001	2185	75
107016003	208034	83
107016005	37125	75
107016006	2185	75
107016007	391	92
107021020	245000	89
107021026	105646	79
107021027	297224	79
107021028	89883	79
107021029	71521	79
107021033	157253	98
107021041	107056	79
107021042	245000	92
107021048	420000	90
107021049	225000	89
108001008	30539	75
108001014	2190	75
109001020	21065	75
128003012	193916	79
128004020	29831	75
128004021	288670	91
129001101	1721	91
129001103	38279	75
129001106	37272	75
129001133	63449	75
129001135	9844	75
129002001	7871	77
129002006	49731	77
130006005	344429	90
130007002	1233534	86
130007003	304843	79
132001007	672151	86
132001008	70350	79
132001016	244	84
132001018	1172118	77

APN Number	Land Value	Year Assessed
132002034	31076	75
132002039	4350000	88
132008027	3000000	88
132009005	5217388	99
132009006	519450	98
132009008	89628	99
132009009	98285	99
132010004	630000	91
132010005	1125000	91
132010008	350000	91
132010009	800000	92
132010014	32500	91
132010015	9681065	91
133001003	39115	91
138006006	749296	97
138006010	93524	98
138006036	1318452	96
138006041	521000	99
138006047	296314	82
138006054	93830	75
138006055	1121086	75
138006056	3293048	88
138006057	477880	99
138006058	458558	97
138008002	147	75
138009018	572746	75
138009020	458600	99
138009023	222262	84
138009024	222577	84
138019022	3937	86
138019027	1231477	80
138021102	129128	75
138021103	4835	98
138021104	511843	87
138021201	22826	75
138021202	9960	98
138021203	76052	98
138021204	14990	75
138021206	12846	98
138021207	64476	75
138023013	2224716	85
138023016	2877419	88
138023021	1199999	75

APN Number	Land Value	Year Assessed
138023026	1375000	75
138023027	1149604	75
138023029	333345	75
138023048	945195	98
138023050	889792	91
139001022	20595	77
139001027	582	90
139001036	736	75
139002201	30000	75
139002212	1219784	75
139015010	130	75
139015011	6251571	96
139015013	529	96
140004525	227500	99
140004526	229000	93
140005101	215418	97
140005102	212000	93
140005103	229000	93
140005104	212000	94
140005105	232000	99
140005106	229000	93
140005107	260999	99
140005108	225000	93
140005109	243420	99
179005001	1363325	87
179005002	127000	87
179005003	1701	75
179005004	311670	98
179005005	4044	75
179007007	28705	82
500001001	50824	77
500001002	391916	75
500001003	682891	91
500001011	227308	84

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Appendix G

Regression Results for the Estimated Costs

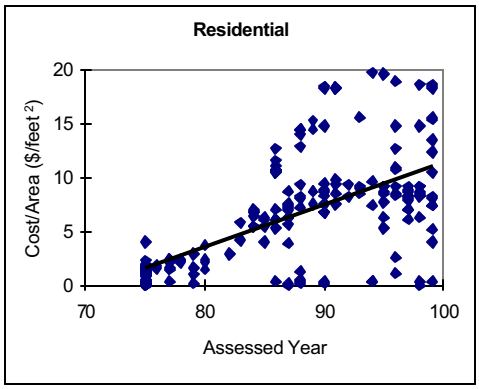
The following tables and graphs shows the regression results and statistics for the estimated costs of the seven land uses.

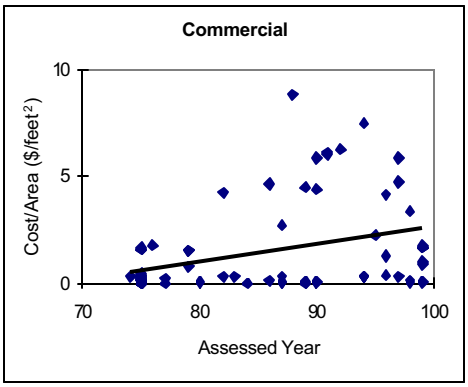
Residential Parcels:

Regression Statistics						
Multiple R	0.67382063					
R Square	0.45403425					
Adjusted R Square	0.45149487					
Standard Error	3.82822069					
Observations	217					
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-28.3286294	2.57671848	-10.994	1.3E-22	-33.4074882	-23.249771
X Variable 1	0.39899885	0.029839449	13.372	4.5E-30	0.340183594	0.4578141

Commercial Parcels:

Regression Statistics						
Multiple R	0.350012939					
R Square	0.122509057					
Adjusted R Square	0.11015003					
Standard Error	2.022284005					
Observations	73					
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-5.412549262	2.211255456	-2.449	0.01685	-9.82166959	-1.0034289
X Variable 1	0.080900175	0.025695526	3.1484	0.00240	0.029664726	0.13213562



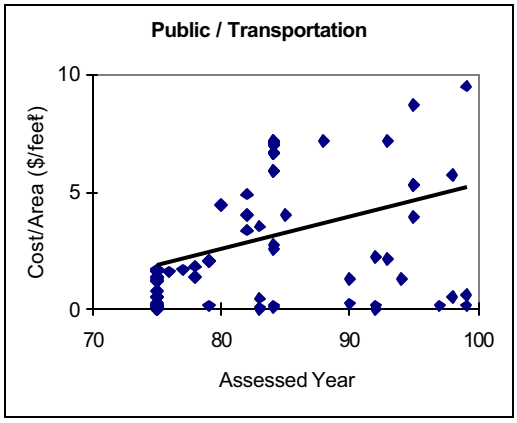


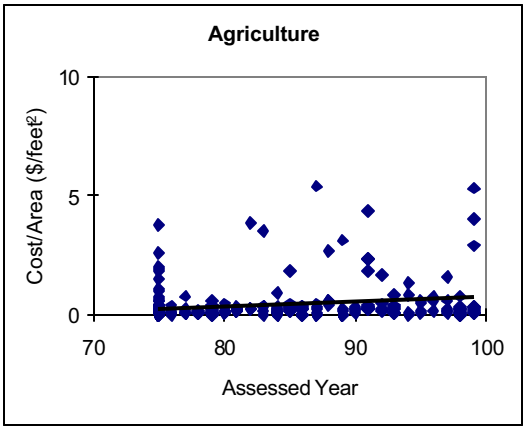
Public/Transportation Parcels

Regression Statistics						
Multiple R	0.35104603					
R Square	0.123233315					
Adjusted R Square	0.112135003					
Standard Error	2.757112663					
Observations	81					
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-8.392737802	3.452751883	-2.430	0.01733	-15.26527432	-1.52020128
X Variable 1	0.137867274	0.041373818	3.3322	0.00131	0.05551468	0.22021986

Agriculture Parcels

Regression Statistics						
Multiple R	0.177550375					
R Square	0.031524136					
Adjusted R Square	0.02786951					
Standard Error	0.688599718					
Observations	267					
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.88891156	0.435194291	-2.04	0.04208	-1.745789966	-0.032033
X Variable 1	0.015442758	0.00525805	2.936	0.00360	0.005089888	0.0257956



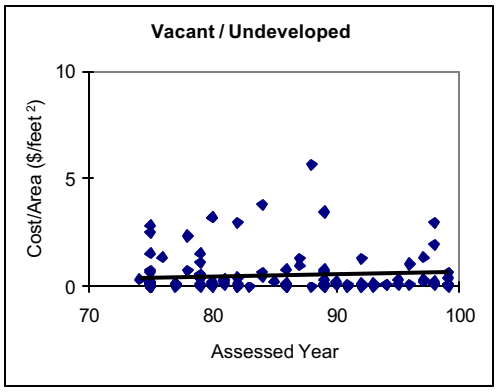


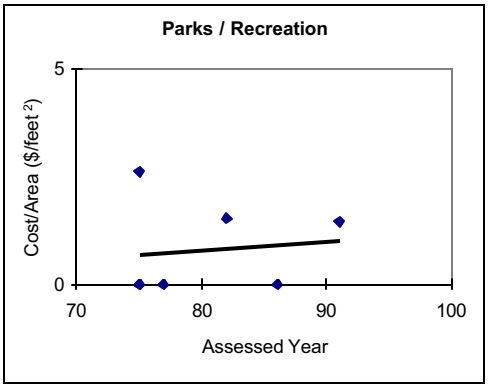
Vacant, Undeveloped Parcels

Regression Statistics						
Multiple R	0.087501065					
R Square	0.007656436					
Adjusted R Square	0.000765162					
Standard Error	0.880976406					
Observations	146					
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.322882904	0.741944073	-0.435	0.66407	-1.789392902	1.14362709
X Variable 1	0.009381334	0.008900226	1.0540	0.29362	-0.008210653	0.02697332

Parks, Recreation

Regression Statistics						
Multiple R	0.297083					
R Square	0.088258					
Adjusted R Square	-0.0637					
Standard Error	4.633686					
Observations	8					
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-15.148	23.0218	-0.657	0.53496	-71.4804	41.18432
X Variable 1	0.216726	0.284377	0.7621	0.47487	-0.47912	0.912572



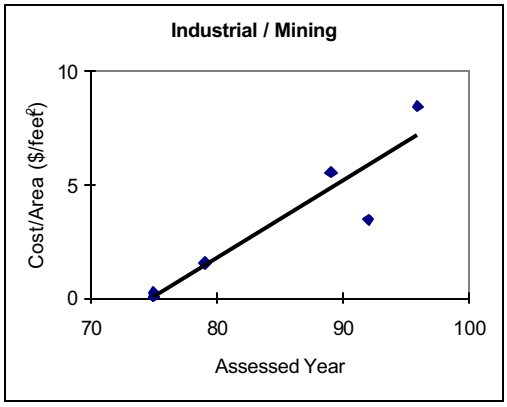


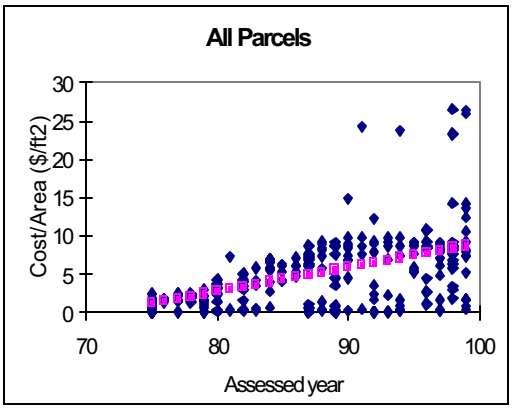
Industrial Parcels

Regression Statistics						
Multiple R	0.93707					
R Square	0.878101					
Adjusted R Square	0.853721					
Standard Error	1.241608					
Observations	7					
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-25.0369	4.660283	-5.372	0.00300	-37.0165	-13.0573
X Variable 1	0.335257	0.055863	6.0014	0.00184	0.191658	0.478856

All Parcels

Regression Statistics						
Multiple R	0.429772					
R Square	0.184704					
Adjusted R Square	0.18377					
Standard Error	5.914464					
Observations	875					
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-23.9958	1.977472	-12.13	2E-31	-27.8769	-20.1146
X Variable 1	0.327306	0.023274	14.063	1.22E-40	0.281627	0.372985





Appendix H

The SITES Model

SITES is a simulated annealing site selection model written by Ian Ball and Hugh Possingham for The Nature Conservancy (TNC), a non-profit organization. TNC recently adopted a planning initiative with the aim of developing "portfolios" that would collectively conserve viable examples of all native species and plant communities within several ecoregions in the U.S., the Caribbean, and Latin America. SITES was developed as an iterative planning tool to assist TNC in identifying conservation areas. SITES has two components: a site selection module (SSM) and an ArcView interface.

Site Selection Module (SSM)

SSM provides a heuristic procedure, known as "simulated annealing", for selecting a conservation portfolio that attempts to meet stated, quantitative conservation goals as efficiently (using as few sites) as possible. The procedure begins with a random set, then swaps sites in and out of the set, measuring the change in cost at each iteration. If the change improves the set, the new set is carried forward to the next iteration. However, even changes that increase the cost (that is, reduce the quality) of the set may be carried forward, so that one may examine a number of different site combinations to avoid getting stuck at a local minimum. The changes to the selected set can be large at first, allowing sites that contribute greatly to reducing cost and improving the portfolio to be removed. Allowable changes are made progressively smaller as the total cost of the solution diminishes. Simulated annealing evaluates alternative complete reserve systems at each step, and compares them to identify a good solution. This procedure is not guaranteed to find the optimal solution, in the mathematical sense, but is believed to come very close as a result of the high number of iterations performed.

SITES Objective Function

The overall objective of SITES is to minimize the objective cost function of the portfolio while ensuring that all conservation goals have been met. The conservation goals include representation goals and goals for spatial configuration. Spatial configuration goals specify the relative importance of contiguity to achieve spatial compactness and connectivity of the final portfolio. The SSM represents this set of objectives as an "Objective Cost function:"

Objective Function = (cost of selected sites) + (penalty cost for not meeting the stated conservation goals for each element) + (cost of spatial dispersion of the selected sites as measured by the total boundary length of the portfolio).

The algorithm seeks to minimize Objective Function by selecting a set of sites that covers as many elements as possible as cheaply as possible in as compact a set as possible. The actual solutions depend on how cost is measured, on the target levels (or representation desired) and the penalty cost for each element, and on how heavily one weighs boundary length (using the boundary modifier, w_b) as an additional cost factor.

Cost

Cost in the objective function is the sum of the acquisition costs for each parcel within a conservation portfolio. The user supplies cost data for each planning unit in an input file.

Penalty

The "penalty" is the sum of the cost of acquiring enough sites to meet the specified conservation "targets". The "targets" or conservation goals in this case are areas of potential endangered species' habitat measured in square feet. "Targets" represent the desired amount of habitat that will be contained within each portfolio. The "penalty" is calculated using a heuristic known as the Greedy Heuristic. It is a stepwise, iterative procedure that accumulates one site at a time, choosing the best site at each step, until the goals have been met. "Best", in this case, means cheapest. SITES looks for the cheapest way to meet the "targets", calculates the cost for acquiring these sites, and adds it to the objective function as a penalty for not reaching the specified its goals. This is intended to encourage acquisition of sites until conservation goals are met.

Boundary Length

It is generally desirable for nature reserves in a portfolio to be both compact and comprised of adjacent planning units. For a conservation portfolio of a given size, the shorter the total boundary length around selected planning units, the more compact the portfolio. One objective of the SSM, therefore, is to minimize the total length of the boundary of the portfolio. Boundary lengths between planning units are supplied by the user. The boundary modifier (or w_b), which is applied to every boundary value, is a scalar that gives relatively greater importance to boundary costs as it is increased. This is intended to encourage "clumping" of solutions, is set by the user, and is entirely data dependent.

ArcView Interface

SITES also provides an ArcView interface that allows the analyst to run the SSM, enter parameters, and display solutions from ArcView. Parameters that are set from the ArcView interface include the cost threshold, and the threshold penalty strength. This feature acts like a budget constraint by setting an optional maximum cost threshold and a penalty for exceeding it. If the cost for a portfolio goes above this threshold at any iteration, then an additional penalty is applied to increase the Objective Function, making the site less desirable. The additional penalty is the amount by which the cost threshold was exceeded, multiplied by the penalty strength factor. This feature allows the user to apply a budget constraint on the "cost" of a portfolio, and allows the user to decide on the absoluteness of that constraint. Increasing the penalty strength by orders of magnitude ensures that the cost threshold will not be exceeded.

Input data

Our data were contained in a GIS database, and had to be manipulated into the format required by SITES 1.0. SITES uses six text files, describing the attributes of each planning unit. We provided files describing the cost, habitat, and boundary length associated with each parcel.

Varying Boundary Modifier (BM)

The boundary modifier is entirely data dependent, so its role was explored by trial and error. It was explored by keeping all other parameters constant and varying the BM slightly, then noting changes, visually, in the amount of clumping achieved. We also looked at the Boundary Length statistic given in the SITES output files, and compared its length for different scenarios. In addition, we noted the changes in results like the cost of the portfolio and the number of parcels included in the portfolio to assess the affect of increasing "clumpiness" on the values of other components of the objective function.

We hypothesized that setting the boundary modifier to 1000 would increase the magnitude of the boundary length portion of the objective equation such that SITES would notably increase the "clumpiness" of the conservation solution. However, this proved to be wrong as we varied the boundary modifier from 0 to 1,000,000 and saw very little change in clumpiness. As a result of increasing the boundary modifier by many orders of magnitude, SITES began to acquire an

increased number of expensive parcels that increased the cost of the portfolio, while adding very little biological value. The nature of the distribution of parcels and potential endangered species habitat is inherently clumped. We decided to set the boundary modifier to zero for every scenario, essentially removing contiguity from our analysis, as imposing an artificial clumping parameter did not yield very different results.

Scenario development

We developed a series of scenarios by varying the cost threshold and the species targets.

Cost threshold

The cost threshold is a constraint that was imposed because of the financial limitations of the Trustee Council and the ARCO settlement. The Trustee Council currently has approximately $8 million to spend on riparian conservation. This is our most specific and straightforward constraint. However, we also realize that one of the limitations of our analysis is that we were not able to get information on willing sellers, or even accurate cost data. As a result, we varied the cost threshold to provide more flexibility for the Trustee Council in deciding which parcels to purchase. We varied the cost threshold from $8 million to $16 million, and included scenarios with no cost threshold. We set the cost threshold penalty to 1,000,000 to ensure that the cost of the portfolio did not exceed the stated threshold.

Targets

Because the Trustee Council did not have specific representation goals, we decided to develop "scenarios", in which targets were systematically increased. The target designations are arbitrary in our analysis because we do not have specific goals we are trying to achieve in terms of area representation. We want our conservation solutions to contain as much potential habitat as possible, subject to a cost constraint. As a result, the role of the target in our analysis became unclear, and had to be explored by trial and error. We ran a series of scenarios that explored the relationship between cost of acquiring a portfolio and the proportion of potential species habitat represented in the portfolio. Our exploratory results guided our decisions regarding target levels in our final analysis. It would seem that the targets should always be set to 100% of the species distribution, as our goal is to represent as much habitat is possible. However, this imposes a large penalty, as the target is not feasible given the budget constraint, which causes the algorithm to perform poorly. We found that the algorithm would most likely reach an optimal solution when the targets were set to levels just above what could be obtained given the budget constraint. This would not artificially inflate the penalty cost as a result of unrealistic goals, and in this way, the cost threshold is always the constraint.

Targets or conservation goals were set as the number of square feet of potential species habitat that should be contained in the resulting conservation portfolio. We set the targets for each species to a proportion of the total square footage of potential species habitat available within the study region. This information came from manipulation of the spatial data contained in our GIS database. We provided a file summarizing the amount in square feet of each element within each parcel. SITES used this information to assess whether a portfolio met the conservation goals. Targets were set at 50% and 75% for the $8 million and the $16 million scenarios, respectively.

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Appendix I

SITES Results for $8 Million and $16 Million Scenarios

The following table lists all the parcels selected in the $8 million and $16 million scenarios. Note that the shaded areas are the additional parcels selected in the $16 million scenario.

*Cluster ID: A cluster is defined by adjacency (see Map 1)
**n/a: Selected parcels that did not occur in a cluster
***Land Use: agr =agriculture; v/u = vacant/undeveloped; res = residential; i/n = industrial/mining

Bio-reach	Cluster ID*	Assessors Parcel Number (APN)	Parcel Cost ($US)	Land Use***	Parcel Area (acres)	Species Present	% of Parcel with Species Habitat	% of Potential Habitat in Parcel
1	n/a**	138006047	8928	v/u	1	vireo	70	0.04
						flycatcher	70	0.09
	n/a	138009024	263353	agr	76	vireo	33	1.90
						stickleback	28	0.56
						flycatcher	21	2.39
	A	179007007	189938	v/u	55	vireo	31	1.27
						stickleback	48	0.70
						flycatcher	30	2.46
		138019022	107698	v/u	31	vireo	37	0.87
						stickleback	37	0.31
						flycatcher	37	1.68
		179005005	93104	v/u	27	vireo	22	0.44
						stickleback	43	0.31
						flycatcher	9	0.37
		179005004	311670	v/u	25	vireo	50	0.93
						stickleback	38	0.25
						flycatcher	43	1.58
2	B	090011004	41270	v/u	12	vireo	26	0.23
						stickleback	49	0.16
		109001020	124218	v/u	36	vireo	25	0.66
						stickleback	12	0.11
3	C	090018008	297072	agr	44	vireo	51	1.68
						stickleback	3	0.03
						flycatcher	44	2.89
		090019049	479790	v/u	138	vireo	35	3.65
						stickleback	61	2.25
						flycatcher	19	3.93

Bio-reach	Cluster ID*	Assessors Parcel Number (APN)	Parcel Cost ($US)	Land Use***	Parcel Area (acres)	Species Present	% of Parcel with Species Habitat	% of Potential Habitat in Parcel
3	C	090019053	33439	v/u	10	vireo stickleback	16 16	0.11 0.04
		090019054	41845	v/u	12	vireo stickleback flycatcher	23 33 2	0.21 0.10 0.04
		090018007	324667	v/u	93	vireo stickleback flycatcher	20 55 0	1.41 1.36 0.05
	D	090019051	102058	v/u	29	vireo stickleback flycatcher	35 64 26	0.78 0.50 1.11
		107012001	15422	v/u	4	vireo flycatcher	82 4	0.27 0.02
		090019024	248925	i/m	64	vireo stickleback flycatcher	13 7 11	0.61 0.12 1.09
	n/a	099007022	5250	res	2	vireo stickleback	16 12	0.02 0.00
	E	099008015	788	v/u	0.23	vireo	87	0.01
		099007006	36459	v/u	10	vireo stickleback	36 100	0.29 0.28
		099008014	10676	v/u	0.47	vireo stickleback	89 9	0.03 0.00
		099008012	10107	v/u	3	vireo stickleback	24 95	0.05 0.07
	n/a	104018102	336877	v/u	97	vireo stickleback flycatcher	16 48 8	1.17 1.23 1.13
	n/a	107005002	15813	v/u	5	vireo	31	0.10
	F	046023021	518860	v/u	149	frog vireo stickleback flycatcher toad	0 12 64 12 64	0.75 1.38 2.51 2.74 3.82
		046023020	623138	v/u	179	vireo stickleback flycatcher toad	55 19 37 19	7.34 0.91 9.74 1.39
		046013201	28256	agr	6	vireo flycatcher	68 68	0.30 0.60
		046015020	102664	v/u	29	vireo stickleback flycatcher toad	7 72 3 72	0.16 0.56 0.12 0.85

Bio-reach	Cluster ID*	Assessors Parcel Number (APN)	Parcel Cost ($US)	Land Use***	Parcel Area (acres)	Species Present	% of Parcel with Species Habitat	% of Potential Habitat in Parcel
3	F	046023008	349402	v/u	100	frog	1	3.71
						vireo	18	1.33
						stickleback	71	1.89
						flycatcher	18	2.63
						toad	71	2.87
		046023009	135557	v/u	39	vireo	13	0.38
						stickleback	64	0.67
						flycatcher	13	0.75
						toad	64	1.01
		046015019	6351	v/u	2	vireo	94	0.13
						flycatcher	94	0.25
		046023004	11811	v/u	3	vireo	91	0.23
						flycatcher	93	0.47
		046023005	5480	v/u	2	vireo	100	0.12
						flycatcher	100	0.23
		046025008	522022	agr	150	frog	15	63.94
						vireo	31	3.54
						flycatcher	32	7.02
		046027009	4355	v/u	1	vireo	97	0.09
						flycatcher	94	0.17
		046023013	101302	agr	29	frog	17	13.67
						vireo	22	0.48
						stickleback	33	0.25
						flycatcher	22	0.94
						toad	33	0.38
		046023023	41891	v/u	9	vireo	16	0.11
						stickleback	97	0.24
						flycatcher	16	0.22
						toad	97	0.36
		046025007	4400	agr	1	vireo	68	0.06
						flycatcher	65	0.12
		046023015	339436	v/u	97	frog	4	11.50
						vireo	24	1.74
						stickleback	55	1.43
						flycatcher	20	2.92
						toad	55	2.17
		46023025	81292	v/u	23	vireo	4	0.07
						stickleback	97	0.60
						flycatcher	1	0.03
						toad	97	0.91

Bio-reach	Cluster ID*	Assessors Parcel Number (APN)	Parcel Cost ($US)	Land Use***	Parcel Area (acres)	Species Present	% of Parcel with Species Habitat	% of Potential Habitat in Parcel
3	F	046015034	613432	agr	151	vireo	19	2.20
						stickleback	23	0.92
						toad	23	1.40
		046023007	298498	agr	86	vireo	13	0.83
						stickleback	7	0.16
						flycatcher	13	1.64
						toad	7	0.25
		046015021	134392	v/u	39	vireo	1	0.04
						stickleback	58	0.59
						toad	58	0.90
		046015005	385141	v/u	80	vireo	30	1.78
						stickleback	22	0.47
						toad	22	0.71
		046013204	83218	agr	14	vireo	32	0.33
						flycatcher	26	0.52
		046012205	7727	agr	1	vireo	22	0.02
						flycatcher	20	0.03
		046027010	11369	v/u	3	vireo	21	0.05
						flycatcher	21	0.10
		046027004	64821	agr	19	vireo	22	0.31
						flycatcher	23	0.63
		046023003	12436	v/u	2	vireo	47	0.07
						flycatcher	47	0.14
4	G	046005001	75690	v/u	22	vireo	48	0.78
						stickleback	34	0.20
						toad	34	0.30
		046009001	244094	v/u	70	vireo	23	1.23
						stickleback	60	1.11
						toad	60	1.70
		046009002	291006	v/u	84	vireo	4	0.12
						stickleback	93	0.41
						toad	93	0.63
		046010012	81200	v/u	23	vireo	7	0.26
						stickleback	67	2.06
						toad	67	3.13

Bio-reach	Cluster ID*	Assessors Parcel Number (APN)	Parcel Cost ($US)	Land Use***	Parcel Area (acres)	Species Present	% of Parcel with Species Habitat	% of Potential Habitat in Parcel
4	G	046005007	200070	agr	41	vireo	27	0.83
						stickleback	1	0.01
						toad	1	0.02
		046010001	118596	v/u	34	vireo	9	0.23
						stickleback	41	0.37
						toad	41	0.57
		046016039	357749	v/u	100	vireo	1	0.10
						stickleback	49	1.29
						flycatcher	1	0.20
						toad	49	1.96
		046016040	42281	v/u	11	vireo	10	0.08
						stickleback	47	0.13
						flycatcher	10	0.16
						toad	47	0.20
	H	046007012	59057	v/u	17	vireo	1	0.02
						stickleback	77	0.35
						toad	77	0.53
		046007013	188895	v/u	54	vireo	1	0.05
						stickleback	81	1.17
						toad	81	1.78
		046006012	144385	v/u	41	vireo	5	0.14
						stickleback	62	0.68
						toad	62	1.03
		041029049	478775	v/u	137	vireo	4	0.39
						stickleback	67	2.43
						flycatcher	0	0.09
						toad	67	3.69
		055026005	436701	v/u	125	vireo	19	1.81
						stickleback	71	2.38
						flycatcher	4	0.74
						toad	71	3.61
		055026006	147676	v/u	42	vireo	2	0.06
						stickleback	77	0.87
						toad	77	1.32
		055026017	156192	v/u	45	stickleback	99	1.18
						toad	99	1.80
		055027029	158894	agr	46	vireo	18	0.63
						stickleback	22	0.26
						toad	22	0.40
		055027028	111332	v/u	32	vireo	22	0.53
						stickleback	72	0.61
						toad	72	0.93
		041029007	239536	v/u	69	stickleback	60	1.09
						toad	60	1.66

Bio-reach	Cluster ID*	Assessors Parcel Number (APN)	Parcel Cost ($US)	Land Use***	Parcel Area (acres)	Species Present	% of Parcel with Species Habitat	% of Potential Habitat in Parcel
4	H	041026028	231220	agr	66	vireo stickleback flycatcher toad	12 7 12 7	0.59 0.12 1.17 0.18
		041029011	461336	v/u	132	stickleback toad	65 65	2.27 3.46
		055026020	146052	v/u	42	stickleback toad	61 61	0.68 1.04
		055026021	146942	v/u	42	stickleback toad	56 56	0.62 0.95
		055027026	533365	v/u	153	stickleback toad	77 77	3.15 4.79
		55027010	288159	v/u	83	stickleback toad	60 60	1.31 1.99
		055026026	62887	v/u	18	vireo	26	0.36
5	I	055027019	36371	v/u	10	stickleback toad	87 87	0.24 0.37
		055027012	36331	v/u	10	stickleback toad	83 83	0.23 0.35
	n/a	057008009	366369	v/u	70	vireo stickleback toad	26 60 60	1.37 1.11 1.69
6	J	55024007	470107	agr	119	vireo flycatcher	27 15	2.39 2.68
		055025002	99761	agr	0.10	vireo	98	0.01
		55024002	45597	v/u	11	vireo	30	0.26
		55024008	613753	agr	155	vireo flycatcher toad	17 19 10	1.95 4.42 0.65
		055025003	638886	agr	183	vireo flycatcher toad	26 19 18	3.57 5.16 1.36

Appendix J

Biological Ranking of Parcels

The biological ranking is based on the '% Habitat'. This percentage was calculated by summing the total acres of habitat in a parcel and dividing by the area of the parcel. (Thus, a parcel that was completely covered with habitat for all eight species would have a % Habitat of 800.) The land use codes are as follows: 1=residential, 2=commercial, 3=public/transportation, 4=agriculture, 5=vacant/undeveloped, 6=parks and recreation, 7=industrial/mining. A 'Y' in the SITES 8 or SITES 16 column indicates that that parcel was selected by the SITES model with a cost constraint of $8 million or $16 million.

Biological Rank	APN	% Habitat	Area(Acres)	Cost/Acre (Dollars)	Land Use	SITES 8	SITES 16
1	046023005	200	1.6	3485	4	Y	Y
2	108001008	200	0.1	146476	7		
3	046027009	191	1.2	3485	4	Y	Y
4	046015019	188	1.8	3485	4	Y	Y
5	046023004	184	3.4	3485	4	Y	Y
6	138008002	176	1.4	57325			
7	McGrath	174	91.7	0	3	Y	Y
8	108001014	160	0.7	87353	2		
9	138005011	155	23.4	53735	1		
10	138005005	151	1.5	87261	4		
11	046023022	144	121.0	40182	2		
12	138006047	140	0.9	10490	4		Y
13	046013201	137	5.9	4796	4	Y	Y
14	046025007	133	1.3	3485	5	Y	Y
15	107015009	131	0.2	145095	3		
16	046023023	129	9.3	4510	5	Y	Y
17	138006056	122	0.8	114765	4		
18	046023020	110	178.8	3485	4	Y	Y
19	046023008	107	100.3	3485	4	Y	Y
20	138019027	105	8.1	87376			
21	046023015	103	97.4	3485	5	Y	Y
22	046023025	101	23.3	3485	4	Y	Y
23	107001032	100	3.7	113216	1		
24	107001077	100	0.2	113216	1		
25		100	11.8	58313	7		
26	041026054	100	0.3	74546	3		
27	046023022	100	0.9	304973	7		
28	107001064	100	31.7	84950	2		
29	055026017	99	44.8	3485	4	Y	Y
30	107001072	99	1.1	105648	1		
31	055025002	98	0.1	6718	4	Y	Y
32	107010013	98	1.4	82559	5		
33	046009002	97	83.5	3485	4	Y	Y
34	107006213	96	6.8	125825	3		

Biological Rank	APN	% Habitat	Area(Acres)	Cost/Acre (Dollars)	Land Use	SITES 8	SITES 16
35	138019028	96	25.1	38264	4		
36	090018008	95	43.8	6787	5	Y	Y
37	046023018	95	1.7	58313	2		
38	055026005	95	125.3	3485	5	Y	Y
39	046023003	94	2.0	6326	4		Y
40	055027028	94	31.9	3485	4	Y	Y
41	046023013	94	29.1	3485	5	Y	Y
42	179005004	93	24.7	12616	1		Y
43	138009020	92	0.3	29885			
44	107001069	92	5.4	70710	2		
45	107014037	91	39.3	46706	3		
46	046023009	90	38.9	3485	4	Y	Y
47	107015010	90	2.5	88621	3		
48	055031001	89	8.9	294344	1		
49	099008014	89	0.5	22715	4		Y
50	046023021	89	148.9	3485	5	Y	Y
51	138019030	88	25.0	59057	3		
52	055029016	87	266.4	6562	5		
53	099008015	87	0.2	3485	5	Y	Y
54	055027019	87	10.4	3485	4	Y	Y
55	057008009	86	69.9	5242	5	Y	Y
56	107012001	86	4.4	3485	5	Y	Y
57	046009001	83	70.0	3485	4	Y	Y
58	055027012	83	10.4	3485	4	Y	Y
59	046007013	83	54.2	3485	4	Y	Y
60	046005001	82	21.7	3485	5	Y	Y
61	046015020	81	29.5	3485	4	Y	Y
62	055026006	79	42.4	3485	5	Y	Y
63	107001076	78	82.2	102057	2		
64	046025008	78	149.8	3485	4	Y	Y
65	179007008	78	9.2	50640			
66	104020011	78	1.1	25183	2		
67	046007012	78	16.9	3485	4	Y	Y
68	055027026	77	153.1	3485	5		Y
69	138019017	77	25.4	61213	4		
70	138019022	74	30.9	3485	6	Y	Y
71	057006003	74	14.4	8345	5		
72	046010012	74	23.3	3485	5	Y	Y
73	041029049	71	137.4	3485	5	Y	Y
74	041029009	68	1.7	12979	5		
75	132008005	67	1.9	44798	4		
76	046016040	67	10.7	3946	4		Y
77	046006012	66	41.4	3485	5	Y	Y
78	041029011	65	132.4	3485	5		Y
79	107015008	64	0.5	141825	3		
80	055025003	63	183.3	3485	4		Y
81	107001061	62	0.4	25183	4		
82	179007007	61	54.5	3485	5	Y	Y
83	055026020	61	41.9	3485	4		Y
84	090019051	61	29.3	3485	5	Y	Y
85	041029007	60	68.7	3485	5		Y
86	055027010	60	82.7	3485	5		Y
87	046015021	59	38.6	3485	5		Y

Biological Rank	APN	% Habitat	Area(Acres)	Cost/Acre (Dollars)	Land Use	SITES 8	SITES 16
88	046013204	58	13.6	6129	4		Y
89	055026021	56	42.2	3485	5		Y
90	138009024	55	75.6	3485	4	Y	Y
91	138019029	54	9.1	87376			
92	090019049	54	137.7	3485	4	Y	Y
93	138006001	53	1.1	54131	2		
94	138006055	52	142.0	93754	2		
95	099009009	52	81.4	39451	2		
96	046015005	52	80.0	4814	4		Y
97	046016039	51	100.0	3578	4		Y
98	046010001	50	34.0	3485	4		Y
99	057007019	50	5.2	11927	4		
100	179005012	49	4.8	44798			
101	104019405	49	0.8	90082	2		
102	055030002	48	0.3	294532	1		
103	057007018	47	59.4	3485	5		
104	090019042	47	14.4	16012	5		
105	055024008	46	155.0	3960	4		Y
106	107014037	46	9.2	51372	3		
107	057002010	45	52.2	13123	4		
108	107001083	45	147.3	12225	5		
109	046027004	45	18.6	3485	5		Y
110	104017051	45	52.6	83977	5		
111	090011021	44	10.1	20057	5		
112	046016033	44	10.7	3485	4		
113	057006003	43	24.7	4865	5		
114	046027010	43	3.3	3485	4		Y
115	046012205	42	1.1	7166	4		Y
116	046015022	42	28.3	3485	4		
117	046015034	42	151.5	4050	4		Y
118	041029033	42	41.1	32840	5		
119	055027018	42	62.2	3485	5		
120	055024007	42	119.1	3946	4	Y	Y
121	046006005	41	41.6	3485	4		
122	090011003	41	4.0	34373	3		
123	055027029	40	45.6	3485	4	Y	Y
124	055026014	40	9.8	97439	3		
125	041029058	39	27.5	3485	5		
126	107001078	39	18.7	105648	5		
127	041029006	38	6.9	3485	5		
128	138009018	37	173.4	144220	3		
129	104019308	37	1.9	90082	2		
130	099007006	36	10.5	3485	4	Y	Y
131	057006001	36	41.0	7728	4		
132	107001079	35	0.2	105648	1		
133	055026025	35	5.2	18777	5		
134	055026003	35	10.3	12175	4		
135	139015012	35	16.6	44798	2		
136	055026022	34	40.3	3485	4		
137	046013203	34	21.2	11189	5		
138	055027032	33	46.8	3485	4		
139	046023007	33	85.7	3485	5		Y
140	055026004	32	9.5	67311	3		

Biological Rank	APN	% Habitat	Area(Acres)	Cost/Acre (Dollars)	Land Use	SITES 8	SITES 16
141	055021013	32	279.0	3485	4		
142	179005005	31	26.7	3485	4		Y
143	099011008	31	112.9	10942	3		
144	046017108	31	64.2	5636	4		
145	055027038	31	81.7	3485	5		
146	107005002	31	4.5	3485	5	Y	Y
147	055024002	30	11.4	3995	5		Y
148	041026028	30	66.4	3485	5		Y
149	055026013	30	11.0	10316	5		
150	046010011	29	84.9	3485	4		
151	107001114	29	0.2	490199	2		
152	138009023	29	77.8	92725	3		
153	057008007	28	5.6	12255	4		
154	046005007	28	41.1	4874	5		Y
155	046007014	28	11.8	13392	5		
156	055029015	28	68.0	4667	4		
157	139001030	28	50.1	44798	1		
158	104020018	28	4.5	25183	5		
159	139001048	27	4.4	44798	4		
160	046010009	27	41.1	3485	4		
161	055026026	26	18.0	3485	4		Y
162	046006013	26	1.8	12983	5		
163	090011004	26	11.8	3485	6		Y
164	107001084	26	9.3	15338	4		
165	107005042	26	25.7	24580	3		
166	046016024	26	152.2	3485	4		
167	090019054	25	12.0	3485	4		Y
168	109001020	25	35.6	3485	6		Y
169	099008012	24	2.9	3485	4		Y
170	104018102	24	96.7	3485	5		Y
171	090019024	24	64.4	3866	5		Y
172	057007015	23	69.2	3485	4		
173	090019055	23	1.6	13536	5		
174	057003016	23	20.8	6994	4		
175	107001066	23	65.0	77478	5		
176	055022004	22	180.1	9613	4		
177	090019006	21	5.4	14800	5		
178	104020019	21	2.2	146376	2		
179	090018007	21	93.2	3485	5		Y
180	046016034	20	4.3	3969	4		
181	041026053	20	4.6	112659	3		
182	055026015	20	23.8	142195	3		
183	055026024	20	11.9	8122	5		
184	099007022	16	1.5	3485	4		Y
185	041029051	16	30.2	99178	3		
186	090019053	16	9.6	3485	5		Y
187	179005002	15	25.8	50220	2		
188	133001002	15	32.2	55469	5		
189	041029059	15	3.2	13916	5		
190	138019033	13	6.0	61213			
191	041026050	13	0.5	3485	5		
192	099008023	13	45.5	13235	5		
193	046007015	13	34.6	33174	5		

Biological Rank	APN	% Habitat	Area(Acres)	Cost/Acre (Dollars)	Land Use	SITES 8	SITES 16
194	132002034	12	94.1	87450	2		
195	104017041	12	23.6	301438	1		
196	104017040	12	13.6	300196	1		
197	099008019	12	28.2	160302	1		
198	041029029	12	32.9	3485	4		
199	104017045	11	5.9	43046	5		
200	046015033	11	68.0	3485	4		
201	099007009	11	43.7	3485	4		
202	132002003	11	18.8	44175	4		
203	046016041	11	81.1	5391	5		
204	057003013	11	8.7	15292	4		
205	055026023	10	17.2	5808	4		
206	138019031	10	6.8	87376			
207	099008016	10	1.4	14395	5		
208	104017046	10	5.9	130115	5		
209	104017039	9	3.2	49582	1		
210	046014204	8	13.1	8662	5		
211	099007016	7	3.9	197687	1		
212	099008003	7	53.3	74199	2		
213	041026038	7	2.9	3485	4		
214	104020020	7	0.7	38308	2		
215	090016004	7	153.0	48003	2		
216	138006010	7	21.5	11200	2		
217	104018061	7	1.1	83142	1		
218	099009004	7	34.0	4804	5		
219	046027003	7	1.2	3485	5		
220	104017033	6	61.9	155908	1		
221	046023002	6	17.1	4406	4		
222	099007005	5	27.3	3485	5		
223	057005009	5	10.6	4669	5		
224	129002006	5	147.6	3485	6		
225	057007013	5	45.1	3485	4		
226	041026042	4	42.6	7948	4		
227	046015014	4	16.0	6384	5		
228	057003012	4	7.3	6128	4		
229	099008021	4	44.4	3485	4		
230	104018101	4	45.3	148873	3		
231	107001067	4	19.0	92167	2		
232	179005010	4	32.0	44798	5		
233	090019058	3	27.4	3485	5		
234	104018103	3	22.8	88449	5		
235	055029014	3	63.2	3485	5		
236	138006058	3	38.1	11878	5		
237	055027027	3	9.3	10201	5		
238	104017037	3	30.7	253098	1		
239	107015004	2	3.0	15431	1		
240	129002003	2	18.6	29800	4		
241	046016032	2	1.4	24263	4		
242	041026012	2	29.8	3485	4		
243	055027009	2	30.8	3485	5		
244	128004005	2	19.0	19743	6		
245	128004020	2	95.2	3485	5		
246	130006005	1	120.9	3485	5		

Biological Rank	APN	% Habitat	Area(Acres)	Cost/Acre (Dollars)	Land Use	SITES 8	SITES 16
247	055018023	1	49.4	3485	4		
248	046015017	1	22.7	11996	5		
249	104017049	1	8.1	294191	1		
250	090019059	1	0.7	13536	5		
251	130007002	1	148.3	57018	2		
252	055026051	1	58.8	3485	5		
253	107016003	1	10.5	73634	2		
254	104017024	1	17.7	3485	4		
255	132001007	1	58.7	10928	4		
256	046007009	1	40.6	33759	5		
257	090019057	<1	8.6	13536	5		
258	052022003	<1	11.0	74546	5		
259	055016028	<1	106.3	3935	5		
260	046008012	<1	50.8	4784	5		
261	055029013	<1	46.1	7696	4		
262	133001003	<1	76.5	3485	5		
263	104017038	<1	1.7	67971	4		
264	090019027	<1	51.6	80290	5		
265	090019002	<1	41.5	83267	5		
266	128003031	<1	3.8	45347	5		
267	129002001	<1	23.3	80487	2		
268	107008003	<1	12.9	3485	4		
269	129001101	<1	1.0	3485	5		
270	129001110	<1	0.2	25012	5		
271	090019040	<1	4.1	14134	5		
272	090019041	<1	1.6	14134	5		
273	129002007	<1	1.5	4835	5		
274	104017025	<1	13.8	3485	4		
275	129001133	<1	3.1	8236	5		
276	129001103	<1	1.6	6185	4		
277	129015604	<1	0.9	4835	4		
278	129015603	<1	0.2	4835	5		
279	129001135	<1	0.9	5672	5		
280	129001106	<1	1.6	5577	4		
281	090017205	<1	0.1	5474	5		
282	099007018	<1	1.0	3485	4		

Appendix K

Photographs of Recommendations

Cluster F

a)

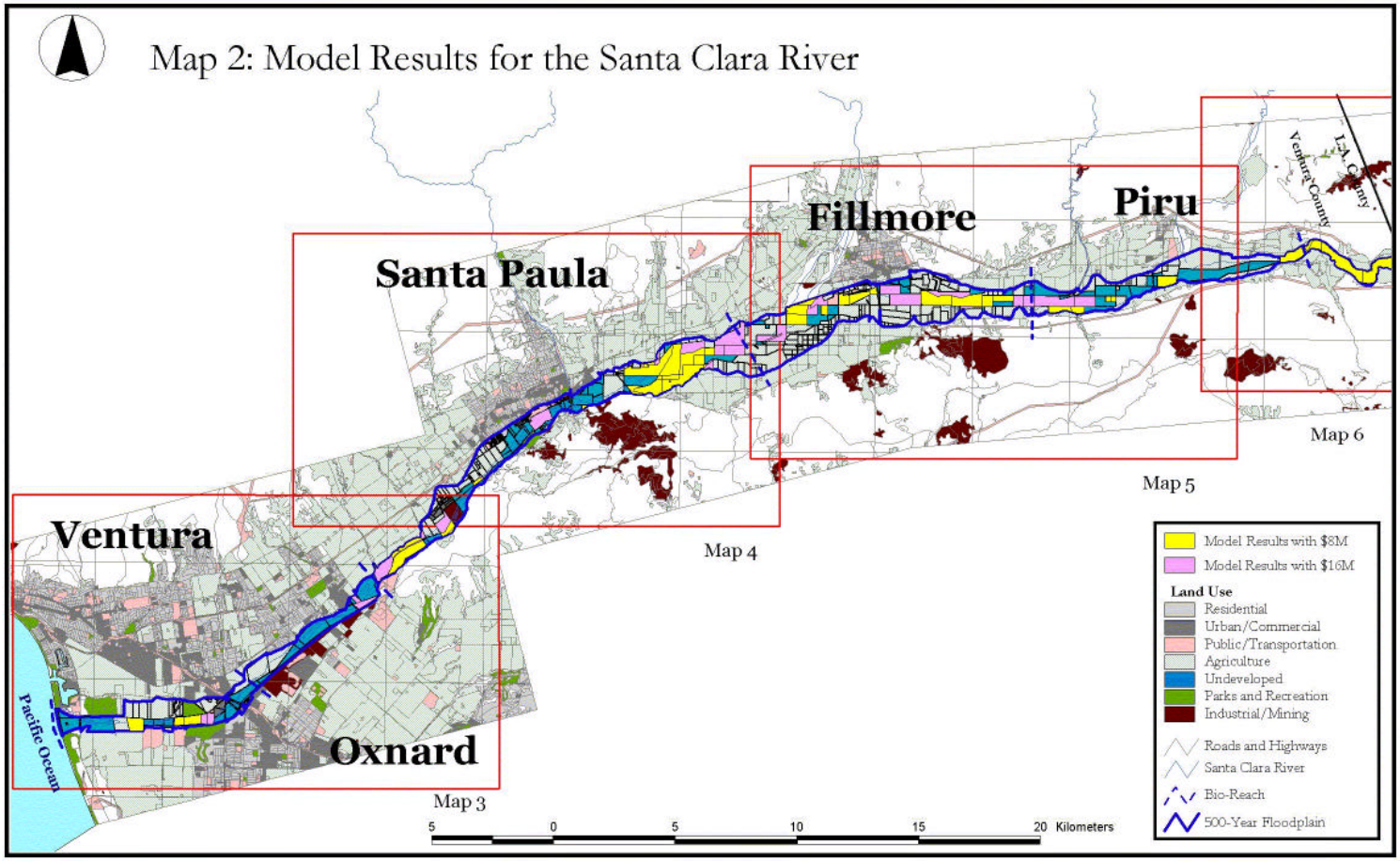
b)

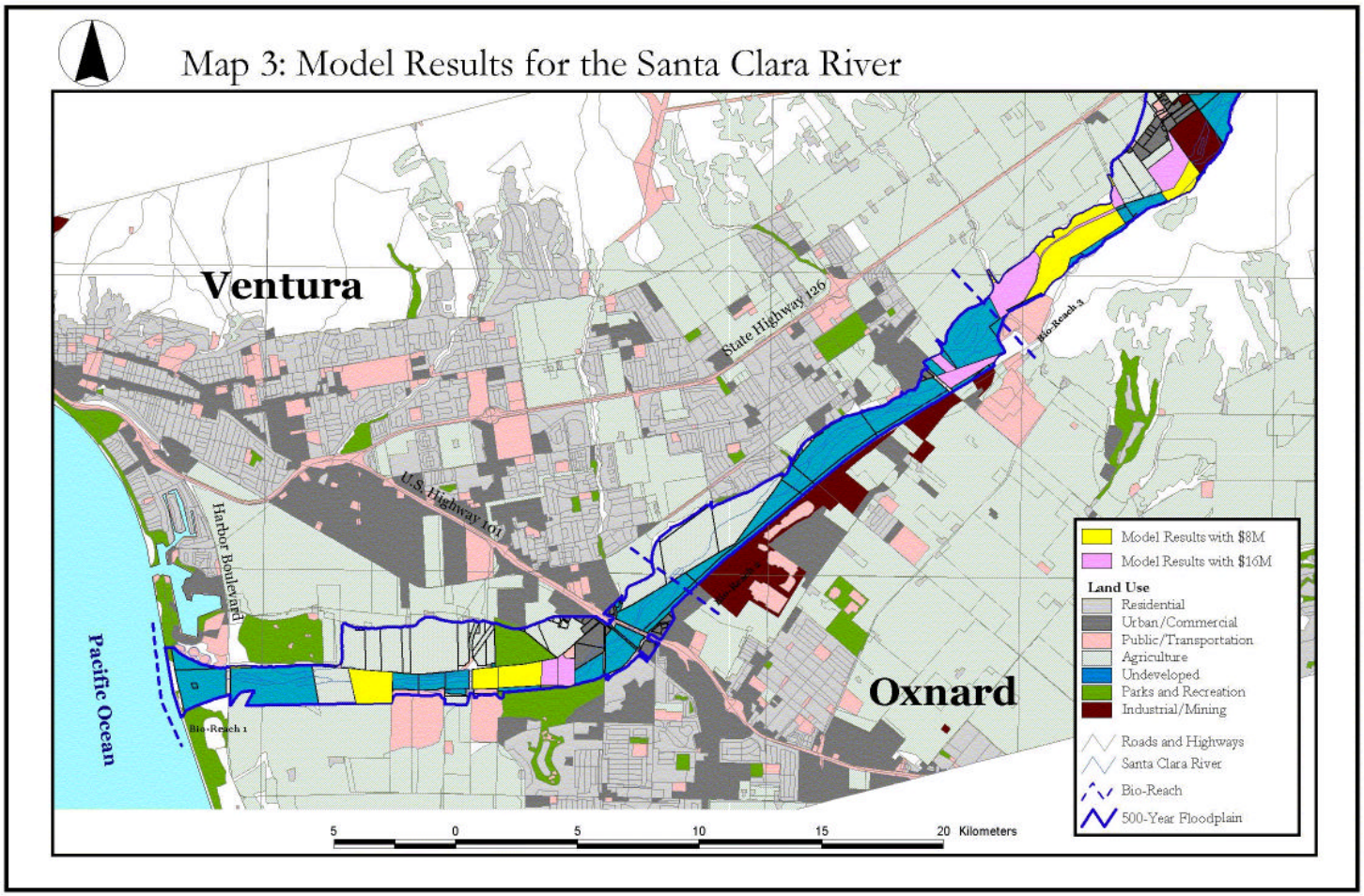
Cluster J

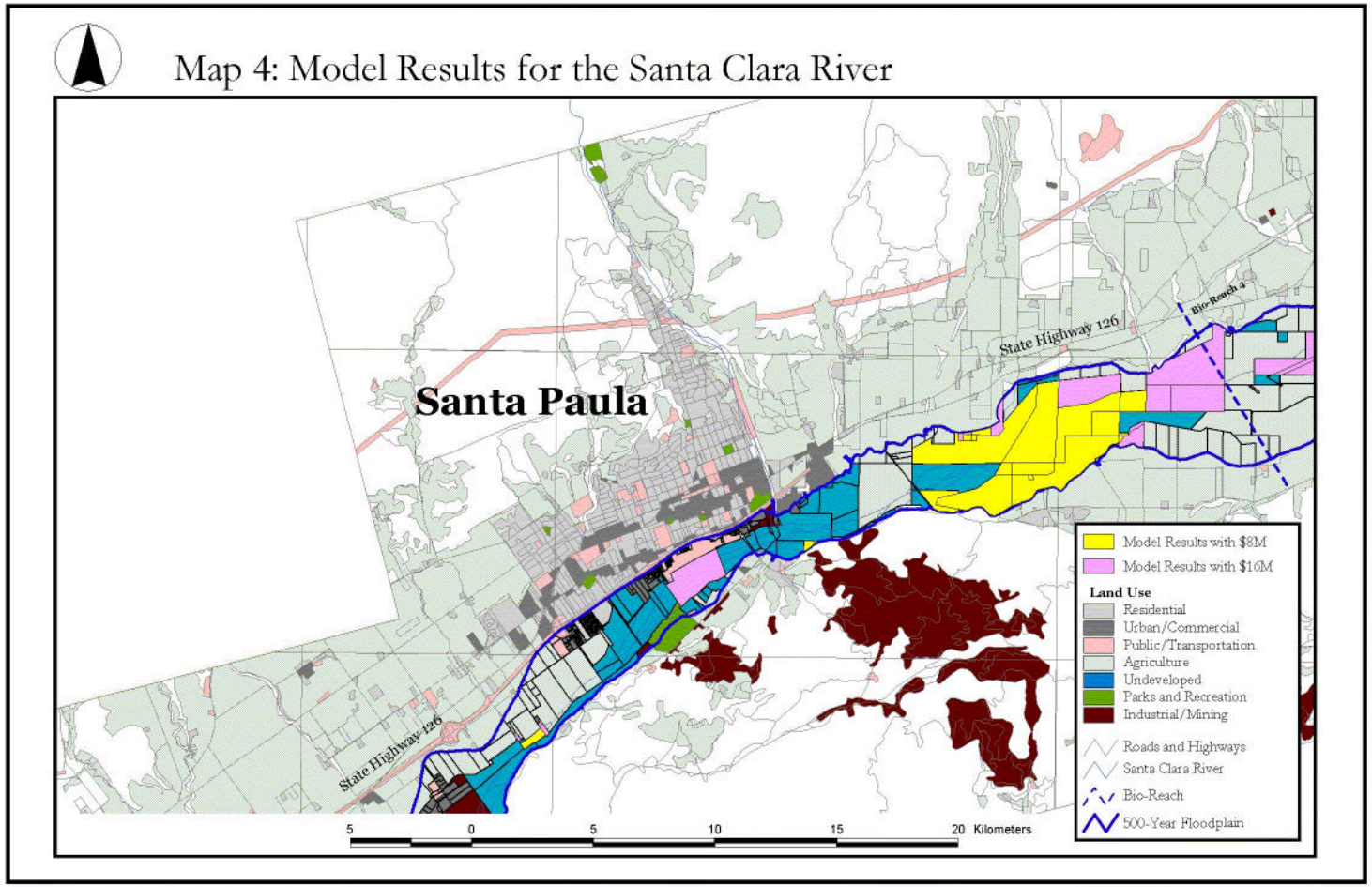
a)

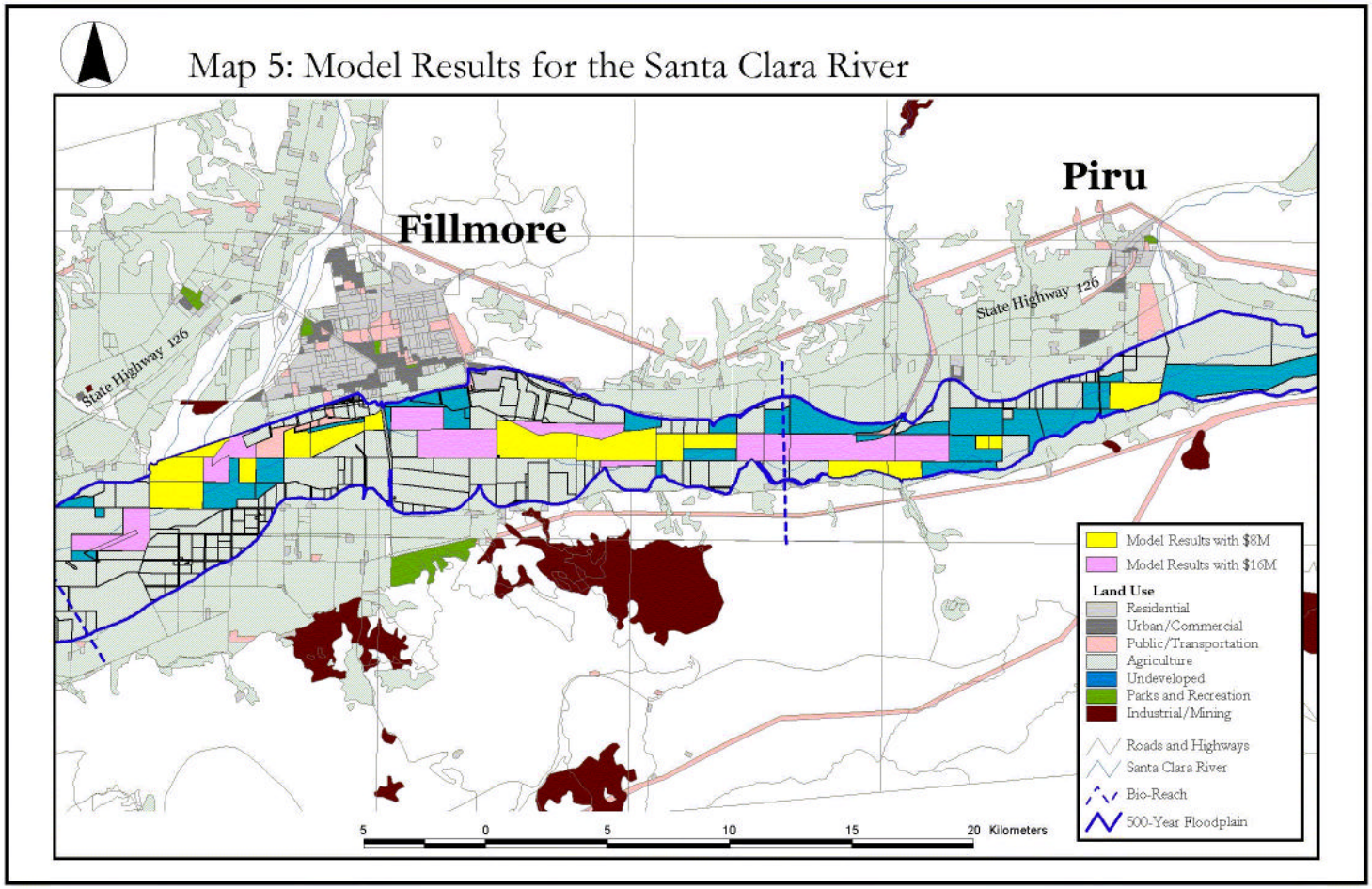
b)

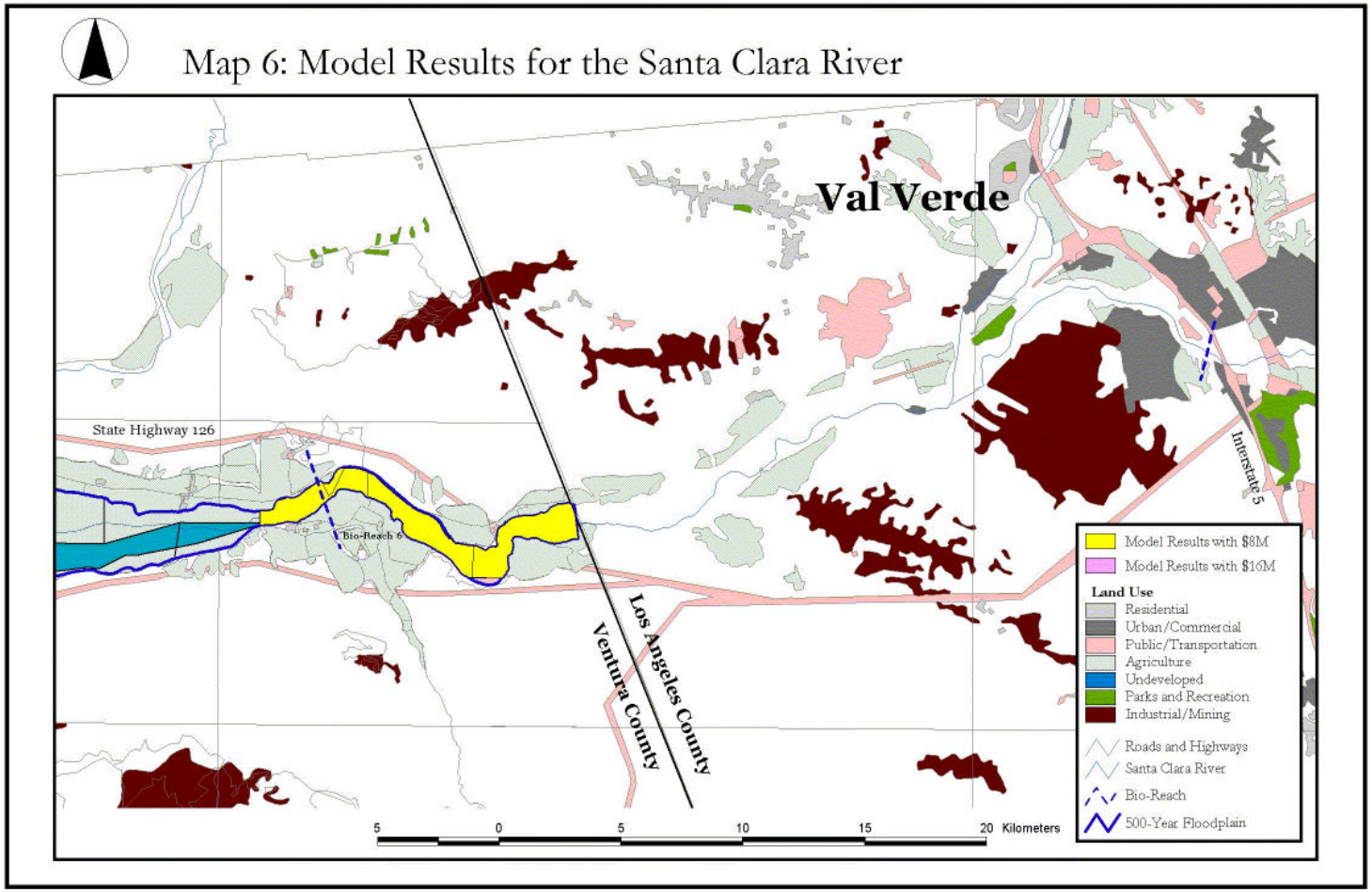
End of Document.


Map 2: Model Results for the Santa Clara River
Ventura
Oxnard
Santa Paula
Fillmore
Piru
Pacific Ocean
Ventura County
L.A. County
Map 3
Map 4
Map 5
Map 6
5 0 5 10 15 20 Kilometers
Model Results with $8M
Model Results with $16M
Land Use
Residential
Urban/Commercial
Public/Transportation
Agriculture
Undeveloped
Parks and Recreation
Industrial/Mining
Roads and Highways
Santa Clara River
Bio-Reach
500-Year Floodplain


Map 3: Model Results for the Santa Clara River
Ventura
Oxnard
Pacific Ocean
Harbor Boulevard
U.S. Highway 101
State Highway 126
Bio-Reach 1
Bio-Reach 2
Bio-Reach 3
Model Results with $8M
Model Results with $16M
Land Use
Residential
Urban/Commercial
Public/Transportation
Agriculture
Undeveloped
Parks and Recreation
Industrial/Mining
Roads and Highways
Santa Clara River
Bio-Reach
500-Year Floodplain
5 0 5 10 15 20 Kilometers


Map 4: Model Results for the Santa Clara River
Santa Paula
State Highway 126
State Highway 126
Bio-Reach 4
Model Results with $8M
Model Results with $16M
Land Use
Residential
Urban/Commercial
Public/Transportation
Agriculture
Undeveloped
Parks and Recreation
Industrial/Mining
Roads and Highways
Santa Clara River
Bio-Reach
500-Year Floodplain
5 0 5 10 15 20 Kilometers

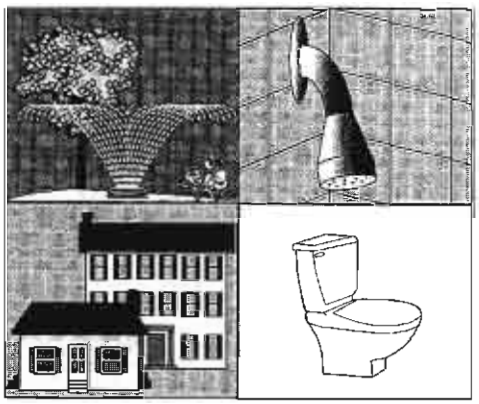

Map 5: Model Results for the Santa Clara River
Fillmore
Piru
State Highway 126
State Highway 126
Model Results with $8M
Model Results with $16M
Land Use
Residential
Urban/Commercial
Public/Transportation
Agriculture
Undeveloped
Parks and Recreation
Industrial/Mining
Roads and Highways
Santa Clara River
Bio-Reach
500-Year Floodplain
5
0
5
10
15
20 Kilometers


Map 6: Model Results for the Santa Clara River
Val Verde
State Highway 126
Bio-Reach 6
Interstate 5
Los Angeles County
Ventura County
Model Results with $8M
Model Results with $16M
Land Use
Residential
Urban/Commercial
Public/Transportation
Agriculture
Undeveloped
Parks and Recreation
Industrial/Mining
Roads and Highways
Santa Clara River
Bio-Reach
500-Year Floodplain
5 0 5 10 15 20 Kilometers

Summary

The Value of Water Supply Reliability:

Results of a Contingent Valuation Survey of Residential Customers



California Urban Water Agencies

Prepared by:
Barakat & Chamberlin, Inc.

August 1994

Summary

THE VALUE OF WATER SUPPLY RELIABILITY:
Results of a Contingent Valuation Survey of Residential Customers

CALIFORNIA URBAN WATER AGENCIES

Participating Agencies:

Alameda County Water District
Contra Costa Water District
Los Angeles Department of Water and Power
Metropolitan Water District of Southern California
Municipal Water District of Orange County
Orange County Water District
San Diego County Water Authority
San Diego Water Utilities Department
San Francisco Public Utilities Commission
Santa Clara Valley Water District

Prepared by:
BARAKAT & CHAMBERLIN, INC.
Oakland, California

August 1994

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Dr. Richard Berk, Department of Sociology, U.C.L.A.
Mr. Arthur Bruington, Municipal Water District of Orange County
Mr. Byron Buck, San Diego County Water Authority
Mr. Norman Buehring, Los Angeles Department of Water and Power
Mr. Shane Chapman, Metropolitan Water District of Southern California
Ms. Leasa Cleland, Alameda County Water District
Mr. Merv De Haas, U.S. Bureau of Reclamation
Dr. Richard Denton, Contra Costa Water District
Mr. Jim Fiedler, Santa Clara Valley Water District
Mr. David Fullerton, Natural Heritage Institute
Mr. Jerry Harrell, California Municipal Utilities Assn.
Mr. Gordon Hess, San Diego County Water Authority
Mr. Ray Hoagland, Department of Water Resources
Mr. Morris Israel, University of California, Davis
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Mr. Jim Simunovich, California Water Service Company
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Ronnie Weiner
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FOREWORD

California Urban Water Agencies (CUWA) is an organization of the largest urban water providers in California. Its member agencies serve water to metropolitan areas comprising about two-thirds of the state's 32 million population. CUWA was formed to work on water supply issues of common concern to its members. Paramount among these concerns is the reliability of our urban water supplies. Statewide surveys show that California citizens rank water shortages close to crime, taxes, and traffic in listing their concerns about current problems in our society.

CUWA has an ongoing program to improve understanding of all aspects of urban water supply reliability. One important component of planning for supply reliability is being able to estimate the economic impact of water shortages so that an appropriate balance between costs and benefits of water management improvements can be found. CUWA and its member agencies sponsored earlier work on the cost of water shortages in California's manufacturing industries and the urban horticulture industry. However, the largest shortage cost component in some communities is in the residential sector, and this factor has proven difficult to quantify. CUWA and its consultant, Barakat & Chamberlin, Inc., determined that contingent valuation (CV) is the best available method for studying residential water shortage losses, and so undertook this survey—the most comprehensive and informative survey of its type conducted in the urban water supply industry.

This report detailed results of the CV surveys which shows that, on average, California residents are willing to pay $12 to $17 more per month per household on their water bills to avoid the kinds of water shortages which they or their regional neighbors have incurred in recent memory. The statewide magnitude of such additional consumer payments would be well over $1 billion per year. This customer value can be considered in planning for various demand- and supply-related options to meet reliability goals. While environmental and social impacts were not assessed in the CV survey, this report points out that they must be considered in water resource planning. CUWA is planning an additional phase of its Water Supply Reliability Program which will help water managers integrate all aspects of reliability planning.

California Urban Water Agencies

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THE VALUE OF WATER SUPPLY RELIABILITY:
Results of a Contingent Valuation Survey of Residential Customers

Summary

INTRODUCTION

California Urban Water Agencies (CUWA) is conducting ongoing research on issues of water supply reliability. The goal of the CUWA reliability project is to provide the framework and tools with which each water agency can better incorporate reliability issues into its overall resource planning. One of the key pieces of information needed to do this is the *value* that customers place on reliability.

To address this question, CUWA engaged the consulting firm of Barakat & Chamberlin, Inc., to design, conduct, and analyze the results of a *contingent valuation* survey to estimate the value to residential customers of water supply reliability. The survey was conducted within the service areas of ten CUWA member agencies. This summary discusses combined results for the ten participating agencies. The individual results for each agency are included as appendices to the full report.

As will be discussed below, estimates and patterns of willingness to pay (WTP) for increased water supply reliability are remarkably consistent across participating agencies. This consistency supports the integrity of the results and general findings of the study. However, contingent valuation is not an exact science, and dollar figures should be used with caution.

THE CUWA CONTINGENT VALUATION SURVEY

The primary purpose of the CUWA contingent valuation (CV) survey is to estimate the value residential customers place on water supply reliability, specifically how much they are willing to pay to avoid water shortages of varying magnitude and frequency.

The CUWA CV survey asked participants whether they would vote "yes" or "no" in a hypothetical referendum. Participants were told that if a majority votes "yes," water bills would be increased by a designated amount, and there would be no future water

shortages; if a majority votes "no," respondents were told that water bills would remain the same as they otherwise would have been, but water shortages of a specified magnitude and frequency would occur. Of course, individual customers differ in their willingness to pay to avoid different shortages.

The survey purposely did not tell customers where additional supply would come from, but rather indicated that it could come from any of a number of different sources. The intent was to avoid responses that were unduly influenced by preferences for or against particular resource types.

The CV questions are preceded by a series of questions that address a number of experiential and attitudinal issues, which help to place the CV questions in context and are also used in the analysis. The actual CV questions include a carefully worded description of the hypothetical "scenario" that will form the basis of a "yes" or "no" vote. The CV questions are followed by several "debriefing" questions that provide information on the reasons why respondents voted as they did. The survey concludes with a series of demographic questions.

Respondents are distributed randomly across a range of shortage scenarios. Shortage magnitudes range from 10% to 50%. Frequencies range from once every 3 years to once every 30 years. Bid amounts range from $1 to $50 increments to monthly water bills.[1]

Magnitudes and frequencies were combined to accomplish three objectives:

- To cover a wide range of shortage severity;
- To present shortage scenarios that would be perceived by respondents as realistic possibilities; and
- To avoid shortage scenarios that are too mild to elicit reliable WTP responses.

There are some critical concerns that are intentionally not addressed by the survey. The amount that some customers are willing to pay to avoid shortages will likely depend on one or more "external" impacts associated with the resource(s) added. These might include environmental or various social impacts. The CUWA Project

[1]Initial bid amounts ranged from $5 to $20. However, the follow-up portion of the double-bounded question accommodated values as low as $1 or as high as $50, if necessary.

Advisory Committee (PAC) and the consultants determined that, in the context of an agency's resource planning process, these issues would be best treated as costs associated with particular resource additions. Pretests and focus groups conducted during the survey design process indicated that, through proper wording of the survey questions, respondents could, in fact, give answers that were not influenced by such matters.

Because of the complexity of a survey of this type, it was decided to use a combination mail/telephone survey. A package of information was mailed to potential respondents. The mail package contained material that explained the purpose of the survey and helped customers understand the impacts of various shortage magnitudes. Interviewers called several days after the mail material was received.

The survey was conducted from August 1993 through February 1994. The total number of completions across all participating agencies was 3,769.

ANALYTICAL APPROACH

As described earlier, the contingent valuation (CV) survey uses the referendum approach. The referendum approach "bounds" the maximum willingness to pay (WTP) by asking the respondent whether he or she would be willing to pay a specified amount. A "yes" response indicates that the respondent would be willing to pay that amount or more, i.e, it gives a lower bound to the maximum WTP; a "no" response gives an upper bound. The mean WTP to avoid particular shortage scenario can be estimated statistically from responses of different residential customers to different shortage descriptions.

An extension of this approach, and one which is more statistically reliable, is the "double-bounded" technique. The CUWA contingent valuation survey asked respondents whether they would pay an additional monthly amount (or bid) to avoid a particular percentage shortage occurring with a specified frequency. A second choice question, whose bid depended on the answer to the first question, was then asked. If the response to the first question was "yes," then the second bid was an amount greater than the first bid, and if it was "no," the second bid was an amount smaller.

The superior statistical efficiency of the "double-bounded" approach makes intuitive sense given that the "double-bounded" approach yields more information than the "single-bounded" approach about each respondent's preferences. The solution to the

double-bounded model used maximum likelihood techniques, applying a program that was written in GAUSS, a statistical software package widely used by economists and statisticians.

Specification of the Statistical Model

As described above, many questions pertaining to sociodemographic, attitudinal, and perceptual variables were included in the survey. Responses to many of these questions were included as explanatory variables in the statistical model. By doing this, we can see how these factors affect WTP. Figure S-1 describes the key explanatory variables included in the model.

Two statistical models were estimated. The so-called "detailed" model included all of the key explanatory variables discussed above. A "simplified" model included only those variables that can be obtained from census or agency billing records. These include:

- Age
- Household income
- Education level
- Dwelling type
- Household size

To the extent that this simplified model is statistically valid, it will enable agencies to reestimate willingness to pay in the future without resurveying residential customers.

The approach results in the following expression for the mean WTP for each shortage frequency (FREQ) and magnitude (REDUCE) combination:

$$WTP(REDUCE,FREQ) = \frac{\log(1+\exp(\alpha+\beta_1(REDUCE)+\beta_2(FREQ)+\sum \gamma_n X_{mean_n}+\sum \delta_i Z_{prop_i}))}{-\beta_3}$$

Figure S-1
KEY EXPLANATORY VARIABLES

- **Number of years living in area**
- **Household size**†
- **Age**†
- **Income**†
- **Education**†
- **Housing type**†
- **Concern for other public issues**
- **Perception of drought severity**
- **Perception of water shortages as a long-term problem**
- **Awareness of agency mandates to cut back on water use**
- **Home ownership/rental status and water bill responsibility**
- **Amount and type (private or shared) of external landscaping**
- **Population growth preferences**
- **Average residential water rate for respondent's water agency**
- **Northern California or Southern California agency**

†Included in simplified model.

where:

X_{mean} = the mean of those explanatory variables that are not binary (i.e., either zero or one)

Z_{prop} = the proportion of customers for which each of the binary explanatory variables takes on a value of one.

This expression enables us to derive *customer loss functions* that express average customer willingness to pay as a function of shortage magnitude and frequency. Such functions can be a key tool for agency resource planners.

ANALYTICAL RESULTS

Willingness to pay (WTP) can be interpreted as the losses that residential customers incur as a result of particular shortage scenarios. The amount that a customer is willing to pay to avoid an event is a measure of the losses that customer would incur if that event were to occur. Therefore, we refer to these willingness to pay results as a "loss function."

Tables S-1A and S-1B present the mean WTP for the detailed model and the simplified model for each magnitude and frequency of shortage. WTP figures represent increments to monthly water bills.

WTP for the detailed model varies from a low of approximately $11.60/month to avoid either a 10% shortage every 10 years or a 20% shortage once every 30 years, to a high of about $16.90/month to avoid a 50% shortage every 20 years. The results of the simplified model are almost identical to the results of the detailed model. While results for individual agencies do exhibit some differences, the range of WTP estimates is remarkably consistent across all participating agencies.

Table S-1A
MEAN MONTHLY WILLINGNESS TO PAY, DETAILED MODEL
(Additional $/Month)

Shortage (Percent Reduction From Full Service)	Frequency (Occurrences/Years)				
	1/30	1/20	1/10	1/5	1/3
10%			$11.63	$11.98	$12.12
20%	$11.62	$12.33	$13.06		
30%	$13.05	$13.80	$14.57		
40%	$14.56	$15.34	$16.13		
50%	$16.12	$16.92			

Blank cells in the table reflect scenarios that were not part of the survey.

Table S-1B
MEAN MONTHLY WILLINGNESS TO PAY, SIMPLIFIED MODEL
(Additional $/Month)

Shortage (Percent Reduction From Full Service)	Frequency (Occurrences/Years)				
	1/30	1/20	1/10	1/5	1/3
10%			$11.67	$12.00	$12.14
20%	$11.71	$12.39	$13.08		
30%	$13.13	$13.84	$14.56		
40%	$14.61	$15.35	$16.10		
50%	$16.15	$16.92			

Blank cells in the table reflect scenarios that were not part of the survey.

The "loss function" is shown graphically in Figure S-2. In examining the tabular and graphical results, two major conclusions can be drawn:

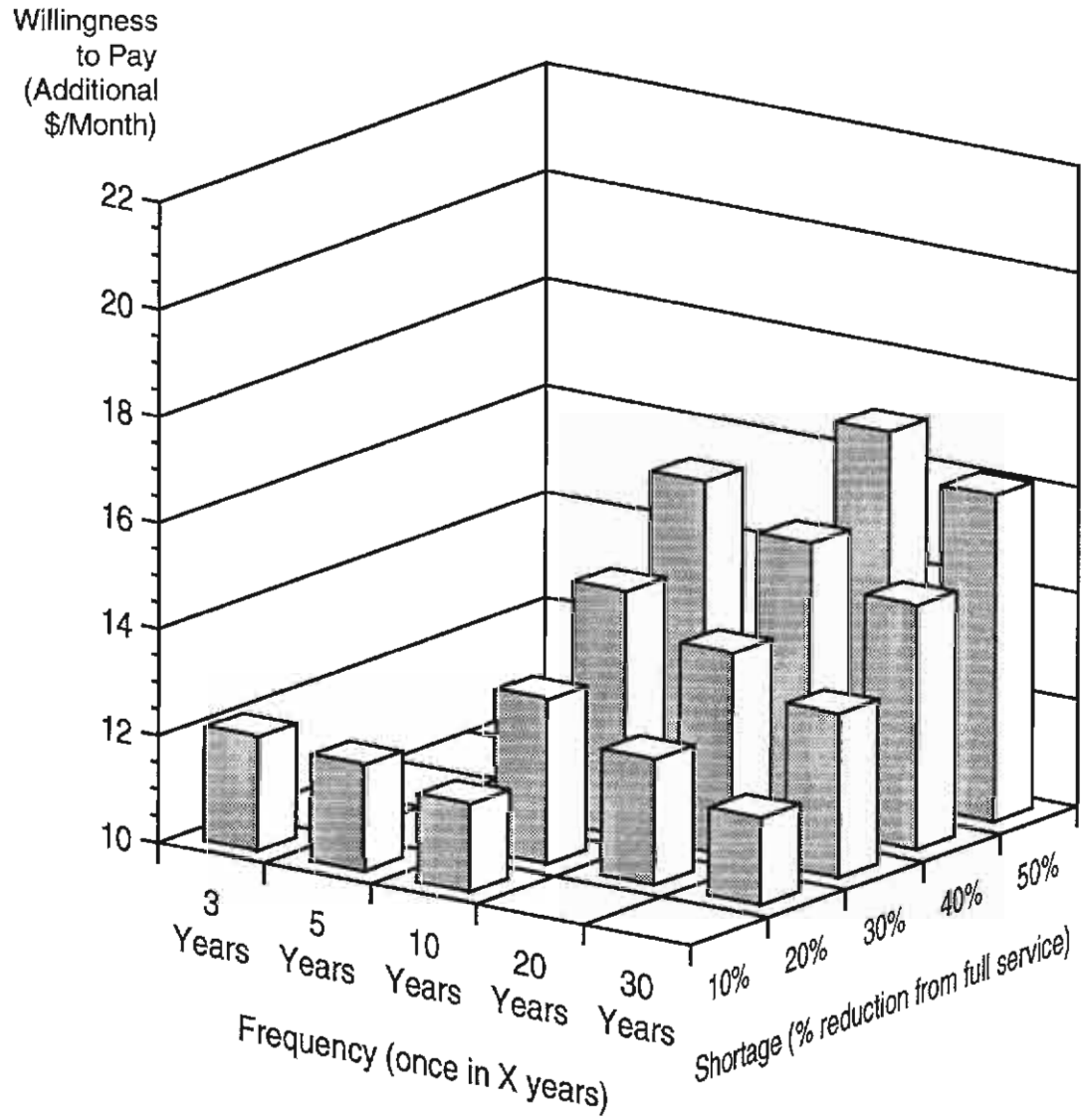
- As expected, respondents are willing to pay more to avoid larger shortages and for shortages that occur with higher frequency. However, the impact of frequency variations is considerably smaller than the impact of shortage magnitude on consumers' responses.

  Put another way, it appears that residential customers believe that infrequent large shortages impose higher losses than more frequent small shortages. This result is also consistent across all of the individual agencies. This type of conclusion may be important to agencies as they plan supply-side or demand-side resource additions and make system operations decisions.

- To avoid even apparently minor shortage scenarios (e.g., 10% once every 10 years), respondents are willing to pay substantial amounts. This type of "threshold" response is not uncommon in surveys of this type and may indicate that respondents regard even a mild shortage scenario as an inconvenience that they want to avoid. They may make a greater distinction between "shortage" and "no shortage" than between different magnitude or frequencies of shortages. Again, this pattern of responses holds for all participating agencies.

Figure S-2

Mean Monthly Willingness to Pay to Avoid Particular Shortage Frequencies and Magnitudes



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Impact of Key Explanatory Variables on Willingness to Pay

As described previously, the statistical model includes many variables that could potentially explain the variation in willingness to pay. For example, the variable "RATE" was included to determine if the average residential rate charged by the respondent's water agency affected WTP. The impact of this variable was not statistically distinguishable from zero. The following discussion selects three explanatory variables that are statistically significant and illustrates their impact on WTP.

Figures S-3 to S-5 show the variation of WTP at various shortage magnitudes when all other variables, other than the one in question, are held constant.

Landscape Area

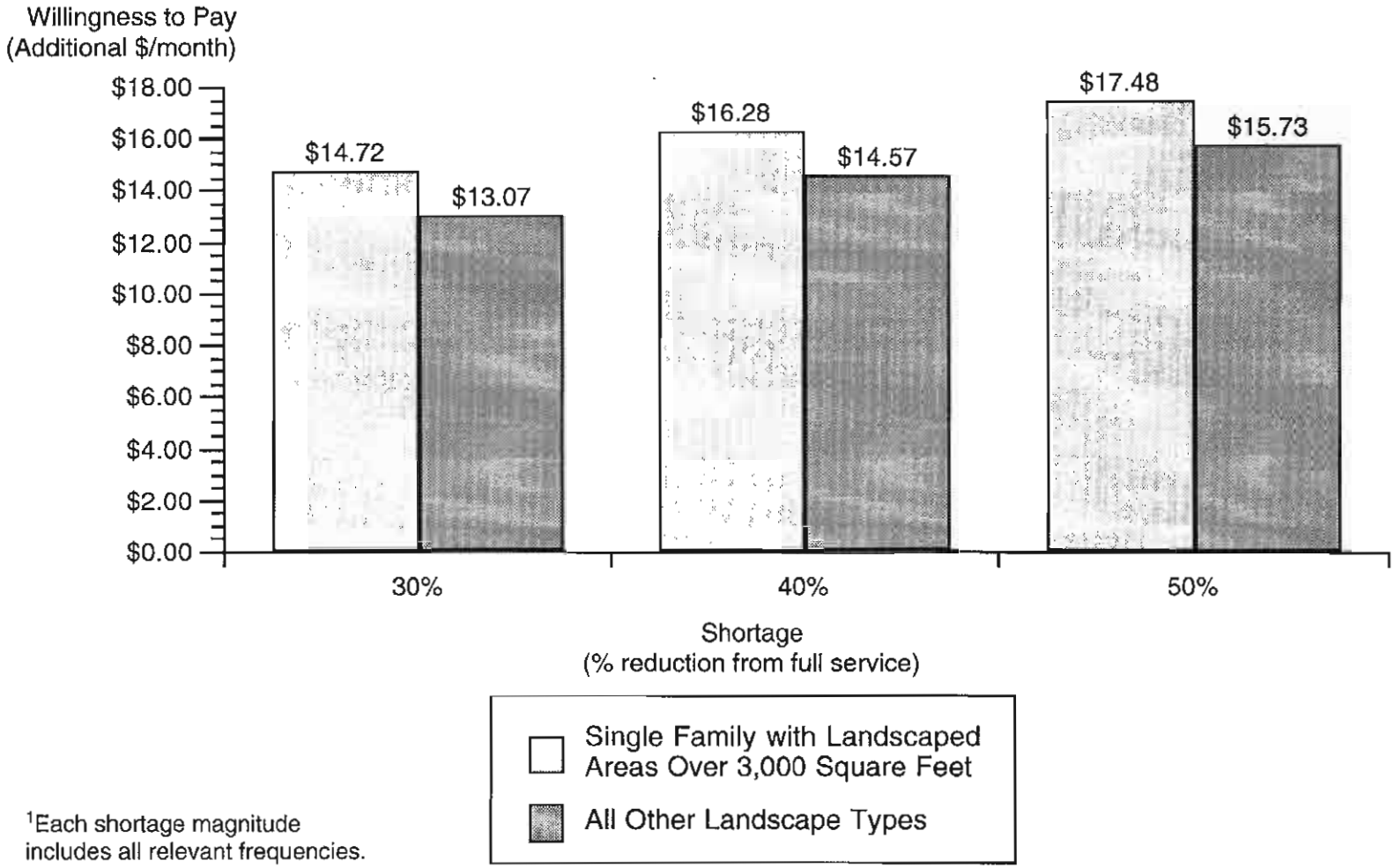
Not unexpectedly, the quantity and type of outdoor landscaping has a statistically significant influence on respondents' willingness to pay to avoid future shortages. Figure S-3 illustrates this by using the variables in the model that capture variations in landscaped area. The results show that respondents who have private lots with landscapes larger than 3,000 square feet have higher WTP than families with other types of landscaping.

Growth Preferences

Another interesting relationship is demonstrated in Figure S-4, which shows the relationship between participant feelings about community growth and their willingness to pay to avoid water shortages. Individuals who indicate a desire for their communities to grow in size have a higher WTP than do people who want their communities to stay the same size or to get smaller. Many in the latter group may perceive a relationship between water resource development and growth and are therefore more likely to prefer enduring more severe and/or frequent water shortages rather than adding to the resource base.

Figure S–3

Effect of Landscape Characteristics on Willingness to Pay[1]



[1]Each shortage magnitude includes all relevant frequencies.

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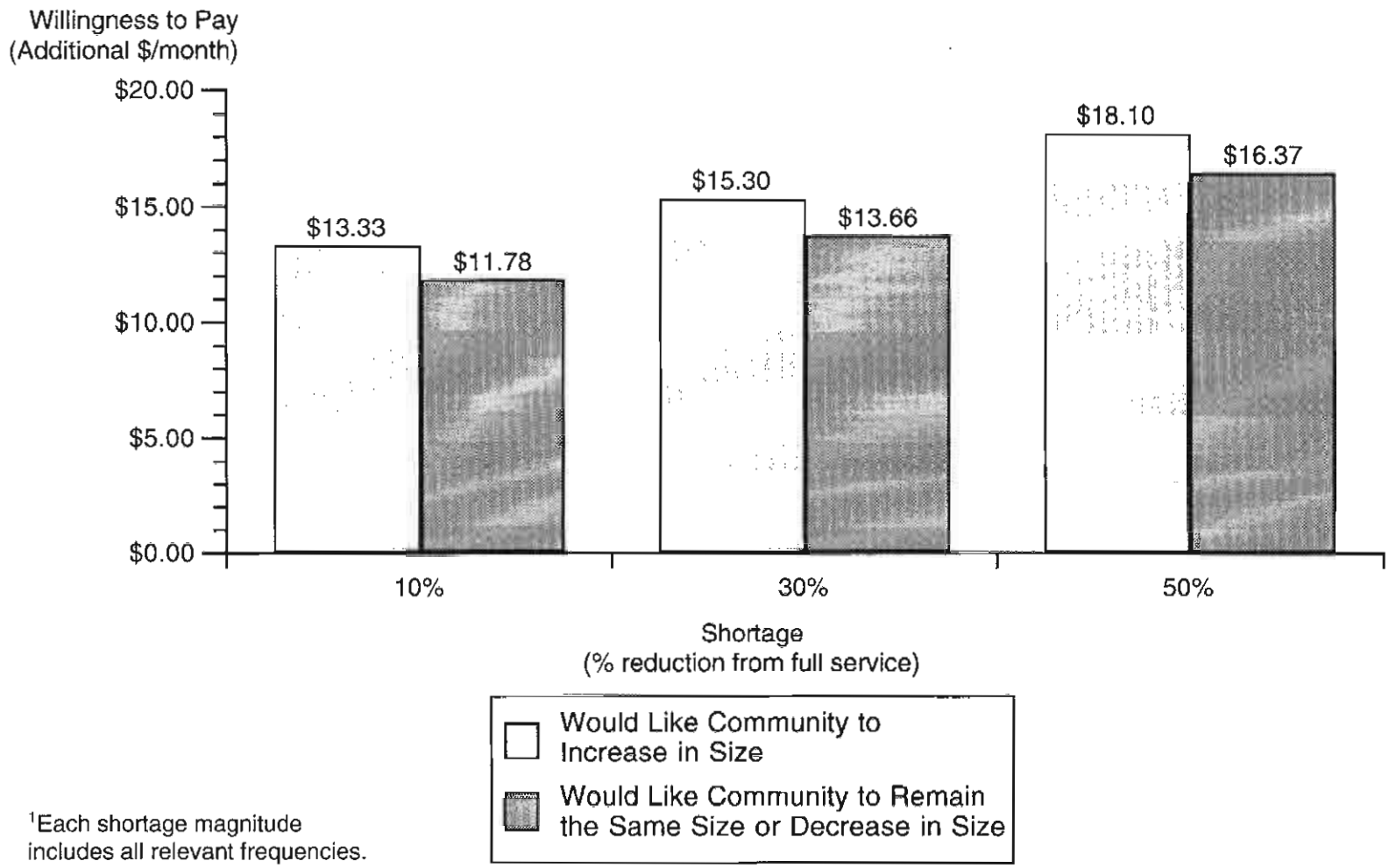
Figure S–4

Effect of Population Growth Preferences on Willingness to Pay[1]



[1]Each shortage magnitude includes all relevant frequencies.

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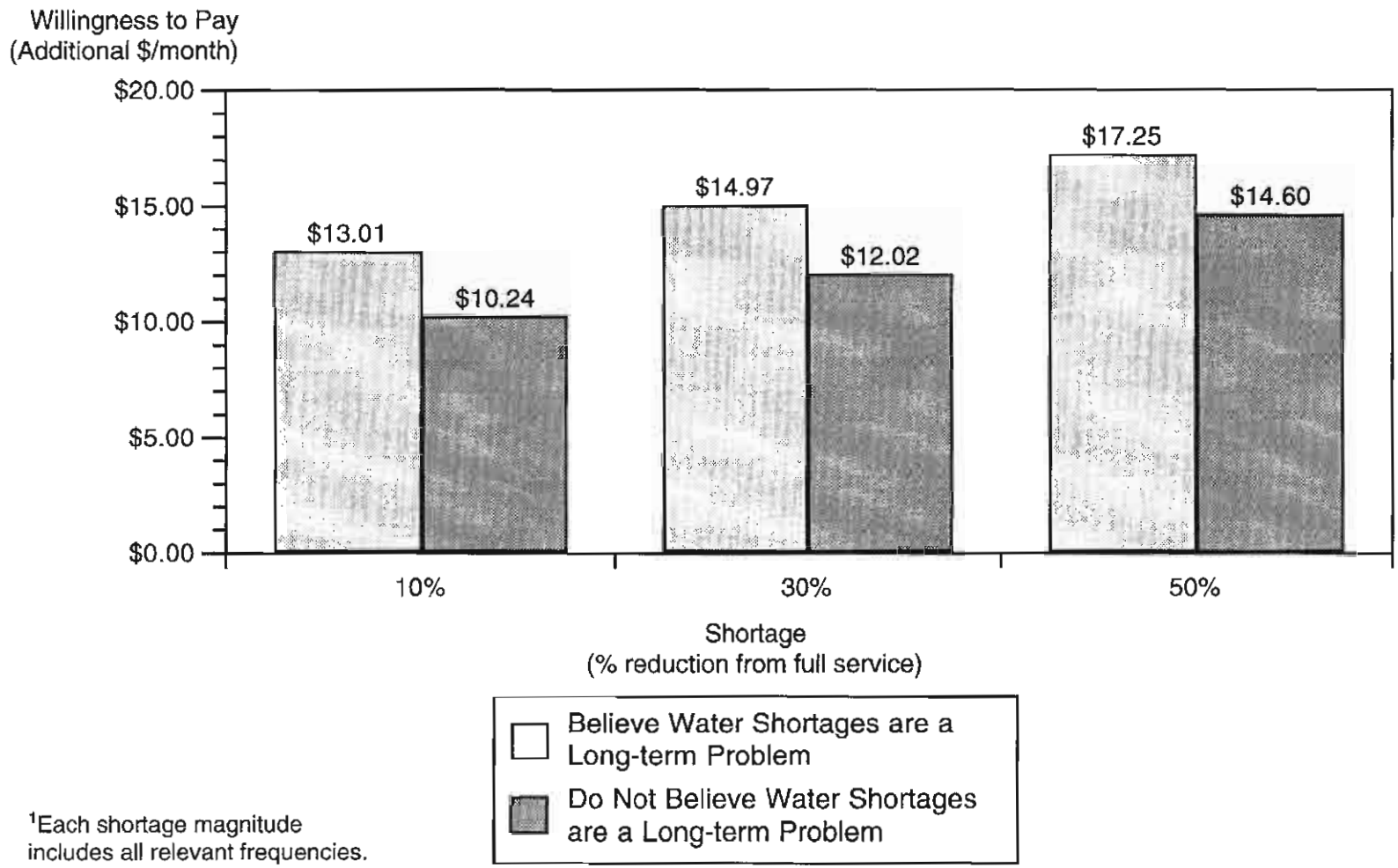
Figure S–5

Effect of Perception of Water Shortages as a Long-term Problem on Willingness to Pay



[1]Each shortage magnitude includes all relevant frequencies.

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Perception of Water Shortages as a Long-Term Problem

Survey respondents were asked to what extent they considered water shortages to be a long-term problem in their area. Those who considered the water shortages to be a long-term problem have higher WTP than those who do not. WTP for these two groups is illustrated in Figure S-5.

Regional Comparisons

An analysis was done to determine whether Northern California respondents had different WTP than Southern California respondents. To isolate the variation that is due to regional differences, a variable NORTH was included in the model. The variable was set equal to 1 if the respondent was in the service area of:

- Alameda County Water District
- Contra Costa Water District
- San Francisco Public Utilities Commission
- Santa Clara Valley Water District

The variable was set to 0 if the respondent was in the service area of:

- Los Angeles Department of Water and Power
- Metropolitan Water District of Southern California
- Municipal Water District of Orange County
- Orange County Water District
- San Diego County Water Authority
- City of San Diego

Although all Southern California mean values are slightly lower than the corresponding Northern California mean values, the variable "North" was not statistically different from zero.

Separate models were then run for the Northern California and Southern California agencies to determine whether, apart from a difference that could be attributed to living in Northern or Southern California, there were demographic and attitudinal differences that were captured in other model variables and that resulted in different estimates of WTP for the two populations. The results, illustrated in Table S-2, indicate no significant differences in WTP.

Table S-2
MEAN MONTHLY WILLINGNESS TO PAY, BY REGION
(Additional $/Month)

Shortage (% Reduction from Full Service)	Frequency (One Occurrence in X Years)	Northern California	Southern California
10%	10	$12.32	$11.13
10%	5	$12.70	$11.50
10%	3	$12.85	$11.64
20%	30	$12.10	$11.19
20%	20	$12.85	$11.93
20%	10	$13.63	$12.68
30%	30	$13.40	$12.75
30%	20	$14.19	$13.52
30%	10	$14.99	$14.32
40%	30	$14.75	$14.38
40%	20	$15.57	$15.20
40%	10	$16.40	$16.02
50%	30	$16.15	$16.09
50%	20	$16.99	$16.93

The confidence interval for the Southern California model is +/- $0.51; the confidence interval for the Northern California model is +/-$0.63. Except at the 10% shortage magnitude, the differences all fall within the overlapping confidence intervals. Given that the confidence interval is underestimated at that level because there are fewer observations, it is likely that the actual confidence intervals overlap at the 10% shortage as well and that there is therefore no statistically significant difference in WTP between Northern and Southern California respondents.

Water Shortages as a Public Concern

In the survey, respondents were asked to rate the importance of various public problems, including water shortages, as "not at all important," "somewhat important," or "very important." There were three reasons for asking this question:

- To analyze the extent to which concern with any given set of issues (e.g., financial issues) affected willingness to pay.

- To test the perceived importance of water shortages relative to other public issues.

- To see how respondents categorized water shortages. With what other issues are water shortages associated?

Overall, the mean response for each issue is illustrated in Table S-3.

Water shortages fall in the middle of the list of concerns.[2]

The factor analysis showed that respondents grouped issues as illustrated in Table S-4. Water shortages fall into the category that includes issues that can best be described as having public service components. The factors are ranked within each category according to the strength of their rating in the factor analysis.

Each of the four factors was included in the model as a binary variable to test its explanatory impact on WTP.[3] Each of these variables was assigned the value of 1 if the mean value of all of a respondent's ratings for the issues included in that factor exceeded the value assigned to the water shortage issue, and zero otherwise. For the combined CUWA results, the social concerns, quality of life, and financial factors are statistically significant in explaining WTP. Respondents who placed any of those concerns above their concern for water shortages had lower WTP.

---

[2]It is possible that had this survey been conducted a year earlier, when the state was still in the grip of a serious drought, water shortages would have been viewed as much more of a concern.

[3]The "public services/environmental" factor included in the model excluded the water shortages variable.

Table S-3
ISSUE RANKING AND MEAN RESPONSE

Issue	Mean Rating	Standard Error
Economy	2.66	.0095
Drug abuse	2.38	.0126
Education	2.35	.0136
Housing costs	2.32	.0122
Taxes	2.31	.0123
Traffic	2.29	.0122
Crime	2.26	.0122
Drinking water quality	2.18	.0138
Water shortages	**2.17**	**.0129**
Air pollution	2.08	.0124
Homelessness	1.98	.0130
Overcrowding	1.92	.0129
Trash disposal	1.88	.0138
Racial issues	1.73	.0126

Table S-4
FACTOR ANALYSIS OF PUBLIC ISSUES

Public Services Concerns	Social Concerns	Quality of Life Concerns	Financial Concerns
Trash disposal	Crime	Overcrowding	Taxes
Education	Racial issues	Traffic	Economy
Water shortages	Drug abuse	Air pollution	
Homelessness			
Drinking water quality			

SUMMARY OF KEY CONCLUSIONS

The important conclusions that can be drawn from the analysis are as follows:

- Monthly willingness to pay higher residential water bills to avoid shortages ranged from $11.60 to $16.90. Individual agency results, while exhibiting some variation, are generally consistent with this range.

- As expected, respondents' willingness to pay increases with increasing magnitude and frequency of shortages.

- To avoid even apparently minor shortage scenarios (e.g. 10% once every 10 years), respondents are willing to pay substantial amounts. This type of "threshold" may indicate that respondents regard even a mild shortage scenario as an inconvenience that they want to avoid. They may make a greater distinction between "shortage" and "no shortage" than between different sizes or frequencies of shortages.

- Shortage frequency is not as important a determinant of willingness to pay as shortage magnitude. Residential customers appear to be more willing to tolerate frequent small shortages than infrequent large ones.

- There are no significant differences in willingness to pay between Northern California and Southern California respondents.

- The simplified model has virtually the same predictive power as the detailed model. Participating agencies who wish to replicate this type of analysis in the future can therefore use the simplified model rather than resurveying their customers to gather data on the remaining variables required for the detailed model.

Source: California Invasive Plant Council

URL of this page: **http://www.cal-ipc.org/ip/management/ipcw/pages/detailreport.cfm@usernumber=8&surveynumber=182.php**

Invasive Plants of California's Wildland

Arundo donax

Scientific name	***Arundo donax***
Additional name information:	(L.)
Common name	giant reed, giant cane
Synonymous scientific names	none known
Closely related California natives	0
Closely related California non-natives:	0
Listed	CalEPPC List A-1,CDFA noxious
By:	Thomas Dudley

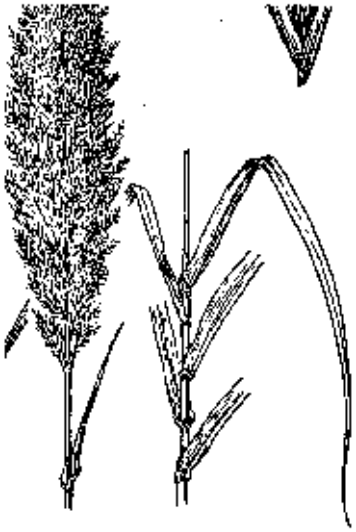
Distribution

HOW DO I RECOGNIZE IT?

Distinctive features: Giant reed (*Arundo donax*) is a robust perennial grass nine to thirty feet tall, growing in many-stemmed, cane-like clumps, spreading from horizontal rootstocks below the soil, and often forming large colonies many meters across. Individual stems or culms are tough and hollow, divided by partitions at nodes like bamboo. First-year culms are unbranched, with single or multiple lateral branches from nodes in the second year. The pale green to blue-green leaves, which broadly clasp the stem with a heart-shaped base and taper to the tip, are up to two feet or more in length. Leaves are arranged alternately throughout the culm, distinctly two-ranked (in a single plane). Giant reed produces a tall, plume-like flowerhead at the upper tips of stems, the flowers closely packed in a cream to brown cluster borne from early summer to early fall. Culms may remain green throughout the year, but often fade with semi-dormancy during the winter months or in drought. Giant reed can be confused with cultivated

bamboos and corn, and in earlier stages with some large-stature grasses such as *Leymus* (ryegrass), and especially with *Phragmites* (common reed), which is less than ten feet tall and has panicles less than one foot long with long hairs between the florets.

Description: Poaceae. Stems: 30 ft (<9 m) tall, stems erect, hollow, and glabrous 1.6 in (<4 cm) in diameter with somewhat swollen nodes; thick, fleshy rhizomes form creeping rootstocks, yielding dense colonies. Leaves: cauline, sheaths > internodes, ligule thinly membranous and fringed with hairs; blade <3.3 ft (<1 m), 0.8-2.4 in (2-6 cm) wide at base, tapering to a sharp tip, flat or folded, margins scabrous; leaves alternate and conspicuously two -ranked.



Inflorescence: as terminal panicle 1-2 ft (30-60 cm) with branches ascending, silver-cream-brown, the numerous spikelets laterally compressed; glumes > florets, membranous and 3-5 veined; florets 4-5, breaking above glumes; lemma 0.3-0.5 in (8-12 mm) and hairy, nerves ending in slender teeth, the middle forming an inconspicuous awn; palea < lemma, 0.12-0.2 in (3-5 mm); anthers 0.1-0.12 in (2.5-3 mm). It does not form viable achenes in North America (Hickman 1993).

WHERE WOULD I FIND IT? Giant reed occurs in central and southern California and in Baja California, usually below 1,000 feet (350 m) elevation. It has invaded central California river valleys in San Luis Obispo and Monterey counties, the San Francisco Bay Area, and in the Sacramento and San Joaquin River valleys, and is also increasing in the North Coast region (Dudley and Collins 1995). Giant reed has been the most serious problem in coastal river drainages of southern California, especially in the Santa Ana, Santa Margarita, Santa Clara, Tijuana, and other major and minor watersheds, where it sometimes occupies entire river channels from bank to bank (Jackson et al. 1994, Bell 1998). Although not currently considered a problem in California deserts, giant reed survives in regularly watered areas of lower-elevation deserts, but does not appear to tolerate high-elevation and continental environments where regular freezing occurs (Sunset 1967).

Giant reed is naturalized and invasive in many regions, including southern Africa, subtropical United States through Mexico, the Caribbean islands and South America, Pacific Islands, Australia, and Southeast Asia (Hafliger and Scholz 1981). In California, the largest colonies occur in riparian areas and floodplains of medium-sized to large streams, from wet sites to dry river banks far from permanent water. Giant reed tends to favor low-gradient (less that 2 percent) riparian areas over steeper and smaller channels, but scattered colonies are found in moist sites or springs on steeper slopes.

Populations also occur in the upper estuaries of coastal streams. It is often found along drainage ditches, where the plant has been used for bank stabilization, and in other moist sites, including residential areas where giant reed is used horticulturally. While it is usually associated with rivers that have been physically disturbed and dammed upstream, giant reed also can colonize within native stands of cottonwoods, willows, and other riparian species, even growing in sites shaded by tree canopy. Plants establish primarily in streamside sites, but expand beyond the margins of riparian vegetation.

Soil preferences are broad, as giant reed is known from coarse sands to gravelly soil to heavy clays and river sediments. It grows best in well drained soil with ample moisture, from freshwater to semi-saline soils at margins of brackish estuaries. In Egypt, Rezk and Edany (1979) found that *Arundo donax* tolerates both higher and lower water table levels than *Phragmites australis*, which is native to California.

WHERE DID IT COME FROM AND HOW IS IT SPREAD?

Three species of *Arundo* occur worldwide in tropical to warm temperate regions. *A. donax* is often considered indigenous to the Mediterranean Basin (Hickman 1993) or to warmer regions of the Old World, but apparently it is an ancient introduction into Europe from the Indian sub-continent (Bell 1998). In Eurasia it similarly inhabits low-gradient river courses and may provide useful wildlife habitat in greatly altered river deltas (Granval et al. 1993, He 1991).

Giant reed was brought to North America quite early, as it was abundant by 1820 in the Los Angeles River, where it was harvested for roofing material and fodder. This plant has played an important role in the development of music, as the cane was the source of the original Pan pipe or syrinx, and remains the source of reeds for woodwind instruments (Perdue 1958). Commercial plantations exist in California for musical instrument production, and other commercial possibilities are being explored. Horticultural propagation is widely conducted, and varieties of Arundo are available and commonly used in gardens or for erosion control (Sunset 1967). Invasive populations almost certainly resulted from escapes and displacement of plants from managed habitats. It spreads vegetatively either by rhizomes or fragments.

WHAT PROBLEMS DOES IT CAUSE?

Giant reed displaces native plants and associated wildlife species because of the massive stands it forms (Bell 1994, Gaffney and Cushman 1998). Competition with native species has been shown to result from monopolization of soil moisture and by shading (Dudley unpubl. data). It clearly becomes a dominant component of the flora, and was estimated to comprise 68 percent of the riparian vegetation in the Santa Ana River (Douthit 1994). As giant reed replaces riparian vegetation in semi-arid zones, it reduces habitat and food supply, particularly insect populations, for several special status species such as least Bell's vireo, southwestern willow flycatcher, and yellow-billed cuckoo (Frandsen and Jackson 1994, Dudley and Collins 1995). Unlike native riparian plants, giant reed provides little shading to the in-stream habitat, leading to increased water temperatures and reduced habitat quality for aquatic wildlife. At risk are protected species such as arroyo toad, red-legged frog, western pond turtle, Santa Ana sucker, arroyo chub, unarmored three-spined stickleback, tidewater goby, and southern steelhead trout, among others (Franklin 1996). In the Sacramento-San Joaquin Delta region *Arundo donax* interferes with levee maintenance and wildlife habitat management (Perrine, pers. comm.).

Giant reed is also suspected of altering hydrological regimes and reducing groundwater availability by transpiring large amounts of water from semi-arid aquifers. It alters channel morphology by retaining sediments and constricting flows, and in some cases may reduce stream navigability (Lake, pers. comm., TNC 1996).

Dense growth presents fire hazards, often near urbanized areas, more than doubling the available fuel for wildfires and promoting post-fire regeneration of even greater quantities of giant reed (Scott 1994, Gaffney and Cushman 1998). Uprooted plants also pose clean-up problems when deposited on banks or in downstream estuaries (Douthit 1994) and during floods create hazards when trapped behind bridges and other structures. Although often planted for erosion control, giant reed can promote bank erosion because its shallow root system is easily undercut and bank collapse may follow.

HOW DOES IT GROW AND REPRODUCE?

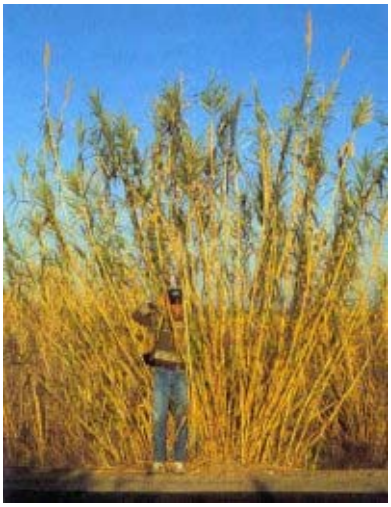
Plants in North America do not appear to produce viable seed, and seedlings are not seen in the field. Population expansion here occurs through vegetative reproduction, either from underground rhizome extension of a colony or from plant fragments carried downstream, primarily during floods, to become rooted and form new clones. Horticultural propagation is routinely done by planting rhizomes, which readily establish, but stems with no basal material are less likely to root. Fresh stems form roots at nodes under laboratory conditions, but survival is poor (Zimmerman and Bunn unpubl. data), and root formation does occur where an attached culm has fallen over and is in contact with the substrate.

[ip/management/ipcw/images/4981.jpg]

New shoots arise from rhizomes in nearly any season, but are most common in spring. Growth likewise occurs in all seasons, but is highly sensitive to temperature and moisture

(click on photos to view larger image)

(Perdue 1958). During warm months with ample water culms are reported to attain growth rates of 2.3 feet (70 cm) per week or about four inches (10 cm) per day, putting it among the fastest growing terrestrial plants. Biomass production has been estimated at 8.3 tons dry weight per acre (Perdue 1958). Young stems rapidly achieve the diameter of mature canes, with subsequent growth involving thickening of the walls (Perdue 1958).



[ip/management/ipcw/images/4983.jpg]

Age of individual culms is certainly more than one year, and branching seems to represent stem growth in later years, while rhizomes show indeterminant growth. Branches also form when a stem is cut or laid over. Dieback is infrequently observed, but culms fade or partially brown out during winter, apparently becoming dormant under cold conditions. The outstanding growth trait of this plant is its ability to survive and grow at almost any time under a wide variety of environmental conditions.

HOW CAN I GET RID OF IT?

Studies of giant reed invasion in California are underway, so more data on its biology and management will be available soon. For further information about monitoring and managing infestations, contact Team Arundo in southern California or Team Arundo del Norte in central and northern parts of the state (see Resources section).

Physical control:

Manual methods: Minor infestations can be eradicated by manual methods, especially where sensitive native plants and wildlife may be damaged by other methods. Hand pulling is effective with new plants less than six feet (2 m) in height, but care must be taken that all rhizome material is removed. This may be most effective in loose soils and after rains have made the substrate workable. Plants can be dug up using hand tools (pick-ax, mattock, and shovel), especially in combination with cutting of stems near the base with pruning shears, machete, or chainsaw. Stems and roots should be removed or burned on site to avoid re-rooting, or a chipper can be used to reduce material, although clogging by the fibrous material makes chipping difficult (Dale, pers. comm.). For larger infestations on accessible terrain, heavier tools (rotary brush -cutter, chainsaw, or tractor-mounted mower) may facilitate biomass reduction, followed by rhizome removal or chemical treatment. Such methods may be of limited use on complex or sensitive terrain or on slopes over 30 percent, and may interfere with reestablishment of native plants and animals.

Mechanical methods: Mechanical eradication is extremely difficult, even with a backhoe, as rhizomes buried under three to ten feet (1-3 m) of alluvium readily resprout (R. Dale, pers. comm., Else et al. 1996). Removal of all such material is infeasible, especially where extensive soil disturbance would be disruptive.

Prescribed burning: In most circumstances burning of live or chemically treated material should not be attempted, as it cannot kill the underground rhizomes and probably favors giant reed regeneration over native riparian species (Gaffney and Cushman 1998). Burning in place is problematic because of the risks of uncontained fire, the possibility of damage to beneficial species, and the difficulties of promoting fire through patchily distributed stands. There may be some cases where burning of attached material can be done, but only if other means of reducing biomass cannot be carried out. Cut material is often burned on site, subject to local fire regulations, because of the difficulty and expense involved in collecting and removing or chipping all material.

Biological control:

Insects and fungi: No biological control agents against *Arundo donax* have been approved by the USDA, although some invertebrates are known to feed on the grass in Eurasia/Africa (Tracy and DeLoach 1999). The green bug (*Schizaphiz graminum*) has been observed to feed on giant reed in winter (Zuniga et al. 1983). In France Phothedes dulcis caterpillars may feed on it. The insect *Zyginidia guyumi* uses giant reed as an important food source in Pakistan (Ahmed et al. 1977). A moth borer (*Diatraea saccharalis*) has been reported to attack it in Barbados. A USDA evaluation of the potential benefits of biological control against giant reed ranked it as a promising candidate and suggested several insects and pathogens as possible control agents (Tracy and DeLoach 1999).

Grazing: Vertebrate grazers such as cattle and sheep may be useful in controlling giant reed, and Angora goats have been partially successful in reducing this plant and other brush in southern California (Daar 1983). Grazers are unlikely to reduce population size sufficiently to eliminate the risks posed. Likewise, management of native plants to increase competition with giant reed probably provides insufficient control, and in fact seems to offer little resistance against the invading reeds.

Chemical control:

In many, if not all, situations it may be necessary to use chemical methods to achieve eradication, especially in combination with mechanical removal. The most common herbicidal treatment against giant reed is glyphosate, primarily in the form of RodeoÂ®, which is approved for use in wetlands (Round-UpÂ® can be used away from water). Because glyphosate is a broad-spectrum herbicide, care should be taken to avoid application or drift onto desirable vegetation. The standard treatment is a foliar spray application of 1.5 percent by volume glyphosate with a 0.5 percent non-ionic surfactant (Monsanto 1992). Most effective application is post-flowering and pre-dormancy, usually late August to early November when plants are translocating nutrients into root and rhizomes (TNC 1996). Foliar uptake and kill may be achieved by spray application during active growth periods, primarily late spring through early fall (Monsanto 1992). Small patches can be treated from the ground using backpack or towed sprayers, and major infestations have been aerially sprayed using helicopters.

Direct treatment to cut culms can reduce herbicide costs and avoid drift onto desirable plants, with fair results year-round and best kill in fall, although it appears to be more successful in shaded sites (Else et al. 1996, Vartanian, pers. comm.). Concentrated glyphosate solution (50 percent to 75 percent Rodeo, or 27 percent to 40 percent glyphosate is applied to stems, cut within two to four inches (5-10 cm) of the substrate, by painting with a cloth-covered

wand or a sponge or spraying with a hand mister. It may be helpful to add a dye or food coloring to the solution to identify treated material. Solution must be applied immediately following cutting because translocation ceases within minutes of cutting; a five-minute maximum interval is suggested (TNC 1996).

New growth is sensitive to herbicides, so a common alternative is to cut or mow a patch and allow regeneration, returning three weeks to three months later when plants are three to six feet (1-2 m) tall to treat new growth by foliar spraying of glyphosate. Promoting regrowth causes nutrients to be drawn from the roots, potentially reducing the movement of glyphosate to the roots (TNC 1996). With all methods, follow-up assessment and treatment should be conducted, and some professional applicators suggest six return spot treatments over six months (Van Diepen, pers. comm.). Other chemical control methods have been tested, including paraquat and triclopyr compounds (Arnold and Warren 1966, Horng and Leu 1979, Franklin 1996), but are not recommended near water.

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VALUING WATER SUPPLY RELIABILITY

RONALD C. GRIFFIN AND JAMES W. MJELDE

Instead of creating water supply systems that fully insulate mankind from climate-imposed water deficiencies, it is possible that for municipal water systems a nonzero probability of water supply shortfall is efficient. Perfect water supply reliability, meaning no chance of future shortfall, is not optimal when water development costs are high. Designing an efficient strategy requires an assessment of consumer preferences pertaining to the reliability of water supply. Contingent valuations of both current and future shortfalls are reported. The consistency of these measures is gauged using an expected utility model.

Key words: reliability, water demand, water policy.

An important dimension of the water scarcity problem is the management of water supply risk, especially as it relates to drought. The traditional management practice for controlling urban water supply risk has been one of avoidance, that is, to develop a sufficiently large water supply that the probability of any tangible shortfall is very small. In light of the high and growing costs of water development, it may be sensible to revise the water planning paradigm, so that periodic shortfalls are regarded as acceptable, even planned, events.

In the municipal water use sector, there is an innate tendency to size the water supply system for severe droughts of low probability (Howe and Smith). Water is usually supplied by an entity that faces no competition and has the legal ability to pass all reasonable costs to consumers. Moreover, water supply systems are operated by people whose performance is gauged by their ability to deliver a dependable, steady, and problem-free water supply. They are not judged by their ability to deliver water that has value in excess of its costs. Consequently, the reliability[1] of water systems may be too high, water supplies dedicated to municipal use may be too great, and infrastructure costs may be too large.

Given that available water is physically limited in many regions, when municipalities increase water system reliability, they are shifting risk to nonmunicipal sectors. Obviously, some water users must incur the shortfall during drought situations. Traditionally, risk has been progressively shifted to the riparian and estuary habitat systems. These natural resource systems have become the residual claimants, possessing only what is left after man has diverted water to satisfy his wants. Recently, public policy emphasis on streamflow protection has begun to reverse this tradition (MacDonnell and Rice). One result may be the redistribution of water supply risk back toward municipalities, thereby increasing the importance of risk-attentive water supply planning.

Three dimensions of reliability analysis are addressed here. First, policy options and consumer behavior relevant to water system reliability are discussed. Second, the theory of optimizing water system reliability is briefly restated and refined. This basic theory outlines a method for optimizing reliability and identifies informational needs. Finally and primarily, contingent valuation analyses of modified reliability are presented.

Reliability Policy and Consumer Behavior

To affect water system reliability, managers can (*a*) adjust the long-run supply of water, (*b*) enhance the short-run supply of water during a shortfall event, (*c*) influence the long-run demand for water by consumers, and (*d*) lessen water demand during a shortfall. Rather than being viewed as substitute approaches, the appropriate planning goal is to develop an efficient package of all options.

The authors are professors in the Department of Agricultural Economics at Texas A&M University.

Appreciation is expressed to Mike Bowker for his advice and critiques of our survey instrument and to the Texas Water Development Board for funding support.

[1] The reliability of a water supply system is commonly regarded as inversely related to the probability of a system shortfall (demand > supply).

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On the supply side, both physical and paper components of a water supply can be adjusted. While the physical components are generally well acknowledged, various paper components (such as water rights, storage permits, contracts with other water suppliers, and dry-year options) represent an increasingly important dimension of planning tools. Either physical or paper components can be modified to adjust long-run water supply reliability, but these supply-side tools are limited for short-run water supply adjustments. Only rapidly executable leases with water right holders or contracts with other water suppliers are practical short-run tools.

Demand management tools have substantial relevance as both long- and short-term measures. Long-run policy options include regulations (e.g., plumbing codes requiring the installation of water-conserving fixtures), education programs, and water pricing. Short-run demand tools involve contingency policies such as water use regulations (e.g., alternate day watering), prohibitions, and pricing. Because of the relative impracticality of most supply policies during shortfall events, demand-based options have enhanced relevance in the short run.

In response to both long-run and short-run policies, consumers make decisions that are broader than merely how much water to consume. Households choose additions to and replacements of their water-using durables. The major durables of consequence are plumbing fixtures, appliances, pools, sprinklers, and lawn/landscaping. These durables are available in different sizes, models, and properties that influence water use and the ability of consumers to continue using durables during water supply shortfalls. Water use associated with a given durable is largely a fixed multiple of its operating time, so important determinants of household water use become less flexible when the household commits to the purchase/installation of each water-using durable. Long-run demand management policies influence these commitments (Dubin, Wirl).

Lawns and landscape plants are unique with respect to their interrelationship with water supply reliability. Lawns and landscaping are durables established for visual and aesthetic satisfaction. This satisfaction flows to residents continually, rising or falling according to the condition of the lawn/landscape. Long water supply shortfalls can depreciate or extinguish lawns and landscaping, thereby lowering their future net benefits. This implies that there may be instances in which consumers attach high value to avoiding a severe, yet transitory shortfall, because they wish to avoid diminished present and future net benefits.

These simple observations disclose important interrelationships among water supply reliability, the value of reliability, water-using durables, and the value of these durables. When making commitments to specific durables, the consumer is implicitly mindful of water price and supply policy. Consumers likely form expectations of future price and reliability based on recent experience and, perhaps, trends. Once a set of durables is acquired by the household, prospective increases in reliability offer little short-run value because the durable base is fixed. On the other hand, decreased reliability constrains the satisfaction available from the accumulated durable base. Thus, consumers have asymmetric attitudes toward increases and decreases in reliability. The change in value for an increase in reliability can be expected to be less, in absolute value, than the change in value for an equivalently measured reliability fall. This asymmetry is likely to be more pronounced in the short run where, by definition, the durable base is fixed. For this reason, as well as the wealth effect, it should be expected that equivalent surplus exceeds compensating surplus for reliability improvements.

Optimizing Reliability

Although interest in water supply reliability is increasing (Lund), there are few empirical studies of the value households associate with the reliability of their water supply. Using a mailed survey in three Colorado cities, Howe et al. asked open-ended willingness-to-pay (WTP) and willingness-to-accept (WTA) questions about modifications to the frequency of a standard annual shortage event (SASE). They define a SASE to be a supply shortfall sufficient to cause the temporary use of a specific lawn watering restriction. An advantage of this approach is that the SASE offers a very tangible and known situation for the surveyed population.

Barakat & Chamberlin, Inc. report a WTP analysis of increased reliability performed for ten California water utilities. This contingent

valuation study uses a combination mail–telephone survey to obtain double-bounded dichotomous choice data. Households are asked if they would pay a specified amount per month to eliminate future shortfalls of a specified strength and frequency. Because the elimination of shortfalls is not a realistic planning scenario, the Barakat & Chamberlin, Inc. findings should be interpreted as upper bounds for consumer valuations pertaining to modified shortfall scenarios.

Howe and Smith et al. present some basic theory outlining the optimal selection of water supply level. A noteworthy observation about their theory, which distinguishes it from leading theory regarding optimal energy supply reliability, is that it sets aside the potential role of price in managing excess demand during shortfall events (Crew and Kleindorfer 1976, 1978, Marino, Meyer). The energy research on optimal reliability addresses the collaborative role of pricing and investment for achieving an optimal policy. The absence of price control in the Howe and Smith et al. theory can be criticized, but water managers remain far more concerned about appropriate concrete and pipe solutions than they are about establishing proper prices. Moreover, for stochastic settings, resource allocation by price may be economically inferior to quantity-based policy such as rationing rules (Weitzman).

A theoretical model offered by Howe and Smith et al. focuses on the concept of SASE. This model posits that the probability of occurrence for the SASE in period t is a decreasing function of supply-side investment I:

$$(1)\quad \text{Prob}\{\text{SASE}_t\} = P_t(I).$$

The objective is to determine a level of investment that minimizes investment costs plus the expected losses caused by the occurrence of the SASE. Let $A(I)$ denote annualized investment costs and let $E[L(P_t)]$ be the expected loss due to excess demand in period t. The expected value of L is an increasing function of $P_t(I)$. The optimization problem is then

$$(2)\quad \min_I [A(I) + E[L(P_t(I))]].$$

This problem yields the first order condition

$$(3)\quad \frac{dA}{dI} = -\frac{dE[L]}{dI}$$

indicating that the marginal cost of investment should equal the negative of the marginal expected losses. Howe and Smith et al. do not optimize I, but they do compare changes in A and in $E[L]$ where the changes are accomplished by sales or purchases of surface water rights.

A deficiency of this theory is its emphasis of a single type of shortage, the SASE (Lund). Nothing is conveyed about the selection of water supply capacity for addressing more moderate or extreme shortage events. Because supply investments alter the frequencies of all degrees of shortage, not just the SASE, this omission is important. To obtain a more broadly applicable theory (also initiated by Howe and Smith et al.), suppose that aggregate water demand D is an increasing function of some short-term climate index which we will call aridity "a." Water supply S is a decreasing function of aridity and an increasing function of investment I. Water price is assumed to be fixed.

When demand exceeds supply for a given aridity level in period t, the loss suffered is $\ell_t(D_t - S_t)$. Otherwise, the loss is zero. The overall loss function can be stated as

$$(4)\quad L_t(I, a_t) = \begin{cases} 0 & \text{if } D_t(a_t) \le S_t(I, a_t) \\ \ell_t\big(D_t(a_t) - S_t(I, a_t)\big) & \\ & \text{if } D_t(a_t) > S_t(I, a_t). \end{cases}$$

If f_t is the probability distribution function for the random variable a_t, then expected losses are

$$(5)\quad E[L_t(I, a_t)] = \int_{a_t^0}^{\infty} L_t(I, a_t) f_t(a_t)\, da_t$$

where a_t^0 is the level of aridity for which $D_t(a_t) = S_t(I, a_t)$.

Assuming the social problem is to minimize the sum of investment costs and the expected welfare loss due to water supply shortfall, the following criterion for investment choice is obtained:

$$(6)\quad \min_I \left[I + \sum_t \int_{a_t^0}^{\infty} L_t(I, a_t) f_t(a_t)\, da_t \right].$$

Discounting may be added explicitly to this model or it may be viewed as implicit in the definition of L_t. After differentiating the objective function with respect to I and simplifying, the first order condition becomes

$$(7)\quad 1 = \sum_t \int_{a_t^0}^{\infty} \ell_t'(\cdots) \frac{\partial S_t}{\partial I} f_t(a_t)\, da_t.$$

The left hand side of this condition is the marginal cost of investment. The right hand side is investment's marginal benefit.

This basic theory has four informational requirements that must be met prior to application. First, an aridity index must be constructed for which a probability distribution function can be determined and which can be used as an argument of demand and supply functions. Second and third, $D(a)$ and $S(I, a)$ are needed. Finally, the function giving the value of loss due to shortfall, $\ell_t(D_t - S_t)$, must be obtained. The latter requirement is the focus of the research reported here.

Survey Design and Procedures

Two lines of inquiry are pursued here using contingent valuation methods. First, the value of current water supply shortfalls—existing shortages of known strength and duration—is addressed. Second, an inquiry into the value of future shortfalls is presented. The latter are probabilistic shortages of differing frequency, strength, and duration.

A questionnaire was mailed to 4,856 households in seven Texas cities.[2] For two of the seven surveyed cities, there were a priori indications of experience with water supply shortfalls. There may be some bias in reliability valuation if assessments are sought solely from shortfall-inexperienced households. Experienced households may attach lower values to reliability for three general reasons. First, inexperience with water supply shortfalls may support an artificially high, physiological objection to an unfamiliar event. Once this unknown is removed, the consumer may have a "that wasn't so bad" reaction. Second, the learning of new water use behaviors is likely to be pronounced during shortfalls. As the consumer becomes more proficient with coping strategies, the value of shortfall-created inconveniences may decline. Third, as discussed previously, if households are accustomed to a highly dependable water supply, they are more likely to have assembled a water-intensive set of water-using durables.

Each questionnaire includes two contingent valuation questions. Paired with each of these questions is a question designed to ferret out protest responses. The first contingent valuation question is a closed-ended WTP question concerning a hypothetical current shortfall. This question establishes an "immediate and known" water supply shortfall of X% of the community's water demand expected to have a duration of Y summer days. The respondent is then asked if he/she would pay a one-time fee of \$$Z$ to be exempt from the outdoor water use restrictions the city would impose during this shortfall. Thirty-six different X-Y-Z combinations are used, and a logit model is fitted with the resulting data.

The second contingent valuation question is an open-ended WTP or WTA question concerning a hypothetical increase or decrease in future water supply reliability. This question poses an initial situation in which approximately once every U years a shortfall of V% would occur with a duration of W days. The question then poses a potential improvement or decline in one of the U or V parameters with the other being unchanged. Shortfall duration W varies among questionnaires, but it is constant in a given questionnaire. In the case of reliability improvements, the respondent is asked for a maximum WTP where this amount is expressed as a permanent increase in monthly water bills. In the case of reliability declines, the respondent is asked for a similarly expressed minimum WTA. Thirty-six distinct before and after regimes (U-V-W combinations) are used. Thus, there are thirty-six WTP questions and, by reversing the before and after components, thirty-six WTA questions. Each survey contains only one of these seventy-two variants. Respondents therefore answer either a WTP or WTA question concerning future shortfalls, but not both. Resulting data are used to estimate two tobit models, one for WTP and one for WTA.

Because there are thirty-six different constructions for the current shortfall question and seventy-two different constructions for the future shortfall questions, each of the current shortfall question variants are employed with two of the future shortfall question's scenarios. These assignments were made randomly.

The future shortfall question is more definitive in that it incorporates frequency information regarding prospective supply shortfalls, and it involves both WTP and WTA formats. However, it also presents a more perplexing proposition to respondents,

[2] Each mailing included a preaddressed and postage-paid return envelope. After two weeks, nonrespondents were mailed a reminder postcard. After three to four additional weeks, individualized surveys were again prepared for nonrespondents and were mailed with a new cover letter and a return envelope.

and there is justifiable concern that this question might overwhelm people. In the health risk valuation literature, it has been observed that probabilistic risk information is difficult to communicate to respondents and that many people may have difficulty processing this information (Loomis and duVair, Smith and Desvousges). The survey's current shortfall question poses a simpler, more comprehensible, and less challenging query for surveyed households. Inclusion of two general question styles offers the possibility of checking the consistency of survey results with expected utility theory.

A WTA version of the current shortfall question is not investigated because of the reduced information provided by close-ended questions (thereby necessitating larger datasets to achieve a given level of explanatory power). Moreover, the normative, status quo foundation of the reliability issue is closer to one where consumers do not possess entitlements to particular reliability positions.

Because water supply reliability is an unusual item for individuals to value, it is important to provide households with a solid informational context. Therefore, the individual questionnaire relayed summary information about the household's own water use patterns and bills. Because water supply shortfalls generally occur during summer months, the survey also includes information regarding the cyclical nature of the household's water use. To accomplish this, monthly 1995 information from city utilities was obtained for every household in the survey sample, and these data were used to calculate personalized information provided on each survey. The calculated information could have been electronically merged into the survey instrument prior to printing, but hand writing of this information into surveys was selected to emphasize the customized nature of the entries.[3] On the questionnaire the customized personal information is preceded and followed by additional contextual information regarding the importance and meaning of water supply reliability. The contextual information is replicated in the Appendix of this paper.

[3] The personalized information includes: total 1995 water use (gallons), peak water use month, water use in peak month (gallons), water and wastewater bill for peak month ($), low water use month, water use in low month (gallons), water and wastewater bill for low month ($), total bill for 1995 water use ($), total bill for 1995 wastewater service ($), and average monthly water and wastewater bill ($).

Overall, 30% of the survey recipients had responded prior to remailing of the survey. The overall survey response is 43%. Across the seven cities, the response rate varies from a low of 32% to a high of 45.8%. These percentages include all surveys returned with at least one question answered. Respondent and nonrespondent water use characteristics are similar, and none of the differences in the water use characteristics are statistically significant.

WTP to Avoid a Current Shortfall

A representative sample of the thirty-six editions of the current shortfall WTP question is as follows:

> Suppose that a community in which you live is facing an immediate and known shortfall of 10% that is expected to last for the next 14 *summer* days. This means that water supply is 10% less than demand. To correct this shortfall, the community is planning to restrict outdoor water use until the problem has passed. The Survey Residence can get a one-time exception from these water-use restrictions if you pay a one-time fee of $10.00.

Would you pay this one-time fee for this one-time exemption at the Survey Residence?

☐ Yes ☐ No ☐ Don't Know

Over all thirty-six scenarios, 437 respondents indicated they would be willing to pay the fee, whereas 1,595 indicated they would not be willing to pay the additional fee or did not know. Of these 1,595 respondents, 171 constituted nonprotest bids. Nonprotest bids are defined to be those meeting one of the following criteria: (*a*) any respondent answering yes to this question, or (*b*) any respondent answering no or don't know to the question *and* indicating the fee was too high to justify the payment in the subsequent protest filtering question. More than one-fourth of the 1,595 selected "Don't Know." The large number of protest bids appears to be partly a consequence of the good being valued. Some respondents indicated in hand-written notes something to the effect that "water

is a god-given right and should not be valued economically." Such public perspectives often confound water policy research because "access to water is regarded as a moral right, and discriminating among claimants to water on the basis of wealth or position is in many places regarded as immoral" (Martin et al., p. 28).

Current Shortfall Model

Because of the structure of the current shortfall question, the following logistic model is estimated using maximum likelihood techniques:

$$(8) \quad F[\beta'\mathbf{x}] = \frac{e^{\beta'\mathbf{x}}}{1 + e^{\beta'\mathbf{x}}}$$

where $F[\beta'\mathbf{x}]$ is the cumulative density function associated with the logistic function, $\mathbf{x}$ is a matrix of explanatory variables, and β is a vector of associated coefficients to be estimated (Judge et al., p. 591). Explanatory variables are:

- rain — mean annual rainfall by city (National Climatic Data Center),
- summer — mean July plus August rainfall divided by the mean annual rainfall for each city,
- price — respondent's total annual water bill divided by total water use,
- fee — fee the respondent must pay to avoid the water use restrictions,
- shortfall — percent shortfall the respondent's community is facing,
- duration — number of days the shortfall will last,
- income — income level of the respondent (five categorical levels correspond to the categories on the survey; the first level is dropped to avoid a singular matrix),
- activities — respondent's preferences toward water use activities[4] (this variable is the sum of a linear index of the importance attached by the respondent to lawn and landscaping, fruit and vegetable gardening, and car washing),
- people — total number of people living at the residence,
- rent — 0/1 dummy variable with a 1 indicating the respondent rents the survey residence from another person or business,
- live — 0/1 dummy variable with a 1 indicating the respondent lives at the survey residence, and
- experience — 0/1 dummy variable with a 1 indicating the respondent has experienced water use restrictions in the past five years.

Surveys from all cities are combined into a single dataset for estimation purposes. City-by-city examinations of the data are available in an expanded report (Griffin and Mjelde). Estimation of the logit model with dummy variables for each city indicated no statistical differences in the probabilities of paying the fee between respondents in different cities. Further, simple correlation coefficients and auxiliary regression equations indicate multicollinearity is not a problem in the dataset.

Estimated coefficients for the logit model are presented in table 1. A chi-squared value of 161 is obtained for the statistical test that

Table 1. Current Shortfall Value Logit Model Coefficients, 508 Observations

Variable	Estimated Coefficient	Standard Error	*p*-value
Intercept	−2.12	2.36	0.37
Summer	5.99	7.34	0.41
Rain	0.0325	0.0382	0.39
Price	−0.132	0.0594	0.03
Fee	−0.104	0.0135	< 0.01
Shortfall	0.0221	0.0168	0.19
Duration	0.0358	0.0237	0.13
Inc2	0.997	0.325	< 0.01
Inc3	1.81	0.347	< 0.01
Inc4	1.80	0.443	< 0.01
Inc5	2.80	0.567	< 0.01
Activities	0.0126	0.0494	0.80
People	−0.0626	0.0679	0.36
Rent	0.201	0.408	0.62
Live	1.07	0.729	0.14
Experience	0.255	0.323	0.43

[4] Instead of asking respondents for an inventory of their water-using durables, they were asked to select one of five levels of "importance" for each of three water activity categories. This preference-based approach avoids the impracticality of obtaining water consumption features of individual durables (e.g., area, condition, species of grass lawns), but it does not enable a testing of the role of durables in determining reliability values.

all coefficients are equal to zero. For this level, the null hypothesis is rejected at a p-value < 0.01, indicating the variables help to explain the probability of choosing to pay the fee to avoid water use restrictions. As the fee increases, respondents are less likely to pay to avoid the restrictions. Respondents are more likely to pay to avoid the restrictions as the duration and/or strength increases. All three coefficients associated with these variables are significant at p-values of 0.20 or less with fee being significant at the 0.01 level. As the respondent's average water price increases, the respondent is less likely to pay to avoid the restrictions. The coefficient associated with water price is significant at the 0.03 level.

Of the variables associated with the respondent's individual characteristics, income is highly significant with respondents in higher income categories generally more likely to pay the fee than respondents with lower incomes. The one exception to this observation is that the fourth income category's estimated coefficient is slightly less than the third income category's coefficient. Respondents who live at the survey residences are more likely to pay the fee than respondent landlords who do not live at the residence. The remaining variables are insignificant at the 0.20 level of significance.

Current Shortfall Valuation

The typical approach to obtaining valuations from such models is to determine the fee amount corresponding to a Prob[Yes] = 0.5, that is, the fee level that the average respondent would find agreeable (Hanemann). Here, this fee level is the value the average household is willing to pay to avoid a current shortfall. Using mean levels of exogenous variables, a low income household would be willing to pay a one-time fee of $17.19 to avoid a current shortfall, and a high income household would be willing to pay $44.04. If shortfall parameters are varied across the questionnaire scenarios and income is varied across the five groupings, the predicted WTPs range from $12.99 to $48.88.

WTPs to avoid current shortfalls of various strengths and durations are presented in table 2. All other variables, including income class binary variables, are set at their means in the calculation of these values. As indicated earlier, WTP to avoid current water supply shortfalls increases with the anticipated strength and duration of the shortfall. For the average respondent, $29.86 is the avoidance value for a three-week current shortfall of 20%. Changes in shortfall parameters affect this value as follows. A one-week increase (decrease) in shortfall duration increases (decreases) this value by $2.41. Every 10% increase (decrease) in shortfall strength increases (decreases) this value by $2.12.

Table 2. Current Shortfall Values (WTP)

		Shortfall Duration		
		14 days	21 days	28 days
Shortfall strength	10%	$25.34	$27.75	$30.15
	20%	$27.46	$29.86	$32.27
	30%	$29.58	$31.98	$34.39

WTP/WTA to Modify Future Reliability

An example of the thirty-six future shortfall WTP questions is as follows:

Current: For your community, suppose that water demand will exceed supply once every 10 years. This shortfall will have an average length of 14 days. Typically, water restrictions will be used in the years of shortfall to decrease demand 20% as needed to manage this shortfall.

Future: Suppose that your community is considering an expansion of its water supply system to improve reliability. Subsequently, water demand will exceed supply once every 15 years. This shortfall will have an average length of 14 days. Typically, water restrictions will be used in times of shortfall to decrease demand 20% as needed to manage this shortfall.

To Summarize:	*Current*	*Future*	
Shortfall Frequency is once every	*10*	*15*	years.
Shortfall Length will average	*14*	*14*	days.
Shortfall Amount is	*20*	*20*	% of the city's demand.

Please consider the next questions carefully.

What is the largest increase in your average water bill of $ ___ per month that you would be willing to pay each and every month to obtain this reliability improvement at the Survey Residence?

$___ per month

The first blank was precompleted with the respondent's average monthly water bill, so the respondent only needed to state WTP. Bids of $0 for this question may be protests. A nonprotest $0 bid is defined here as one in which the respondent either (*a*) checked "the reliability improvement wouldn't help me much" in the accompanying protest filter question or (*b*) did not provide any responses to the protest filter.

Households receiving a future shortfall WTA survey encountered a boxed summary nearly identical to that above followed by this question:

> **What reduction in your average water bill of $___ per month is the minimum you would be willing to accept each and every month in exchange for this reliability reduction at the Survey Residence?**
>
> **$___ per month**

Nonprotest bids are defined to be those who selected the following response to the paired protest filtering question: "My answer is about right for the added inconvenience."

Future Shortfall Estimation Procedures

Both the WTP and WTA open-ended questions result in a censored sample; that is "... some observations on the dependent variable corresponding to known sets of independent variables are not observed" (Judge et al., p. 609). In the WTP and WTA samples, the observable range of WTP and WTA range from zero to the highest bid. In such cases, ordinary least squares estimators are biased and inconsistent (Judge et al., p. 615). Consequently, tobit analysis is used here.

The underlying tobit model for this study is

$$(9) \quad y_i^* = \beta'\mathbf{x}_i + \varepsilon_i$$

where $\mathbf{x}_i$ are the independent variables for observation i, y_i is the dependent variable, β's are coefficients to be estimated, and ε_i is an error term. Also, $\varepsilon_i \sim N[0, \sigma^2]$; if $y_i^* \leq 0$, then $y_i = 0$; and if $y_i^* > 0$, then, $y_i = \beta'\mathbf{x}_i + \varepsilon_i$. This model is estimated using maximum likelihood techniques (Greene). Conditional means (prediction) from the tobit model are

$$(10) \quad E[y|\mathbf{x}_i] = \Phi(\hat{\beta}'\mathbf{x}_i/\hat{\sigma})\hat{\beta}'\mathbf{x}_i + \hat{\sigma}\phi(\hat{\beta}'\mathbf{x}_i/\hat{\sigma})$$

where Φ represents the cumulative standard normal distribution function, ϕ represents the standard normal density function, $\hat{\sigma}$ is the estimated standard error for the error term, and $\hat{\beta}$ is the vector of estimated coefficients.

Independent variables used in the estimation procedure for both the WTP and WTA models are the same. These variables are defined equivalently to those used in the current shortfall logit model previously presented with the exception of new variables defining water reliability. The two new variables are:

- severity — the initial severity of the water shortfall, defined as probability of shortfall occurring in any given year times shortfall strength, and
- shortype — a binary variable which equals zero if the proposed change affects the probability of a shortfall occurring and equals one if the proposed change affects shortfall strength.

By design, the number of usable responses for the WTP and WTA questions will be less than the value of current shortfall question. Four hundred and sixty-six usable observations are available for estimation of the WTP model, whereas 240 observations are usable from the WTA surveys. The difference between WTP and WTA usable responses may pertain to two factors. First, water is better understood as a good for which one pays rather than as a good for which one might receive a payment. The unfamiliar WTA perspective may have caused some confusion. Second, the wording of the WTA question is more confusing than the WTP question. A large number of respondents checked "I don't understand the question" in the protest filter.

Of the 466 usable responses in the WTP data set, 21.4% (100/466) of the respondents indicated a monthly WTP equal to zero. Using dollar intervals of 0.01–1, 1–5, 5–10, 10–15, and 15 + , the percent of responses in each interval are 1.7%, 22.1%, 21.7%, 17.8%, and 15.2%. The WTA sample is less censored, with only 5.4% (13/240) of the respondents indicating a WTA equal to zero. Also, 0%, 12.9%, 25.4%, 23.8%, and 32.5% of the respondents lie in the dollar intervals 0.01–1, 1–5, 5–10, 10–15, and 15+.

WTP for Reliability Enhancements

Presented in table 3 are the estimated coefficients and statistics for the WTP model.

Table 3. Future Shortfall Value Tobit Model Coefficients

	WTP Model 466 Observations		WTA Model 240 Observations	
Variable	Estimated Coefficient	p-value	Estimated Coefficient	p-value
Intercept	47.8	0.00	27.3	0.08
Summer	−42.5	0.32	5.97	0.90
Rain	−0.751	< 0.01	−0.643	0.01
Price	−0.113	0.78	−1.09	0.09
Severity	−0.527	0.23	−0.178	0.83
Shortype	0.618	0.67	2.18	0.13
Duration	−0.0711	0.57	0.0222	0.86
Inc2	5.03	0.01	−2.50	0.22
Inc3	3.70	0.10	−4.79	0.02
Inc4	4.17	0.11	−2.76	0.34
Inc5	8.45	< 0.01	0.207	0.94
People	1.22	0.05	0.716	0.19
Activities	−0.104	0.73	0.946	< 0.01
Rent	2.23	0.37	−0.684	0.78
Live	−8.28	0.03	3.08	0.49
Experience	−6.18	< 0.01	−0.882	0.65
σ	14.7		10.8	

The Wald chi-squared test that all coefficients are jointly significantly different from zero is rejected at a p-value below 0.01. The water reliability variables are all insignificant at p-values less than 0.23. Insignificance of the severity variable suggests that consumer valuations are unaffected by dimensions of the initially posed shortfall. The insignificance of the shortype variable indicates respondents did not value improvements in shortfall frequency or shortfall strength differently. These results corroborate the "threshold" nature of valuations suggested by Barakat & Chamberlin, Inc.:

> ...respondents regard even a mild shortage scenario as an inconvenience that they want to avoid. They may make a greater distinction between "shortage" and "no shortage" than between different sizes or frequencies of shortages (p. 15).

Individual income levels are significant at p-values of 0.11 or less. Respondents in income categories two through five (inc2–inc5) are willing to pay more for reliability increases than respondents in income category one (inc1—the base which is omitted from the model). Rain is significant at the 0.01 level with respondents in cities with higher rainfall willing to pay less than respondents in drier cities.

In contrast to the value of a current shortfall, individual characteristics appear to help explain WTP bid levels. Live, experience, and people are highly significant. As the number of people living at a residence increases, the respondent is willing to pay more for the reliability enhancement. Respondents who have experienced water shortfalls in the last five years are on average willing to pay less for the reliability increase than those who have not experienced a shortfall. The signs associated with the live variable are different than prior expectations. It was expected that respondents who do not live at the survey residence would be willing to pay less than respondents who do. One possible explanation for this discrepancy is that the variables are not picking up the desired impact. By far the majority of respondents live at and own the survey residence. In the usable dataset only sixteen observations fall into the "don't live at the residence" category; mean WTP for these sixteen is $14.56, whereas the mean WTP for the remaining observations is $8.25. Remaining variables are insignificant at p-values below 0.20.

WTA for Reliability Declines

Also presented in table 3 are the estimated coefficients and standard errors from the WTA estimation. The Wald chi-squared test that all coefficients are jointly equal to zero

is rejected. The magnitudes, signs, and significance of the estimated coefficients differ between the WTA and WTP models. As in the WTP model, rain's impact is negative and significant at the 0.01 level. Summer and rent are insignificant in both the WTP and WTA models. In contrast to the WTP model, both water price and water activities are significant in the WTA model. The signs and significance of the income categories change, weakening results relative to the WTP model. Similarly, variables for experience and live are insignificant in the WTA model.

As with the WTP model, the coefficients associated with initial severity and duration are insignificant. The coefficient associated with shortype is, however, significant at a p-value of 0.13. The coefficient implies that mean WTA is approximately \$2.00 higher for an increase in shortfall strength than an increase in shortfall frequency.

Future Shortfall Valuations

WTP and WTA measures can be obtained as means from survey responses, or they can be calculated as means of the in-sample predicted values from the tobit models using the conditional means equation presented earlier. Both methods are employed here. Presented in table 4 are summary statistics associated with the monthly WTP and WTA measures. Mean data WTP is \$8.47, whereas the predicted WTP is \$9.76. These WTP measures constitute 22.2% and 25.6% of the respondents' mean monthly water bills. These values compare with means of \$11.63 to \$16.92 (depending on initial shortfall frequency) reported by Barakat & Chamberlin, Inc. for the complete elimination of future Californian shortfalls. Consistent with earlier discussion regarding consumer behavior, both the predicted and data mean WTA are larger than the WTP mean values. Mean WTA is \$12.66 and \$13.20 for the raw data and predicted values, respectively. These mean WTAs are 32.4% and 33.8% of mean monthly water bills.

Consistency of Results

A useful inquiry pertains to whether obtained future shortfall valuations are consistent with the current shortfall valuations reported earlier. That is, are consumer valuations of modified shortfall probabilities compatible with the values they assign to avoiding current shortfalls?

The future shortfall WTP question asks respondents to state a payment p to accompany a lowered shortfall frequency such that the new state would be viewed indifferently to the initial state. Adopting the expected utility model, this means that initial expected utility must equal subsequent expected utility. Therefore,

$$(11)\quad b \cdot U(y - v) + (1 - b) \cdot U(y) = c \cdot U(y - v - p) + (1 - c) \cdot U(y - p)$$

where b is initial shortfall probability, c is subsequent shortfall probability, $U()$ is the utility function, y is income, and v is the value of a known (current) shortfall. This equality implicitly relates future shortfall value p to current shortfall value v.

The utility function is assumed to be locally given by the constant absolute risk aversion form $U(w) = n - me^{-rw}$, where n, m, and r are constant preference parameters. With this assumption, an explicit function can be obtained for p:

$$(12)\quad p = \frac{1}{r} \ln \left[\frac{be^{rv} + 1 - b}{ce^{rv} + 1 - c} \right]$$

where r is the Arrow–Pratt risk aversion coefficient. For demonstrative purposes, we employ two coefficients, $r = 0.01$ and $r = 0.05$. Both of these values lie at the high end

Table 4. Summary Statistics on Willingness-to-Pay and Willingness-to-Accept Using Individual Observations (\$/Month).

	Data				Predicted			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
WTP	8.47	12.90	0.00	100.00	9.76	2.90	2.77	28.41
WTA	12.66	11.12	0.00	60.00	13.20	3.53	2.20	24.19

of empirically estimated ranges—indicative of a high degree of risk aversion (Raskin and Cochran). For before and after shortfall probabilities, we use the two scenarios posed in the WTP versions of the survey: $\langle b = 1/10, c = 1/5 \rangle$ and $\langle b = 1/5, c = 1/10 \rangle$.

Table 5 contains the results of calculating future shortfall values based on current shortfall values and the above methodology. For example, a household willing to pay \$30 to avoid a current shortfall and having a risk aversion coefficient of 0.05 should be willing to pay a one-time fee of \$1.80 to support a project that alters shortfall frequency from 1/10 to 1/15. The same household should be willing to pay \$4.59 for a project that alters shortfall frequency from 1/5 to 1/10. Our respondents provided average indications of being willing to pay larger amounts than these each and every month. Consequently, the future shortfall values reported here appear inconsistent with the reported current shortfall values.

One is inclined to look to the future shortfall valuation work for the source of the discrepancy because (*a*) the context of the current shortfall valuation offers a firm and well understood platform for respondents, (*b*) this platform is not confused by the added dimension of frequencies or probabilities, and (*c*) the resulting logit model performs well. Several potential reasons for the incompatible current and future shortfall valuations can be hypothesized. First, respondents may not have understood the future shortfall query well. Even though only one parameter was altered, we may have parameterized shortfalls beyond common comprehension. Second, using frequency to convey probabilistic information may be a bad idea because of scaling problems. When shortfall frequency is altered from one out of ten years to one out of fifteen, the change in probability is quite minor (0.033). In retrospect, we wonder whether respondents could grasp the smallness of this change. Third, perhaps respondents place some value on the convenience or social fairness of regular payments to achieve high system reliability as opposed to one-time payments to sidestep temporary shortfall policies. These hypotheses may be useful suggestions for the conduct of future research in this arena.

Conclusions

If economists are to contribute policy advice concerning water system reliability, we must establish and refine a guiding theory, understand the behavior and reactions of managers and consumers, and investigate the values associated with probabilistic shortfalls. The research reported here builds upon prior contributions in each of these areas.

The theoretical development offers modest improvements and questions the use of a "standardized shortage event" in theoretical or applied research. Given the range of potential water shortfalls, in terms of probability, strength, and duration, it is important to examine empirical options for obtaining shortfall values as a function of shortfall parameters. Such pursuits promise to be a challenging departure from the valuation of a standardized shortfall.

Whereas prior research has acknowledged the attitudes of water managers toward system shortfall, important features of consumer behavior have not been examined. When consumers are considered, it becomes evident that their accumulated bundles of water-using durables influence their actions as well as the values they assign to shortfalls. There is noteworthy feedback here too. The potential for shortfalls affects the selection of durables

Table 5. Consistent Future Shortfall Values (*p*).

	Δ Frequency: $b \to c \equiv \frac{1}{10} \to \frac{1}{15}$		Δ Frequency: $b \to c \equiv \frac{1}{5} \to \frac{1}{10}$	
Current Value (v)	$r = 0.01$	$r = 0.05$	$r = 0.01$	$r = 0.05$
\$10	\$0.35	\$0.41	\$1.04	\$1.18
\$20	\$0.72	\$1.00	\$2.14	\$2.74
\$30	\$1.14	\$1.80	\$3.32	\$4.59
\$40	\$1.57	\$2.78	\$4.58	\$6.58
\$50	\$2.05	\$3.87	\$5.91	\$8.48

by consumers. Another crucial observation is that durable fixity in the short run gives rise to asymmetric values for reliability improvements and reliability declines.

When contingent valuation methods are employed to assess consumer losses due to shortfall, the contingent valuation analysis can address either the value of avoiding a current shortfall or the value of changing the character of probabilistically defined future shortfalls. The probabilistic information necessary for future shortfall surveys confounds respondents and reduces data quantity and quality. A demonstrated option is to employ expected utility theory in conjunction with assessments of current shortfalls to calculate implied future shortfall values. This alternative eliminates the need to convey probabilistic information to respondents but requires additional assumptions regarding consumer risk preferences. Moreover, current shortfall values can be directly used to specify the loss function, $l_t(D_t - S_t)$, needed to ascertain optimal water supply. Given these findings, future research should concentrate on refining the value of current shortfalls rather than pursuing contingent valuation of probabilistically specified future shortfalls.

Even in the absence of probabilistically defined contingent valuation scenarios, there are pitfalls for the nonmarket valuation of shortfall losses. Two such pitfalls can be encountered in other arenas, but they are certainly pronounced for water issues. These are the "birthright" perspective and consumers' lack of personal consumption information. With respect to birthright, water is popularly thought of as a public good to which people have some inalienable entitlement. Many see water bills as a tax rather than as an invoice for the on-demand delivery of treated, pressurized tap water. Consequently, there is a strong tendency for respondents to protest proposed WTP scenarios. Overcoming this pitfall appears extremely difficult at this time, but some redress may be achieved through very carefully worded survey prefaces. The analyst's burden is high here.

With respect to the second pitfall, most households are not aware of their actual water use or their water bills. Not only is water a low budget share item for most households, thus failing to motivate much attention, but water bills are lumped into utility bills that may include electricity, natural gas, and solid waste components. This lack of consumer information also raises the burden for survey instruments. Our instrument's inclusion of consumer-specific data is a novel approach worthy of use, and perhaps testing, by future research.

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Appendix: Background Information

The questionnaire's introduction included contextual information highlighting four key points:

- A temporary water supply shortfall is when water supply is less than water demand. During a temporary water supply shortfall, households usually experience a drop in water pressure, NOT the loss of all water.
- A water pressure drop causes water to flow more slowly through pipes. Sinks and bathtubs take longer to fill. Water-using appliances such as washing machines take longer to operate. Outdoor sprinklers operate more slowly, and the sprinklers will not spray as far.
- Usually, water supply shortfalls occur during the summer months. Average Texas households use 40% less water in December/January than in July/August.
- During a shortfall, your community may employ voluntary or mandatory outdoor water use restrictions (such as restrictions on lawn watering or car washing) to reduce use.

After the customized household data, the questionnaire includes two short paragraphs containing basic details about why shortages tend to occur during the summer and about the important tradeoffs this creates.

> In Texas, water use and water supply change seasonally. Water demand is highest during the summer because of outdoor uses like lawn watering. This is also the season when water supply may be the lowest.
>
> Texas water utilities have traditionally designed their water supply systems to reliably provide peak summertime needs. The full capacity of these systems may be utilized only a few days a year. A portion of water supply systems costs and the rates you pay are therefore for capacity which is used only part of the year. On the other hand, this service capacity also offers Texas communities some insurance against short-term droughts and unexpected water system failures.

Information synthesis and priorities regarding steelhead trout (*Oncorhynchus mykiss*) on the Santa Clara River

Photo by: EJ Remson

By
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Post – doctoral researcher
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February 2004

for

The Nature Conservancy

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Abbreviations

ACOE	Army Corps of Engineers
AF	Acre-feet
Caltrans	California Department of Transportation
CFG	California Fish and Game Department
cfs	Cubic feet per second
CSWRCB	California State Water Resources Control Board
FERC	Federal Energy Regulatory Commission
FOSCR	Friends of the Santa Clara River
LA-RWQCB	Los Angeles Regional Water Quality Control Board
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
pers. comm.	personal communication
POTWs	Publicly Owned Treatment Works
RT	Rainbow Trout
SCR	Santa Clara River
SCREMP	Santa Clara River Enhancement and Management Plan
SP	Santa Paula
TMDLs	Total Maximum Daily Loads
TNC	The Nature Conservancy
UWCD	United Water Conservation District
VFD	Vern Freeman Diversion
WRP	Water Reclamation Plants (or Wastewater Treatment Plants)

Introduction

The findings in this report reflect a 9-month investigation into the state of steelhead trout (*Oncorhynchus mykiss*) in the Santa Clara River of southern California. Prior to the 1940s, the Santa Clara River was the site of a large southern steelhead trout run each year. Southern steelhead are now listed as endangered by the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA), and very few run up the Santa Clara. The recovery of this species will depend upon the re-establishment of viable spawning runs on rivers and creeks in southern California. The intent of this study was to understand the state of steelhead on the Santa Clara River, and to devise a list of actions that would lead to rehabilitation of a steelhead trout run on the river.

Information relevant to the restoration of southern steelhead trout was collected - including written and on-line materials, as well as interviews and conversations with people familiar with the Santa Clara River. The summary and findings are organized as follows:

1. **Executive Summary** – provides an overview of the findings of the study.
2. **Methods and Sources** – discusses the methods and sources used during the investigation.
3. **Analysis and Priorities** – presents an overview of all possible actions that could benefit steelhead and prioritizes them.
4. **Appendix** – summarizes and details the information obtained during the investigation.

Executive Summary

Prior to 1940, the Santa Clara River is estimated to have had more than 8,000 adult steelhead run its waters every year.
Next to the Santa Ynez River the Santa Clara was one of the largest steelhead runs in southern California. Fewer than 100 adult fish run either of these rivers' waters now. Unlike other major rivers in southern California, the Santa Clara retains much of its natural features, including major undamned tributaries, and could play an important role in the recovery of southern steelhead.

One of the major problems that steelhead face on the Santa Clara River is artificially reduced flows during migration periods.
The river reach between the estuary and the Vern Freeman Diversion (located approximately 14 miles above the estuary) is often reduced to shallow sheet flows, or becomes dewatered; the connectivity between the mainstem and tributaries is ephemeral and provides inadequate opportunity for either the upstream passage of adult, or the downstream passage of juvenile steelhead. Water is removed from both the surface flow and from groundwater basins for residential, commercial, and

agricultural use. Insufficient information is publicly available regarding the flows in the river, how much and where water is removed, and whether flows could be adjusted to provide sufficient water for migrations while still meeting human needs.

A second major difficulty during migrations is the anthropogenic and natural barriers to migration such as water diversions, road-crossings, and channel modifications for sand and gravel extraction or flood control purposes. While it is known these barriers and impediments exist, almost nothing is known about how significant these barriers are or what solutions there are to the migration difficulties they present.

The tributaries provide the majority of spawning and rearing habitat, while the mainstem of the Santa Clara River is primarily a migration corridor.
Santa Paula and Sespe Creeks are the main steelhead spawning tributaries, though Hopper Creek may also provide some spawning habitat. Piru Creek historically was a major spawning tributary but Santa Felicia Dam now blocks steelhead access. Little is documented about the resident trout populations in the tributaries, their location, the quality, quantity, or location of habitat, or the extent of the exotic fish predator threat from bullhead catfish, bullfrogs, green sunfish, and small and large mouth bass.

The Santa Clara River estuary has been significantly altered, and these changes may be impacting steelhead smolt survival.
A significant portion of the original Santa Clara estuary has been filled by adjacent development. Additionally, between seven to ten million gallons of nutrient-rich effluent are released per day into the estuary from the City of San Buenaventura's Wastewater Treatment Plant. While it is unknown to what extent Santa Clara River smolts used the estuary historically, it has been demonstrated that northern and central coast steelhead smolts use estuaries to gain size and acclimate to the higher concentrations of salt in ocean water. The impact of these changes on Santa Clara River steelhead smolt survival is unknown.

There are very few adult steelhead trout that have been counted making their way upstream in the Santa Clara River over the past ten years.
However, the number of smolts observed emigrating out of the system has increased by an order of magnitude over the same period. This indicates that there is natural reproduction of *Oncorhynchus mykiss* in the Santa Clara River watershed, and that if migration and habitat issues can be addressed there is a good possibility this fish stock can be rehabilitated.

Southern steelhead trout ecology and biology are generally unknown.
There is little data or information on life history, habitat usage, historical numbers, length of time required for up-stream migration, timing of downstream emigration, or the population age-class structure for southern steelhead. The majority of information and data regarding steelhead are the result of studies of northern pacific stocks. While the steelhead in southern California have been shown to be genetically and physiologically different from their northern counterparts, there is very little data or studies on southern

steelhead ecology or biology.

The LA-Regional Water Quality Control Board is establishing TMDLs (Total Maximum Daily Loads) for the Santa Clara River in order to lower the amounts of excess chlorides and other pollutants in the river.
A chloride TMDL of 100 mg/L, has been established for the upper river. Other TMDLS scheduled to be determined are: toxaphene, fecal coliform, and nitrate.

Methods and Sources

The sources for the documents and data obtained during this investigation included the Mark H. Capelli Southern California Steelhead Watershed Archive at the University of California at Santa Barbara's Davidson Library, the United Water Conservation District's (UWCD) library in Santa Paula, various websites on the Internet, and a variety of individuals. The documents that are a part of this summary are listed in the bibliography.

In addition to the documents, in-person or telephone interviews were conducted with 17 individuals who were familiar either with the Santa Clara River or southern steelhead. The findings from these interviews are incorporated into the Appendix.

The information from these documents and interviews were collated and organized into the various sections of the Appendix. The following section discusses the topical areas evaluated and potential actions for rehabilitating southern steelhead in the Santa Clara River. The actions discussed below were derived from individual suggestions, from work on other rivers, or are the result of conceptual analysis on the part of the author.

Analysis and Priorities

Potential issues for steelhead on the Santa Clara River were eventually organized into four categories: physical impediments to steelhead passage, steelhead ecology, water flow and balance, and point source and non-point source pollution. The issues discussed are either possible challenges that face steelhead on the Santa Clara River, ways to address challenges that face steelhead, or represent a lack of knowledge regarding steelhead and their environment.

These issues were reviewed and revised at a meeting at the University of California at Santa Barbara on May 28, 2003. Present at that meeting were Mark Capelli, Dr. Ramona Swenson, E.J. Remson, Dr. Elise Kelley, and Dr. Mark Reynolds and Dr. Scott Morrison via phone. Each of the issues was discussed in depth and prioritized. Reasons for an issue receiving either a high or low priority rating had to do with timing associated with it, the capacity of the organizations involved to address the issue, and the likelihood that resolution of the issue would increase the number of steelhead utilizing the Santa Clara River.

Dr. Peter Kareiva, Mark Capelli, Dr. Leal Mertes, Dr. Mark Reynolds, Dr. Scott Morrison, Dr. Elise Kelley, and E.J. Remson conducted a final review of the prioritized issues at the University of California at Santa Barbara on June 3, 2003.

In general it was realized that there was insufficient information in several areas to develop a steelhead restoration plan for the river, and that additional basic information was needed. Issues discussed at the June 3rd meeting are presented below within their category and as action items. The items determined as having the highest priority are discussed in greater depth following the initial presentation.

I. Physical Impediments To Steelhead Passage

The items in this category are focused on assessing anthropogenic and natural barriers to steelhead passage that occur on the river.

The action items are:

1. Encourage California Department of Transportation (Caltrans) to modify the apron of the Highway 150 bridge at Thomas Aquinas College. It has been noted that this apron is impassable to steelhead at certain flows, with some jump pools being too shallow among other problems.
2. Encourage the Army Corps of Engineers (ACOE) to repair and/or modify the fish passage facility in its flood control project on Santa Paula Creek. Currently the first jump pool in the "ladder" structure of this flood control project is too shallow to allow up-stream migrating adult steelhead to enter the facility.
3. Conduct a Steelhead Cumulative Impact Analysis. Given the challenges that steelhead encounter in their migrations it would be useful to know the amount of energy steelhead expend overcoming anthropogenic and natural barriers during their migration, and whether that energy expenditure adversely affects their reproductive success. This analysis would include the probability of steelhead making it past all barriers and spawning.
4. Monitor structures on the river to make sure that steelhead can get past these barriers.
5. Evaluate the benefits on steelhead passage of reducing sedimentation to Santa Paula Creek from Mud Creek.
6. Evaluate the role of sediment transport in the mainstem of the Santa Clara River, in steelhead migration.
7. Inventory and assess all physical barriers to steelhead passage within the mainstem of the Santa Clara River and on all major tributaries.

Of these potential actions, three have been selected as priorities.

Encourage Caltrans to modify the apron for the Highway 150 bridge at Thomas Aquinas College.
As of spring 2003, Caltrans had the funding available to correct this problem; however no action has been taken to remedy the situation.

Encourage ACOE to repair the first step in the ladder for the flood control project near the mouth of Santa Paula Creek.
At least an interim solution to the problem does not appear to be involved or costly. The first jump pool needs to be deepened by drilling and then reformed to prevent sediment accumulation.

Inventory and assess all physical barriers to steelhead passage.
It is unclear how much of a barrier the various diversions, flood control projects, and other facilities along the mainstem of the river or its major tributaries, present to steelhead passage. There is also the potential for natural barriers to occur. A barriers analysis would provide an understanding of the obstacles that affect the steelhead run, and a list of the actions that could be taken to eliminate or modify those obstacles.

II. Steelhead Ecology

The primary objective of these actions is to increase the understanding of southern steelhead trout ecology, especially the populations within the Santa Clara River watershed.

The eleven actions discussed include:

1. Assess the steelhead and rainbow trout population structure (age-class numbers and distribution, genetic make-up, etc.).
2. Study the in- and out-migration ecology of southern steelhead (timing and duration of adults and smolts, acclimation time in estuary, etc.).
3. Characterize and evaluate steelhead habitats (spawning, rearing, and refugia) on Santa Paula, Hopper, Sespe Creek, and Piru Creeks.
4. Identify non-native and native predators of southern steelhead, and survey population numbers, sources, and locations.
5. Assess smolt utilization and survival in the estuary.
6. Evaluate how the fish counters work at the Harvey and Freeman diversions and what, if anything, can interfere with a reliable count being obtained.
7. Compare how many adults spawn in other southern California rivers, along with egg, fry, and smolt numbers. This would provide general information regarding the southern steelhead population and would help put fish counts on the Santa Clara into perspective.
8. Study the ocean ecology of southern steelhead and their degree of straying from their natal streams.
9. Acquire properties in the tributaries that contain pristine or restorable steelhead habitat in order to protect spawning and rearing areas.
10. Assess the native gene pool of resident fish to determine the degree of introgression between native southern steelhead and descendants of hatchery trout.
11. Research historical evidence regarding steelhead runs in the Santa Clara River prior to 1955.

Of these eleven actions, six were selected as priorities. One other is discussed because it is going to be conducted by the NMFS.

Assess steelhead and rainbow trout population structure.
Locate and evaluate habitat on Santa Paula, Hopper, Sespe, and Piru Creeks.
Assess smolt utilization of and survival in the estuary.
Identify non-native and native predators, population numbers, sources, and locations.

These four actions were condensed into the single action of conducting habitat and population surveys in three of the tributaries (Santa Paula, Hopper and Sespe Creeks) and the estuary. The surveys will provide baseline information on trout survival, threats, and actions necessary to reduce those threats. It will provide the location of land within the tributaries that are good candidates for restoration. These actions were selected as priorities and are therefore discussed in the later section on habitat and population analyses in more detail.

Evaluate how the fish counters work at the Freeman and Harvey diversions.
It would be helpful to understand more clearly how effectively the fish counters operate, and what, if anything, might interfere with a reliable fish count.

Assess native gene pool in resident fish.
The NMFS will be conducting genetic studies of steelhead trout throughout southern California in the summer of 2003 and in the future. The Santa Clara River will be included in these genetic assessments with collections being conducted in Piru, Sespe, and Santa Paula Creeks.

III. River Water Flow and Balance

The objective of these actions is to evaluate water flow and balance in the river and determine sufficient flows for steelhead passage.

1. Assess and model water flow and usage for the mainstem and tributaries
    a. Determine when and for how long connectivity exists between the tributaries and the mainstem.
    b. Determine the amount of flow from Sespe, Santa Paula, and Piru creeks.
    c. Determine the amount of water historically available to steelhead from November to May.
    d. Determine the location and number of wells and diversions, and the amount diverted or pumped from the mainstem and the major spawning tributaries.
    e. Develop a water budget: determine how much surface water flow there is in normal years and in drought years, how much comes from the State Water Project; and how much water has been appropriated to support out-of-stream uses.
    f. Determine how much water is used residentially, agriculturally and industrially.

    g. Determine the effects on surface flows in the mainstem of the Santa Clara River resulting from the current pattern of releases from Santa Felicia dam.
    h. Model the amount of water necessary for steelhead to make it up and down the river and over what time periods.
2. Evaluate the suitability of different levels of flow downstream of the Vern Freeman Diversion to pass adult steelhead, with particular attention to flow depth and width. Until 2003 after a major storm when the river had dropped below 415 cfs, UWCD released 40 cfs for the first 24 hours post-storm, and 20 cfs for the second 24 hours after a storm. However it is unclear that this is enough water for a long enough period of time to allow steelhead migration to occur from the estuary (the distance from the estuary to the diversion itself is approximately 11 miles). UWCD has begun changing its flow regime to release more water post-storm, and this action will provide an evaluation of the ability of fish to make it from the estuary to the Vern Freeman Diversion.
3. Consider buying water rights on the mainstem and tributaries. Buying water rights might position The Nature Conservancy (TNC) to negotiate with UWCD to allow that water to remain in the river for fish passage, or to allow UWCD to take that water in the summer, but pass more along in the winter when steelhead are migrating. This idea has not been discussed yet with UWCD, and the details of whether and how it could work are unknown.
4. Inventory the types of crops in the valley (which are increasing or decreasing) and determine the amounts of water used by each.
5. Once the types of crops and water usage are determined, assess whether a demonstration project using soil sensitive irrigation equipment would be appropriate.
6. Assess potential for water saving measures such as xeriscaping; use of reclaimed water; water metering where it isn't currently being used; and consumer water saving fixtures.
7. Assemble a diverse working group that would evaluate sustainable water management in the Santa Clara River valley.

Of these eight actions only the first one was determined to be both a priority and within the scope of The Nature Conservancy. This action would be conducted in two parts. The first being a water balance and assessment of inflows and outflows to the Santa Clara surface and groundwater resources. The second would be a hydrological analysis with models to assess the amount of water flow necessary in all lower segments of the river in order to provide sufficient water for steelhead passage during the winter months**.**

For the purposes of re-licensing the hydro-facility at Santa Felicia Dam, UWCD is studying the effects of different levels of water releases. While the scope of this work is limited and is unlikely to provide a comprehensive review of fish flow requirements for the Santa Clara River, it should provide some data on the effects of certain release levels.

IV. Point source and non-point source pollution

The objective of these actions would be identify and evaluate the sources of pollutants into the mainstem of the Santa Clara River, and major tributaries.

The potential actions include:

1. Conduct water testing near landfills and wastewater recovery plants (WRPs) to determine if there is pollution or leaching.
2. Determine where and when water quality assessments are taking place in the tributaries.
3. Support the Los Angeles Regional Water Quality Control Board's designation of the Santa Clara River as a Significant Natural Resource. Obtaining such a designation for the Santa Clara River would be akin to a beneficial use designation and would limit the permissible hydrologic and water quality impacts of further urbanization on the watershed.
4. Assess contribution of non-point sources of pollution, including fine sediments stemming from various land use practices such as developments and agricultural crops on steep slopes.
5. Conduct a survey for evidence of species existing in the estuary prior to the presence of the wastewater treatment plant.
6. Summarize all water quality assessments on the Santa Clara River and identify gaps in collecting areas and tests.

Of these five actions, none was identified as being as critical to steelhead trout restoration as those prioritized above. Non-point sources of pollution, particularly find sediments, may limit rearing in some tributaries. These are issues that should be investigated, but were determined to be beyond The Nature Conservancy's current scope.

The Priority Actions

The three major actions that were selected as high priorities and that merit a more detailed discussion are habitat and population assessments, a steelhead barriers assessment, and water flow and management.

Habitat and Population Assessments

The objective of these assessments would be to provide baseline information regarding steelhead populations and habitat within the lower sections of the Santa Clara River, and major tributaries. Currently there is no baseline information on steelhead habitat or population structure that can be used for decision-making or to promote change in the facilities or activities that adversely affect steelhead within the watershed.

The main purpose of the assessments would be to document steelhead ecology. This would include gathering information on:

- Steelhead and resident rainbow trout age-class structure, density, genetic structure, and location
- Numbers and locations of predator species
- Location, quality and quantity of habitat, and habitat carrying capacity
- Quality and state of estuarine habitat
- Smolt utilization of and survival in the estuary

These assessments would be from the county line to the mouth of the river, including the tributaries and the mainstem.

This information would provide the foundation for monitoring the state of steelhead within the Santa Clara watershed, the basis for generating a list of potential lands for acquisition and/or restoration, and a list of activities related to improving the steelhead run.

Some of the issues that could arise with this study are gaining access to lands in order to conduct the surveys, difficulty conducting surveys on Sespe Creek due to the rugged terrain, and finding a cost-effective method of evaluating smolt utilization and survival in the estuary.

River Barriers Assessment

The objective of a river barriers assessment would be to identify both anthropogenic and natural impediments to steelhead passage. There are a number of known partial and potential anthropogenic barriers to steelhead passage on the mainstem and on the tributaries. There are also potential natural barriers within the mainstem and at the confluences of the mainstem and each tributary. A barriers analysis would provide:

- An inventory of all barriers, natural and manmade.
- An analysis of each individual barrier and specific problems related to that barrier.

The information from this assessment would be the first thorough, independent evaluation of the barriers to steelhead migration on the Santa Clara River. The likely biggest challenge facing steelhead on the Santa Clara River is being able to complete their migration runs, both as adults migrating to spawning areas, and as juveniles emigrating to the estuary and the ocean. Without an understanding of the challenges and obstacles that steelhead encounter during their migrations, it will be very difficult to rehabilitate a significant run of steelhead in the Santa Clara River.

Water Balance and Flow

Another obstacle to steelhead migration is a lack of adequate surface flows (timing, level and duration) during the migration season. The water balance and hydrology of the Santa Clara River have not been studied outside of a commercial or human use context. A study of water flow and the natural and anthropogenic impacts on water

availability would assist in the development of a hydrologic regime that meets both steelhead and human needs.

Information on rainfall and pumping would be available from Ventura County Watershed Protection District and UWCD. UWCD has also done some modeling of groundwater and surface water interactions. A cooperative working relationship with the water agencies is important if we are to find a workable solution for all.

The deliverables associated with this work would be:

1. A mass water balance spreadsheet checked against existing data and information that encompasses the current flow scenario including information on water rights, inputs, outputs, wells, diversions, and trading. Alternative scenarios would also be considered for critical high and low water years.

2. A hydrologic model of flows on the Santa Clara River and scenarios for water management. These scenarios will determine amount of water needed for fish passage up to and including Hopper Creek.

Conclusion

A significant amount of information regarding the Santa Clara River and its steelhead populations has been compiled and synthesized through this effort. The main conclusions from that effort are that steelhead face three major challenges to increasing their population size and spawning runs. The first is a lack of adequate flows to reach prime spawning and rearing areas in major tributaries. The second is impacts on migratory, spawning, and rearing habitats from anthropogenic changes to the river such as flood control structures, water extraction facilities, the alteration of the estuary, and the introduction of exotic fish predators. The third challenge is a general lack of detailed information on the amount, location, and quality of spawning and rearing habitat. In order to assess the level of threats that these challenges represent, and to establish a foundation of knowledge regarding steelhead in this river the following it is proposed that the following be done:

1. An analysis of barriers to steelhead migration,
2. An assessment of the water balance and amount of water flow needed for steelhead passage, and
3. A steelhead habitat and population density survey.

Appendix

A Brief Introduction

This appendix synthesizes information gathered during a 9-month investigation into the state of steelhead trout on the Santa Clara River. Much of the information contained here is directly quoted from the original material. Seventeen people were also interviewed and their comments along with comments from other conversations and emails are noted as “personal communication”.

Citations are provided for almost all the material with the references listed in the bibliography. The citation for a source generally follows the last sentence in a bulleted paragraph when all the information is from one source. Where different sources are used in a paragraph, the citations are contained within the relevant sentence.

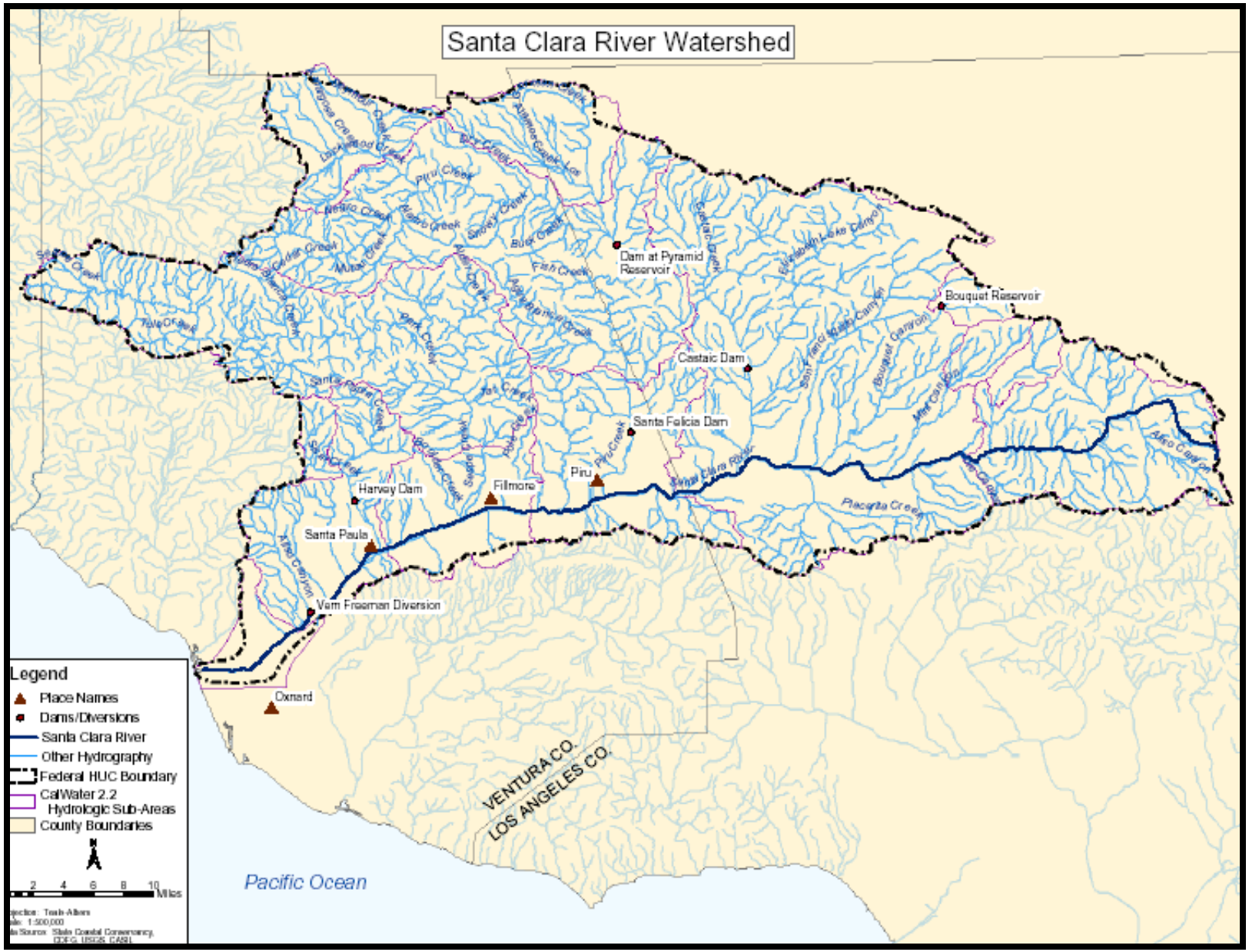
In general, the Appendix chapters conform to the following format:

1. **Issues** – a summary of the most important issues related to that topic. Issues are not listed in any particular order.
2. **Potential research questions** – a list of research areas and action items for that topic
3. **Section I. Santa Clara River** – information specific to that topic and the Santa Clara River
4. **Section II. General Information** – information specific to that topic, but more general in geography or scope than Section I.

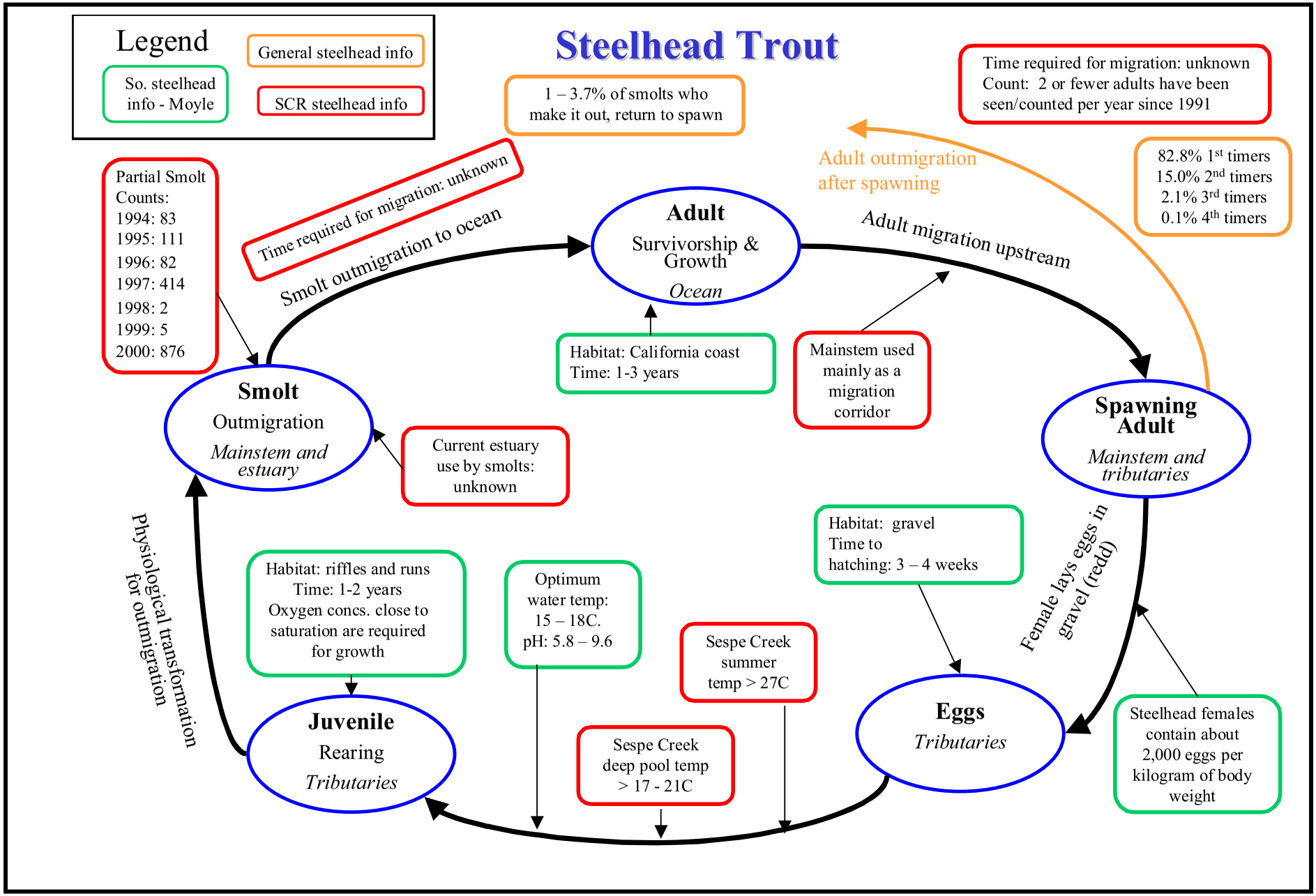
Subheadings are contained within both Sections I and II, in order to better organize the material.

The information presented here was gathered from a variety of sources and these sources do not always agree with each other. The purpose of the Appendix is not to choose amongst these sources, but rather to present published reports or informed opinions regardless of their agreement.

Map


Santa Clara River Watershed
Dam at Pyramid Reservoir
Bouquet Reservoir
Castaic Dam
Santa Felicia Dam
Piru
Fillmore
Harvey Dam
Santa Paula
Vern Freeman Diversion
Oxnard
Piru Creek
Sespe Creek
Santa Clara River
Placerita Creek
Mint Canyon
Bouquet Canyon
Aliso Canyon
Tule Creek
Fish Creek
Bear Creek
Shoey Creek
Hopper Creek
Lockwood Creek
Alamos Creek
Castaic Creek
Elizabeth Lake Canyon
South Fork Mint Canyon
VENTURA CO.
LOS ANGELES CO.
Pacific Ocean
Legend
Place Names
Dams/Diversions
Santa Clara River
Other Hydrography
Federal HUC Boundary
CalWater 2.2 Hydrologic Sub-Areas
County Boundaries
2 4 6 8 10 Miles

Conceptual Model of Steelhead Trout on the SCR


Legend
General steelhead info
So. steelhead info - Moyle
SCR steelhead info
Steelhead Trout
1 – 3.7% of smolts who make it out, return to spawn
Time required for migration: unknown
Count: 2 or fewer adults have been seen/counted per year since 1991
Adult outmigration after spawning
82.8% 1st timers
15.0% 2nd timers
2.1% 3rd timers
0.1% 4th timers
Partial Smolt Counts:
1994: 83
1995: 111
1996: 82
1997: 414
1998: 2
1999: 5
2000: 876
Time required for migration: unknown
Smolt outmigration to ocean
Adult
Survivorship & Growth
Ocean
Adult migration upstream
Habitat: California coast
Time: 1-3 years
Mainstem used mainly as a migration corridor
Smolt
Outmigration
Mainstem and estuary
Current estuary use by smolts: unknown
Spawning Adult
Mainstem and tributaries
Habitat: gravel
Time to hatching: 3 – 4 weeks
Female lays eggs in gravel (redd)
Physiological transformation for outmigration
Habitat: riffles and runs
Time: 1-2 years
Oxygen concs. close to saturation are required for growth
Optimum water temp: 15 – 18C.
pH: 5.8 – 9.6
Sespe Creek summer temp > 27C
Eggs
Tributaries
Steelhead females contain about 2,000 eggs per kilogram of body weight
Juvenile
Rearing
Tributaries
Sespe Creek deep pool temp > 17 - 21C

Santa Clara River Timeline

1769	Observations by Father Juan Crespi of tall and thick cottonwoods and oaks in the Santa Clara riverbed. He described it as an arroyo with a great deal of water which runs in a moderately wide valley, well grown with willows and cottonwoods. [1]
1769	Father Juan Crespi names the river after Saint Clare of Assisi who had an upcoming feast day.[1]
1785	San Buenaventura Mission established by Spanish priests.[1]
1820s – 1860s	Livestock raised on large rancheros. [1]
1842	Gold mining begins. [1]
Mid-1800s	870 acres of estuary are estimated to have existed at the mouth of the river. [1]
1850s	Timber and willows along the creek filled the whole valley between the ridges on either side; freshwater marsh in the same region.[1]
1860s	Euro American immigrants began arriving. [1]
1870s	Agriculture and oil; dry farming techniques. [1]
1870's through the end of WWI	Arrival of Euro-American immigrants results in increasing control of water usage and land for agriculture. [1]
1870s	First artesian wells drilled in the Oxnard Plain.[1]
1876	Main line of the Southern Pacific railroad completed.[1]
1883	Water quality lowered by livestock waste; increased erosion resulting from grazing of riparian groundcover. Lowell Hardison recalled, "the valley was so full of dust that South Mountain was only an outline against the sky. The SCR became a dry bed of sand."[1]
1887	A Southern Pacific branch line extended from Newhall west down the length of the river to Ventura.[1]
1890s	Demand for water in Oxnard reduces water pressure and first pumps are installed.[1]
Early 1900s	Over 16,000 acres irrigated by the surface flows.[1]
Prior to 1910	Harvey Dam built.[2]
1917	29,000 acres of orchard land in Ventura County.[1]
Before 1920	Lowlands in the Oxnard Plain had a high water table.[1]
1918 – 1934	Increased use of groundwater.[1]
Mid-1920s	Water rights becoming an issue.[1]
1920s	Increased urban demand for dairy products led to increased planting of alfalfa for cattle feed.[1]
March 12, 1928	St. Francis Dam disaster.[1] Reshaped the topography of valley lands.[3]
1928	Water diversion commences east of Saticoy; precursor to Vern Freeman Diversion[12]
1930s	Seawater intrusion becomes an issue on Oxnard Plain.[1]
1938	Large flood, over 100, 000 cfs.[1]
1939 - 1969	Harvey Dam fish ladder operational.[2]
Early 1940's	Fish hatchery at Fillmore opened.[1]
1944	21,000 steelhead from Santa Ynez river were planted in the Santa Clara lagoon.[4]
1930s and 1940s	SCR estuary large; fresh/saline mixture; surrounding vegetation/ saltgrass, etc. variety of flora and fauna including smelt/grunion, etc.[5]
1930's to today	Loss of riparian thickets along gravel bars and floodplain; especially near aggregate extraction operations downstream because of lowered water tables from mining and natural scouring.[1]
Pre-1946	Large numbers of huge basking sharks started arriving in Pierpont Bay during the summer months.[6]
1946	Basking sharks in Pierpont Bay killed for industrial use (fertilizers, vitamins, etc.).[6]

1946	Water district started diverting water at the Saticoy Spreading Grounds during the winter months.[7]
1949	107,689 irrigated acres in Ventura County.[1]
Late 1940s	Many farms were under 100 acres.[1]
1950	66,000 acres of orchard land in Ventura County.[1]
1955	Santa Felicia Dam is constructed. [1]
1956	Fillmore WRP comes on-line.[8]
1958	Ventura WRP comes on-line. [8]
Post 1950s	River bed lowering occurred; sand and gravel extraction intensified.[1]
1960s	Surface flow had diminished and use of groundwater replaced earlier sources.[1]
1964	Interstate 5 constructed; Valencia development announced.[1]
1965	SCR surface flows irrigated 2,500 acres because of reduction of surface flow. Same amount irrigated in 1969. [1]
1966	Valencia WRP comes on-line.[8]
1969	Urban use of water along SCR is 39% of local water service.[1]
1969	Largest natural flood on the river.[9]
1970s/80s	A red line was created that limited mining in the river.[1]
Pre-1977	Cool, nutrient-rich ocean phase with high ocean salmon productivity.[10]
Post 1977	Low-production warm ocean phase.[10]
1978	Large flood, over 100, 000 cfs.[9]
1980	UWCD proposes the Pumping-Trough-Pipeline and the permanent Freeman Diversion to solve seawater intrusion problem.[1]
1983	Large flood, over 100, 000 cfs.[9]
1989	Vern Freeman Diversion fish ladder and intake screens installed.[2]
1986	Department of Water Resources – protested that the finding of three adult steelhead did not constitute a "run" and that all water should be diverted from the river to UWCDs percolation grounds.[11]
1991	VFD fish ladder and screen become operational.[12]
1991	Mobil spill. Pipeline ruptured most likely from poor maintenance, oil flowed toward and into the river, in same general area as the later Arco spill. Settlement recently arrived at with Exxon/Mobil. ~$2.7M [1]
1992	Large flood, over 100, 000 cfs.[9]
1992	31.5 miles of the Sespe is designated as Wild and Scenic.[13]
1992	Saugus WRP comes on-line.[8]
1994	Arco spill. Pipeline rupture as result of Northridge Earthquake. Settlement ~7.5M, at $9M as of 1995 due to interest accumulation.[1]
1995	Large flood, over 100, 000 cfs.[9]
As of 1995	There were cattle operations near Piru and in Los Angeles County with occasional cattle drives crossing the river.[1]

References

1. Schwartzberg and Moore 1995
2. National Oceanic and Atmospheric Administration and National Marine Fisheries Service 2000
3. Taylor 1994, as cited in Schwartzberg and Moore 1995
4. Carpanzano 1996
5. Henke 1995
6. Henke 1970
7. Outland 1971
8. Pers. comm. with respective WRP agencies/departments, 2003
9. Santa Clara River Project Steering Committee 1996
10. Reinard 2002
11. Kennedy April 1986
12. Pers. comm. Murray McEachron
13. Blecker 1997

Santa Clara River Watershed Factsheet

Headwaters	**Pacifico Mountain** in the San Gabriel Mountains		
Size	**Watershed Area:** 1,600 square miles		
	Naturally Occurring Waterways: 2623.92 miles		
	Percentage of Free Flowing River Miles: 94		
	Percentage of River Miles in Protected Lands: 21		
Main tributaries	Agua Blanca Creek	Aliso Canyon	Bouquet Canyon
	Canada De Los Alamos	Castaic Creek	Elizabeth Lake Canyon
	Gormon Creek	Lockwood Creek	Mint Canyon
	Piru Creek	Santa Paula Creek	Sespe Creek
	Seymour Creek	Snowy Creek	Hopper Creek
Average annual precipitation	Mean annual precipitation ranges from approximately 8 inches in the easternmost part of the watershed to more than 34 inches near the headwaters of Sespe Creek.		
Land	**Protected Lands:** 20%		
	47 percent, or 480,000 acres of land in the watershed is **publicly owned** (the Los Padres and Angeles National Forests)		
Dams	**7**		
	Vern Freeman, a diversion dam		
	Bouquet Canyon Reservoir (1934; 628 acres)		
	Pyramid and Castaic dams control about 37% of the watershed. **Castaic Lake** is created via an earthen dam across Castaic Creek (324,000 AF)		
	Lake Piru (used for groundwater replenishment)		
	Castaic Lagoon (197 acres)		
	Dry Canyon Reservoir (1,313 AF) is the terminus for the West Branch of the California Aqueduct.		
Species	**Number of Special Status Species:** 26		

Faults	**Santa Clara River Valley Fault Lines:** San Gabriel and Holser
Sea water intrusion	New facilities and management practices introduced in the 1980s and 1990s slowed seawater intrusion
Habitat	**Harbor Blvd. to the U.S. Highway 101 Bridge:** riparian woodland riparian scrub small pockets of *Arundo donax*
	Highway 101 to Saticoy vegetation sparse small pockets of riparian/oak woodland habitat areas infested with *Arundo donax*
	Saticoy to Santa Paula southern willow riparian woodland coastal sage scrub coast live oak woodland large *Arundo donax* infested areas
	Santa Paula to Fillmore vegetation changes to large concentrations of alluvial scrub watercress southern willow scrub large concentrations of *Arundo donax*
	Fillmore to Piru alluvial scrub
	Piru to the Ventura/Los Angeles County line southern willow scrub southern willow riparian woodland
	Los Angeles County line to the upper reaches alluvial scrub southern willow riparian woodland alluvial scrub southern willow scrub

*Main data sources for table were the Southern California Wetlands Recovery Project Information Station on-line at http://www.wrpinfo.scc.ca.gov/, Santa Clara River Enhancement and Management Plan (SCREMP) documents, and the McGrath State Beach Natural Resources Management Plan (April 2003).

Sespe Creek Subwatershed Factsheet

Headwaters	Northwestern corner of the Ojai Ranger District near Ventura/SB County boundary
Size	207,700 acres
Major tributaries	Lion Canyon, Hot Springs Canyon, Timber Creek, West Fork Sespe Creek
Small tributaries	Abadi, Adobe, Cherry, Ladybug, and Burro Creeks
Average annual volume	Near Wheeler Springs was 10,000 AF from 1947 to 1985. Near Fillmore was 86,220 AF from 1927 to 1985. Sespe Creek contributes 40% of the total natural runoff in the Santa Clara River Basin
Land uses	Campgrounds
	Urban (the City of Fillmore) and agricultural development
Water quality	Affected by the older marine sedimentary rocks. Hot Springs Creek is a major source of fluoride, chlorine, and boron.
Habitat	Established in 1992, the 219,700-acre Sespe Wilderness Area encompasses 31.5 miles of Sespe Creek and contains a 53,000-acre Sespe Condor Sanctuary. 31.5-mile reach of Sespe Creek from its confluence with Rock Creek and Howard Creek downstream to where Sespe Creek leaves Section 26, Township 5 N., Range 20 W. of the Fillmore USGS Quadrangle map.
Species	Common wildlife species observed within the subwatershed include black bears, deer, mountain lions, bobcats, coyotes, rattlesnakes, red-tailed hawks, and golden eagles. Black bear populations have maintained their numbers at a relatively constant level over the past few decades.
	Arroyo toad largest surviving populations: 15 miles of Sespe Creek from the mouth of the Tule Creek downstream to the Hot Springs Canyon vicinity
	Vireo and Flycatcher recovery: efforts have been focused at the mouth of Sespe Creek near the Fillmore Fish Hatchery
	Cowbird control: brood parasitism by cowbirds fell to less than 10%, with none detected since 1993
	Southwestern willow flycatcher: recovery team under leadership of the USFWS.
Fillmore Wastewater Treatment Plant	Discharges 1.33 million gallons per day of treated domestic and industrial wastewaters, and constitutes a threat to surface water quality in the lower Sespe Creek and Santa Clara River

*Main data sources for table were the Southern California Wetlands Recovery Project Information Station on-line http://www.wrpinfo.scc.ca.gov/, and Santa Clara River Enhancement and Management Plan (SCREMP) documents.

Santa Paula Creek Subwatershed Factsheet

Headwaters	Springs are on the southern slopes of the Topatopa Mountains in Los Padres National Forest. The headwaters are located near Hines Peak at an elevation of approximately 6,704 feet above MSL
Size	45-square miles or 75,050 acres
Tributaries	Sisar Creek, Mud Creek
Average annual precipitation	17.43 inches
Average annual volume	112 AF from 1927 to 1932
	300 AF from 1949 to 1985.
	No flows were recorded for long periods in most years
Land Uses	Residential development, campgrounds, fishing, swimming, hiking
Surface water quality	Good but not considered potable.
	High amounts of suspended clays, presence of natural oil and sulphur seeps (Sulphur Springs area).
	High biological oxygen demand believed to originate from anthropogenic sources (septic system leacheate and recreational uses at Steckel Park).
Habitat	The natural communities present in the Santa Paula Creek subwatershed include riparian woodland, riparian scrub, coast live oak-walnut woodland, coastal sage scrub-grassland, and chaparral.
Structures	CalTrans bridge for highway 150 near the Thomas Aquinas College. Footings for bridge are in a concrete apron just below the confluence of Santa Paula and Sisar Creeks.
	Harvey Diversion: Santa Paula Water Works, Ltd. Recently sold this diversion to Canyon Irrigation District. The diversion occurs approximately 1,000 feet south of Steckel Park just below a USGS gauging station and just upstream of the confluence with Mud Creek. It is a source of water for the City of Santa Paula. The diversion was built in 1923 and the fish ladder was recently rebuilt in 2000 on the southern wall of the approximately 30-foot dam. Downstream of the dam, the creek is deeply eroded for approximately one mile.
	A flood control channel built and operated by the ACOE. Occurs just prior to the confluence with the mainstem.
	Three road crossings consisting of fill with culverts occur within the streambed of the Santa Paula Creek

*Main data sources for table were the Southern California Wetlands Recovery Project Information Station on-line at http://www.wrpinfo.scc.ca.gov/ and Santa Clara River Enhancement and Management Plan (SCREMP) documents.

Piru Creek Subwatershed Factsheet

Headwaters	Lockwood Valley located northwest Los Angeles and approximately 25 miles northeast of the City of Ventura.
Size	318,000 acres
Tributaries	Lockwood, Alamo, Seymour, Amargosa, San Guillermo, Agua Blanca, and Fish Creeks
Average annual volume	Above Lake Piru, from 1956 – 2001, average annual streamflow: 66.8 cfs
Land uses	Camping, cattle grazing, urban development, citrus, avocado, pasture, small grains, and alfalfa
Water Quality	Threats include waste discharges from the Gorman Water Pollution Control Plant and Pyramid Power Plant; agricultural returns to the Pico Formation near the mouth of Piru Creek. Approximately 60,000 gallons of domestic wastewater is treated and discharged per day to the Peace Valley area.
Habitat	The upper portion of the subwatershed is rugged, undisturbed terrain located in the Los Padres National Forest. Open valleys and steep gorges before the Pyramid Lake Reservoir. Below Pyramid Dam scattered riffle-pool formations.
	Oaks, pines, fir, and juniper species occur above 5,000 feet while cottonwood, and willow communities occur within the streambed and near springs. Seasonal grasses are dominant on the soils formed on finer grained sedimentary rocks and alluvium. Adjacent upland terraces are relatively arid, supporting oaks, grassland and chaparral.
Dams	Pyramid Dam built in 1973; impounds water from the State Water Project (SWP) and subwatershed runoff. Santa Felicia Dam was built in 1955 and impounds runoff from the subwatershed. Approximately 87,000 acre-feet (AF) of water are stored in Lake Piru.
Species	Vegetation throughout lower Piru creek consists of white alders (*Alnus rhombifolia*), California sycamores (*Platanus racemosa*), arroyo willows (*Salix lasiolepis*), coast live oak (*Quercus agrifolia*) and mule fat (*Baccharis salicifolia*). The dominant overstory is alders and sycamores, with some portions being dominated by coast live oaks. The midstory is composed of smaller willows, mule fat, and poison oak (*Toxicodendron diversilobum*), with and understory of the aforementioned species as well as California wild rose (*Rosa californica*), California blackberry (*Rubus californicus*), cattails (*Typha sp.*), and other herbaceous species.
	Middle section of Piru creek (between Pyramid and Lake Piru) contains a wide diversity of aquatic species including abundant rainbow trout. Piru Creek has been stocked by the CDFG with small rainbow trout (*Oncorhynchus mykiss*) since the early 1950s. Stocking of fingerling brown trout (*Salmo trutta*) stopped in the late 1970s.
	Black bear; southwestern willow flycatcher, least Bell's vireo, Cooper's hawk (*Accipiter cooperii*), arroyo toad, and California red-legged frog are either known to occur or potentially occur within subwatershed.
Hydrology	Flow on Piru Creek is controlled by Pyramid and Santa Felicia Dams, which serve as both flood control and water supply reservoirs.

*Main data sources for table were the Southern California Wetlands Recovery Project Information Station on-line http://www.wrpinfo.scc.ca.gov/, the California Department of Water Resources, and Scott, K., J. Ritter, and J. Knott. 1968. *Sedimentation in the Piru Creek Watershed, Southern California*: U.S. Geological Survey, Water-Supply Paper 1798-E, 48 p.

Ecology and Population of Steelhead

Issues

1. Steelhead ecology and biology are poorly known in this river. There is little current data or information on life history, habitat usage, historical numbers, length of time to migrate, etc.
2. The utilization of the estuary by smolts is undocumented. Currently the estuary is shallow, lacks cover, is ¼ of its historical size, and the gravel bed has been covered by silt - removing food sources for smolts.
3. Southern steelhead ocean ecology is virtually unknown.
4. The most likely major cause of steelhead population decline in the SCR was the increase in water diverted at the Vern Freeman Diversion beginning in 1950s when it was operated without a fish screen (i.e. a significant majority of smolts and spawned adults were diverted into the percolation ponds and died) until 1991. Other potential impacts were increased use of water by agriculture and increased aggregate mining.
5. Sespe Creek harbors the largest and highest quality spawning opportunity for steelhead on this river.

Potential Research Questions

- Assess habitat quantity and quality in Santa Paula Creek, Sespe Creek, and Piru Creek including summer water temperatures, oxygen levels, etc.
- Assess carrying capacity of each of the tributaries in terms of food, habitat and water temperature.
- Investigate steelhead tolerances to turbidity, and water temperature.
- Assess historical use of river and estuary by smolts.
    - How has the changing water chemistry in the estuary likely affected smolt utilization?
    - What is the overall condition of the estuary?
    - How much suitable estuarine habitat is available for smolts?
    - How easily and quickly do smolts adapt to the estuary and then to the ocean?
    - How much time do smolts spend in the estuary?
    - What is an optimal size for ocean-going smolts? Do smolts in the SCR reach the necessary size in one year or do they need additional time in the estuary?
    - Is there a beneficial level of freshwater input to the estuary?
- A count at the estuary of the number of smolts making it to the ocean, by size and sex.
- Where in the ocean do steelhead trout go? How well do they survive? What affects their population/survival?
- What is SCR's transportation efficiency? Do adults/juveniles get caught in shallows or hydrologically disconnected reaches and experience high mortality rates?

Section I. Santa Clara River

Fish Counts

- In 1997 there was a high kill of smolts in the out migrant trap at the VFD. UWCD and DFG took scales and used the opportunity to sex fish. There was an extremely skewed sex ratio with females making up 85 - 90%. The normal ratio in other rivers has been 1:1. Similar results to these found at VFD have also been found in Central Valley Coho salmon. It is unclear why the skewness occurred – it could have been an unrepresentative sample, or it could have been some effect of temperature that caused the females to smoltify and emigrate downstream, but not the males, etc. (Robert Titus, California Fish and Game, pers. comm. November 2002)
- Probably more than 1% of smolts make it back to spawn in general (Robert Titus, California Fish and Game, pers. comm. November 2002). Shapovalov and Taft (1954) stated that 3.5% made it back on Waddell Creek.
- Prior to 1954 the DFG required a screen over the VFD headworks to prevent the induction of downstream migrant steelhead. However after Jack White, the DFG warden who worked on the Santa Clara, retired the seasonal installation and maintenance of the screen was allowed to lapse. This change in operations, plus the enlargement of the diversion works, increased groundwater pumping, and the construction of reservoirs on the Piru and Castaic Creek tributaries led to a sharp decline in the SCR steelhead fishery in the late 1950s. (Capelli 1983)
- The size of the SCR drainage has been used to make some run-size estimates. A reasonable estimate is on the order of 1,000s of fish. (Robert Titus, California Fish and Game, pers. comm. November 2002)
- About 1946 the UWCD district started diverting water at the Saticoy Spreading Grounds during the winter months. Local historian Charles Outland never personally saw a native run trout after that time. (Outland 1971).
- 1946 was the beginning of one of the worst droughts on record (Murray McEachron, United Water Conservation District, pers. comm. January 2004).

Migration timing

- In general, upstream migration of adult steelhead occurs from January through March. Downstream emigration of smolts and spawned out adult steelhead occurs from April through June. (Moore 1980c)
- Flow and hydrology are historically inconsistent throughout the SCR watershed. Both upstream and downstream migrating fish have likely developed migration behavior that accounts for the relatively short "migration windows" common to Southern California river systems (Rick Rogers, pers. comm. December 2003)

Return spawners

- It is unknown how likely SCR steelhead are to return to the SCR. Shapovalov and Taft (1954) found 98% of Waddell Creek spawned steelhead returned to their natal creek. However, flows in southern streams like the SCR are less reliable, and make it more likely that these fish seek whatever river openings they can find.

Habitat

- The mainstem of the SCR acts as a fish migratory corridor. Adults swim upstream and do not linger in the mainstem.
- Monitoring-oriented instream habitat surveys are difficult to execute in the SCR because the channel(s) shift(s) from year to year, along the mainstem. Not a static channel. Difficult to monitor. (Matt Carpenter, Entrix, pers. comm. November 2002)
- From above the estuary to the VFD the river is mostly low flows with warm water; lacks instream cover and deep pools. Predominantly sand substrate (Matt Carpenter, Entrix, pers. comm. November 2002).
- Main tributaries on the SCR provided 89 miles of spawning and rearing habitat prior to 1948 (Moore 1980c):

Drainage	SP creek	Sespe Creek	Piru Creek
Mile of historical habitat	11	53	25
Miles of current habitat	2	47	0

Santa Paula Creek

- Due to its smaller watershed size, SP creek was historically a minor contributor in steelhead runs compared to Sespe and Piru. (Rick Rogers, National Marine Fisheries Service, pers. comm. January 2003)
- Adult steelhead still occur but in low numbers. Heavily fished. About 10 – 11 miles of good habitat occurs above the Harvey Dam diversion. East Fork's habitat limiting factor is turbidity due to extensive mass wasting from unstable canyon walls. (The National Oceanic and Atmospheric Administration and the National Marine Fisheries Service 2000)
- ACOE did a wildlife assessment (invertebrates, fish, birds, etc.) from the mouth of SP Creek to Thomas Aquinas College. Pools, riffles, and glides probably not assessed.

Sespe Creek

- Sespe Basin is good rearing and spawning habitat up as far as Cherry Creek. (Buck Yedor, United Water Conservation District, pers. comm. December 2002)
- Sespe is naturally high in total dissolved solids (TDS), which makes for a productive aquatic environment. It is high in calcium and phosphorus. Rich macroinvertebrate community. Stream clears up quickly from a rain.

(Mark Moore, California Department of Fish and Game, pers. comm. December 2002)

- Timber Canyon creek is a cool water addition to Sespe. It has barriers in its middle section. (The National Oceanic and Atmospheric Administration and the National Marine Fisheries Service 2000)
- Coolest tributaries to the Sespe include Pine Canyon, Coldwater, and West Fork Creeks with summer temps generally staying below 64F. (Blecker *et al.* 1997)
- Maintaining migration access to Sespe creek is essential to restoration and recovery of southern California steelhead (Matt Carpenter, Entrix, pers. comm. November 2002). Sespe is the main spawning opportunity and is regarded as the crown jewel of the system (Rick Rogers, National Marine Fisheries Service, pers. comm. January 2003).
- Below Vantrees property, the Lower Sespe is probably only a migration corridor. (Mark Moore, California Department of Fish and Game, pers. comm. December 2002)
- On Sespe Creek, the most suitable steelhead spawning areas are the riffles of the mid to upper section of the Sespe, Lion and Tule Creeks. These areas support the highest trout fry densities. (Blecker *et al.* 1997)
- Sespe creek water chemistry suggests a moderately productive aquatic community with insects in moderate densities. (Blecker *et al.* 1997)
- On the Sespe there is 134,004 m^2 of available spawning habitat, and 242,270 m^2 rearing habitat. Therefore an estimated 94,772 smolts could potentially be supported to smoltification. These fish would equate to approximately 9,472 adults or 2% of the spawning potential of the creek. In drought years rearing capacity would be less. (Blecker *et al.* 1997)
- In the Sespe dead wood does not play a significant role as in-stream fish cover but it does contribute to the erosion potential of floods. (Blecker *et al.* 1997)
- Landslides do not play a long-term beneficial role in supplying the stream with bedload materials. (Blecker *et al.* 1997)
- 1992 – a major section of Sespe was given protection as a federally designated wilderness area, and at the same time a 31.5-mile section was given protected status as a Wild and Scenic River. (Blecker *et al.* 1997)
- Sespe watershed includes an unusually high concentration of perennial creeks and streams for Southern California. (Blecker *et al.* 1997)
- There is currently no active grazing within Sespe. (Blecker *et al.* 1997)
- There are 6 birds, 1 reptile, and 2 amphibian species listed or proposed as threatened, endangered or sensitive, known to potentially occur within the Sespe watershed. (Blecker *et al.* 1997)
- There is a general trend of declining riparian vegetation along the mainstem Sespe as a result of fires, roads, and trails. (Blecker *et al.* 1997)
- Efforts to return the watershed to a more natural or desirable cycle of fire return (i.e., more frequent, less large/hot) may be the most significant contribution to restoration of steelhead habitat. Siltation would be

lessened and hydrology could be improved to lessen the effects of drought and scouring floods. (Blecker *et al.* 1997)

- Water temperatures exceed 60F on the potential steelhead spawning areas approximately 20% of the days in Feb – June. Water temperatures regularly rise above 68F during July – September. Riparian canopies are not adequate to moderate summer water temperatures. (Blecker *et al.* 1997)
- Large boulder material frequently plays the role of large woody debris, and water temperatures are locally influenced by upwelling of cooler spring water. (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)
- Sespe creek and its tributaries (Dvorsky 2000):
    - The dominant habitat variable in the nine subwatersheds influencing fish densities was pool depth, and to a certain degree, pool volume.
    - Some Sespe tributaries may produce a large number of fry but show very few large individuals suggesting the spawning quality of the creek is good but other habitat characteristics are poor such as food production or temperature.
    - Alder Creek for example has low densities for the smaller trout sizes indicating that spawning success was relatively low yet densities for higher classes were fairly high suggesting that habitat is able to support adult rainbow trout populations in Alder Creek but that production of fry and juveniles is low. Creeks lined by alder trees are often associated with year-round surface flow, but sediment storage characteristics may limit the supply of gravel creating insufficient spawning habitat.
    - In Trout Creek small trout densities are relatively high, yet the larger size classes have small amounts of representation. This suggests that Trout Creek provides adequate spawning habitat as indicated by its sediment storage characteristics but may provide poor rearing and adult habitat.
- The middle reach of the Sespe is a demanding area to survey because of its very ruggedness and inaccessibility. Hasn't been done utilizing systematic survey methods such as the Habitat Suitability Index method. Middle reach is the main spawning area, from above and below Alder Creek downstream to Devil's Gate. Big water, deep ponds. May require diving. Smolt population is high. (Maurice Cardenas, California Department of Fish and Game, pers. comm. December 2002; Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)
- Bear Canyon Creek -1979 - Good habitat (summer nursery) and trout numbers in the lower river. (The National Oceanic and Atmospheric Administration and the National Marine Fisheries Service 2000)
- Lion Creek -1979 - rainbow trout abundant. (The National Oceanic and Atmospheric Administration and the National Marine Fisheries Service 2000)

Pole Creek

- Natural impassable 30 ft waterfall 3.9 miles upstream of Fillmore city limits. Potential artificial barrier 0.8 miles above Hwy 126. No fish observed in 1992 survey. (The National Oceanic and Atmospheric Administration and the National Marine Fisheries Service 2000)

Hopper Canyon Creek

- RT observed 1992. Fair to good spawning and rearing habitat throughout upper portions (The National Oceanic and Atmospheric Administration and the National Marine Fisheries Service 2000)
- Hopper Canyon has great wildlife habitat. Hopper Creek is a good creek, but there's no size to it. However, the creek has good potential to support trout and smolts. (Maurice Cardenas, California Department of Fish and Game, pers. comm. December 2002)

Piru Creek

- No steelhead were found below Santa Felicia Dam in 1978 seining survey. Abundance of naturally-reproduced RT found in 1987 in reaches near old Hwy 99. (The National Oceanic and Atmospheric Administration and the National Marine Fisheries Service 2000)
- Historical data on Piru Creek is spotty at best, but the current headwaters (above both Piru and Pyramid Lakes) contain stretches of suitable steelhead spawning and rearing habitat. (Rick Rogers, National Marine Fisheries Service, pers. comm. January 2003)
- Piru Creek contains approximately 30% of the total amount of historic steelhead spawning and rearing habitat in the Santa Clara River watershed. (Moore 1980c)

Estuary

- Estuary is shallow due to siltation; recent seining found no steelhead; lack of cover minimizes chances of a successful out-migration of smolts (National Oceanic and Atmospheric Administration and National Marine Fisheries Service 2000). Estuarine conditions in the SCR lagoon have changed dramatically over the past fifty years (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004). In particular the natural frequency of lagoon breaching has been disrupted. Levees, decreased river flows, and pollution have impacted the lagoon environment (Comstock 1992).
- The Santa Clara River Estuary formerly consisted of a series of shifting river mouths that have now been restricted by development to a single location and reduced to approximately 1/4 of its previous aerial extent. Prior to the late 1940s when upstream diversions altered the flow regime in the lower river, smolts were commonly seen in the estuary waiting for the sand bar to breach and allow their emigration to the ocean. The estuary bottom consisted of more coarse sediments than today, which

provided a suitable substrate for benthic organisms upon which smolts could feed. Currently, the silt-covered bottom of the estuary provides more suitable habitat for marine species of fish such as stripped mullet, which were not common before, but are now seen more frequently and in increasing numbers. (Mark Capelli, National Marine Fisheries Service, pers. comm. October 2003)

- Estuary lost part of its earthen levee on the east bank in 1995, and the rest of it is eroding back. Sediment is building up along the east (downcoast) bank. (Virginia Gardner, California State Parks, pers. comm., October 2003).
- Currently there is no authorized, artificial breaching of the levee by either California State Parks or the City of Ventura. (Virginia Gardner, California State Parks, pers. comm., October 2003)
- The Army Corps of Engineers has rejected McGrath Farms' claim that they have a right to breach the estuary. The Ventura County Resource Management Agency's Environmental Health Department has suggested artificial breaching of the sandbar as a means of mosquito control, however the California Department of Parks and Recreation manages the majority of the estuary as a Natural Preserve and does not support the practice. (Waln 2004)
- The City of Ventura's wastewater treatment plant's effluent is currently in violation of the copper limits established for a saltwater environment (i.e., for the estuary). The City commissioned a study of the estuary that showed that the majority of the species in this environment were either freshwater species tolerant of brackish conditions or brackish water species. (Entrix 2002)
- The Santa Clara River estuary is unique among other estuaries found in the Southern California Bight (Point Conception south to the California/Mexico border). Published information on invertebrate communities and hydrologic conditions was found on seven estuaries of similar size to the Santa Clara River estuary within the Southern California Bight. Among these estuaries, the SCR estuary is unique in that it receives constant year-round freshwater flows and does not have its mouth manually dredged for water quality purposes. The seven estuaries examined generally share many benthic invertebrate taxa in common. With the exception of San Dieguito Lagoon, the Santa Clara River estuary shares very few invertebrate taxa with these other estuaries. The species compositions of the other estuaries are in general more estuarine and marine than the SCR estuary. (Entrix 2002)
- During a recent water quality profile of the estuary, low salinities (1 to 4ppt) were observed near the discharge channel and upper estuary, where the Santa Clara River flows in. Brackish conditions (5 to 10 ppt) were observed in the middle of the Estuary. More marine-like (>10 ppt) conditions were isolated to the area near the mouth and far southwestern portion of the estuary, the highest salinity measurement being 30 ppt. (Entrix 2002)

- The temperature of the reclaimed water discharge (treatment plant effluent) is essentially identical to the temperature of upstream river flows. The city of Ventura has available extensive temperature, nutrient and chlorophyll A data that they have collected for upstream flow, estuary waters, and reclaimed water discharge. The upstream sampling sites for the City of Ventura are at the Harbor Blvd. bridge and 0.5 miles upstream of the Harbor Blvd. bridge. There are also four sampling sites within the estuary. (Waln 2004; Don Davis, City of Ventura, pers. comm. March 2004)
- UWCD no longer releases smolts near the outfall for the City of Ventura's wastewater treatment plant. Sampling from February through April of 2001 revealed the outfall water temperature to be 5°C warmer than that at the Vern Freeman Diversion. (Buck Yedor and Murray McEachron, United Water Conservation District, pers. comm. March 2004)
- The City of Ventura WRP's discharge directly to the Santa Clara River estuary has substantially altered the water chemistry and quality of the estuary. (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)

Aggregate Mining

- During the time when poorly-regulated, active gravel mining occurred in the active river channel and for as long as excavations remained, fish perished as a result of mining operations. Mining would disrupt surface flow continuity creating holes into which the surface water (and fish) would disappear. (Mark Moore, California Department of Fish and Game, pers. comm. December 2002)

Climate

- The Upper Santa Clara River is characterized by semi-arid Mediterranean-type climate and temperature ranges from 100° F to 30° F. Eighty percent of the average annual precipitation occurs between November and March. (United Water Conservation District and Castaic Lake Water Agency 1996)
- Lower Santa Clara River temperature ranges from 69° F near the coast to 61° F inland. Most precipitation occurs between December and March. Average annual rainfall from 1950 – 1992 was from 13.7 inches to 18.7 inches. (United Water Conservation District and Castaic Lake Water Agency 1996)

Section II. General Information

Southern Steelhead

- South of Point Conception the climate is much more hostile to steelhead. It is generally hotter, drier, and more variable, etc. Most habitat criteria developed for steelhead (i.e., temperature, instream shelter, etc.) are not

always applicable to streams south of Point Conception. (Matt Carpenter, Entrix, pers. comm. November 2002)

- Steelhead were listed before systematic population and habitat monitoring studies were able to begin on southern steelhead, thus our ability to understand and recover the population is diminished due to a lack of long term monitoring data (Matt Carpenter, Entrix, pers. comm. November 2002).
- Southern steelhead show unique genetic characteristics as well as high genetic diversity, suggesting that they developed from a population that survived in a Baja California refuge during the Pleistocene and that has recently come into contact with steelhead of more northern origin (Nielsen 1999). This ESU's high diversity may help to explain its remarkable capacity to persist in seemingly unfavorable environments.
- Due to drought and/or human-related activities, southern steelhead are often impeded or blocked from accessing their natal streams due to low-flow conditions. It appears that when faced with this prospect southern steelhead adapt, and either delay their upstream spawning migration until adequate flows exist or enter and ascend another suitable stream nearby. This action of straying from their stream of birth appears to be an important survival technique for a species whose freshwater habitat is characterized by extremely variable climatic conditions and human competition for resources, which may effectively eliminate upstream migration for a number of years. (Stoecker 2002)
- Studies by Moore (1980b) and others have shown that length of residency decreases in the more southern drainages. This variety in time to reach the smolting stage is probably related directly to growth rates, which in turn are influence by the length of the growing season, water temperatures, and the abundance of aquatic food materials. Moore's (1980b) study on the Ventura River indicated that a juvenile steelhead might reach the smolting stage in a single growing season. (Capelli 1983; Moore 1980b).
- Biologically and genetically we don't know how resilient these fish are. Migration windows are tiny. (Mark Moore, California Department of Fish and Game, pers. comm. December 2002)
- In 1999 on the Santa Ynez River eight adult steelhead were counted below Bradbury Dam. While there are few rivers monitoring the number of steelhead that run each year, steelhead have been sighted in rivers ranging from the Santa Maria southward into Orange County.

Regulation

- In 1989 both the genus name and species name of the rainbow trout were changed from *Salmo gairdneri* to *Oncorhynchus mykiss*.
- Southern ESU declared endangered in 1997 (National Oceanic and Atmospheric Administration and National Marine Fisheries Service 2000).

Habitat Qualities

- Escape cover can exist in the form of boulders, logs, undercut banks and trees, root wads, and overhead riparian vegetation (Hager 2001). In southern California rivers, boulder debris can serve the same function as large woody debris in providing refugia for migrating and rearing steelhead (Mark Capelli, National Marine Fisheries Service, pers. comm, January 2004)
- Loss of riparian vegetation reduces shade, cover, food supply, and streambank stability. Vegetation provides habitat for insects upon which steelhead feed, nutrients to streams via detritus, and cover for predator avoidance. Vegetation also prevents erosion by slowing runoff rates and reducing soil loss. (Hager 2001)
- Habitats with increased current speeds and turbulence usually contain higher dissolved oxygen and food levels, and when steelhead have access they preferred such habitat, particularly under conditions of oxygen stress at higher temperatures. (White 1991, as cited in Stoecker 2002; Hill and Grossman 1993, as cited in Stoecker 2002)
- Juvenile steelhead require living space (different combinations of water depth and velocity), shelter from predators and harsh environmental conditions, food resources, and suitable water quality and quantity for development and survival. (Lent 2001)
- Wetlands, estuaries and lagoons provide critical nursery habitat for all juvenile salmonids migrating to the ocean, as a feeding area and in their acclimatization to higher salinities. The ocean survival for juvenile salmonids is greatly increased if rearing fish are able to attain larger size for an extended period in the estuary. (Bryant and Lynch 1996)
- In other southern California rivers, sewer treatment plant effluent has been noted to supply more surface water than was available historically. The water is often much warmer than natural waters emerging from underground sources. Its high nutrient load encourages a different suite of species and can put the native fauna (and flora) at a competitive disadvantage (Swift *et al.* 1993; Morris 1991 as cited in Swift *et al.* 1993).

Migration and Spawning

- Migration and life history patterns of southern California steelhead depend more strongly on rainfall and stream flow than is the case for steelhead populations further north (Moore 1980, as cited in Lent 2001).
- The CFG Salmonid Stream Habitat Restoration Manual (Flosi *et al.* 1998) reports that an adult steelhead can maintain a maximum swim speed of 6.0 ft/sec. for 30 minutes until exhaustion and a maximum burst speed of 10.0 ft/sec. For 5 seconds until exhaustion. The maximum leap, or jump, speed is listed as 12 ft/sec. Jumping upstream of a structure becomes difficult or impossible when the jump pool depth becomes less than 1.25 times the jump height of the structure from the pool surface.
- When migrating upstream, steelhead use up to 80% of their energy reserve. Any major changes in steelhead energy expenditure, such as

overcoming barriers, may prevent the success of migration and spawning. Steelhead are capable of leaping 6 to 10 feet, however this requires adequate pools for resting above and below the obstacle. (Hager 2001)

- Shapovalov and Taft (1954) caught steelhead with four age type combinations at maturity. The relative abundance of these types varies from river to river, but Shapovalov and Taft's abundances were:

Years in fresh water	Years in salt water	% of fish
2	1	30
2	2	27
3	1	11
1	2	8

- Waddell Creek in Santa Cruz County (Shapovalov and Taft 1954):
  - 82.8% = 1st time spawners
  - 15.0% = 2nd time spawners
  - 2.1% = 3rd time spawners
  - 0.1% = 4th time spawners
- Adult males predominate in the early portions of the run while females predominate in the latter portions.
- After spawning spent steelhead often move gradually downstream and hang out in pools for periods of time during the downstream migration.

Feeding

- After steelhead leave their home streams they feed on estuarine invertebrates and marine krill, but as they increase in size, fish gradually become more important to their diet (Moyle 2002).
- Spent adult steelhead typically do not resume feeding while in fresh water (Shapovalov and Taft 1954).

Native fish and hatchery stock

- Native fish are less susceptible to disease than hatchery fish (Bryant and Lynch 1996)
- Steward and Bjornn (1990, as cited in Bryant and Lynch 1996) found that hatchery stocks might produce fewer smolts and returning adults.

Effects of sediment and turbidity

- Effects of increased sedimentation include: clogging and abrasion of gills and other respiratory surfaces; adherence of grains to the chorion of eggs; increase in conditions conducive to entry and persistence of disease-related organisms; the inducement of behavioral modifications; the entombing of different life stages; alteration of water chemistry by the adsorption of chemicals; degradation of useable habitat by scouring and filling of pools and riffles and changing bedload composition; reduction in photosynthetic growth and primary production; and an affect on intergravel

permeability and dissolved oxygen. (Bryant and Lynch 1996; Cordone and Kelley 1961; Walters 1995)

- Turbidity reduces drift feeding (Barrett *et al.* 1992).
- In a small coastal California stream, Cross (1975, as cited in Stoecker 2002) found that 67%-96% of young-of-the-year steelhead resided in pools. Similar results were reported by Spina (2003). Loss of pools due to excessive sediment input and filling can greatly reduce a streams capacity to rear steelhead to smolt size. Barnhart and Parson (1986) observed that dissolved oxygen be, at least, 80% of saturation for successful spawning to occur. Embryonic and alevin survival is highly dependent on intragravel, dissolved oxygen and concentrations of less than 7.2 mg/L can cause total mortality.
- Turbidity can reduce aquatic plant life by limiting photosynthetic growth, therefore reducing the number of aquatic invertebrates which are the primary food source for steelhead. An excess of sediment in spawning gravel can fill the interstitial spaces preventing water and oxygen from entering the redd. Egg survival increases with permeability. Sediment concentrations greater than 4,000 mg/L have been found to cause migration to cease. (Hager 2001)
- Sigler *et al*. (1984, as cited in Stoecker 2002) observed that chronic turbidity in streams during emergence and rearing of steelhead negatively affects the number and quality of fish produced. Suspended sediments can cause physiological damage to steelhead at concentrations of 3,000 parts per million or greater; when sediments settle out of suspension they frequently cover essential spawning sites, cover eggs, prevent emergence of recently hatched young, and decrease the amount of shelter available to fry that were able to hatch. Deposited sediment also reduces the production of aquatic insects that are essential prey to steelhead survival (Mark Capelli, National Marine Fisheries Service, pers. comm. 2004).

Ocean Life

- Southern steelhead are rarely caught by commercial or recreational fishers in the ocean, principally because adults do not tend to swim in large schools as do other pacific salmonids (Mark Capelli, National Marine Fisheries Service, pers. comm. 2004). However, high seas driftnet fishing has been implicated as a cause for decline of steelhead from coastal streams along the Pacific Coast since high seas steelhead distribution and driftnet fisheries overlap. Unauthorized high seas driftnet fisheries harvest between 2 percent (32,000) and 28 percent (448,000) of the steelhead that are destined to return to the Pacific Coast. Even the combined authorized and unauthorized take of steelhead in the open seas, at the highest estimate of 31%, cannot account for the greater than 50% decline observed in North American steelhead runs from 1986 – 1991. (Bryant and Lynch 1996)
- When northern steelhead smolts enter the Pacific Ocean they begin a directed movement into offshore waters of the Gulf of Alaska. California

steelhead stocks may have more restricted western migrations than do more northerly stocks due to sea surface isotherm temperatures. (Bryant and Lynch 1996).

- Steelhead experience most of their marine phase mortality soon after they enter the ocean. Ocean mortality is poorly understood however because few studies have been conducted. Predation is likely the primary cause of mortality among juveniles. (McEwan and Jackson 1996)
- There may be a tendency for populations of steelhead in the Southern California ESU to remain in close proximity to their natal streams within nearshore waters, which are vulnerable to upland runoff (Capelli 1999)

Ocean Climate

- El Nino is an environmental condition often cited as a cause for the decline of west coast salmonids. El Nino is an unusual warming of the Pacific Ocean off South America caused by atmospheric changes in the tropical Pacific Ocean (Southern Oscillation-ENSO). El Nino events occur when there is a decrease in the surface atmospheric pressure gradient from the normal-steady trade winds, there is a drop in pressure in the east off South America and a rise in the pressure in the western Pacific. The resulting decrease in the pressure gradient across the Pacific Ocean causes the easterly trade winds to relax, and even reverse in some years. When the trade winds weaken, sea level in the western Pacific Ocean drops, and a plume of warm sea water flows from west to east toward South America. Coast currents are changed as is upwelling. (Bryant and Lynch 1996)
- Good fish catches in Alaska generally reflect poor catches for the west coast of the U.S. and vice versa. One set of ocean conditions here, different from those in Alaska, persist 20 to 30 years. Then the conditions become reversed. The entire process of these cycling events is called the Pacific Decadal Oscillation. The abrupt reversal in a short time period is called a regime shift. (Reinard 2002)
- Before a 1977 regime shift occurred, the U.S. had a cool, nutrient-rich ocean phase with high ocean salmon productivity. The 1977 shift brought the low-production warm ocean phase to us. Meanwhile, pristine Alaska suffered alarmingly low salmon populations before the 1977 shift, after that, salmon productivity prospered. (Reinard 2002)

Fish surveys and counts on the Santa Clara River

Smolt Counts

Month	Year	# of days	Count	Source	Pub.	Notes
Apr - May	1981	12	21	CFG	1981	3 month survey on lower SCR; June 1981
May	1981	2	30	CFG	1981	Same study as above but at UWCD spreading grounds
Jan - June	1983	150	1	Puckett and Villa	1985	-
Feb - Apr	1984	60	1	Puckett and Villa	1985	-
Feb - May	1994	74	81	Entrix	1994	Vern Freeman Diversion; partial count
Jan - June	1995	141	111	Entrix	1995	Vern Freeman Diversion; partial count
Mar - Apr	1996	33	82	Entrix	1996	Vern Freeman Diversion; partial count
Nov - June	1997	187	414	Entrix	1999	Vern Freeman Diversion; partial count
Apr - July	1998	88	2	Entrix	2000	Vern Freeman Diversion; partial count
-	1999	-	5	UWCD	-	Vern Freeman Diversion; partial count
-	2000	-	876	UWCD	-	Vern Freeman Diversion; partial count
Nov - June	2003	-	35	UWCD	-	Vern Freeman Diversion; partial count

Adult Counts

Month	Year	# of days	Count	Source	Pub.	Notes
-	1978	-	0	Titus	2002	Bell 1978; mainstem only
May	1980	14	0	Titus	2002	Areta and Willsrud, 1980; mainstem only; sampling was done in backwaters, side streams, pools, etc. i.e., habitats that steelhead do not frequent.
Apr - May	1981	12	0	CFG	1981	3 month survey on lower SCR; June 1981
Jan - June	1983	150	2	Puckett and Villa	1985	Sespe creek: weir and hook and line
Nov - Apr	1983 - 84	152	1	Puckett and Villa	1985	weir
Apr	1986	?	0	McEwan	-	Sespe Canyon. Phone interview.
March	1987	-	2	Titus	2002	USFWS electrofishing survey SP creek
-	1987 - 1988	-	several	Comstock	1992	Kaufman 1989
Mar - Apr	1991	7	0	Entrix	1994	SCR didn't open to ocean until March
June	1992	30	0	Parmenter & McEwan	1999	Hopper, Pole and Santa Paula Creeks
Dec - Jan	1992	3	0	Entrix	1994	at Vern Freeman Diversion
Feb - May	1993	90	0	Entrix	1994	at Vern Freeman Diversion
Feb - Apr	1994	32	1	Entrix	1994	at Vern Freeman Diversion
Jan - May	1995	135	1	Entrix	1995	at Vern Freeman Diversion
Feb - Mar	1996	25	2	Entrix	1996	at Vern Freeman Diversion
Nov - Feb	1997	51	0	Entrix	1999	at Vern Freeman Diversion
-	1998	0	0	Entrix	2000	Upstream trap not operated
April	1999	-	1	UWCD	-	seen in bay area at Vern Freeman
March	2000	-	2	UWCD	-	seen in fish ladder
April	2001	-	2	UWCD	-	seen in fish ladder
-	2002	-	-	UWCD	-	too dry
-	2003	-	-	UWCD	-	fish counter operational

Mainstem: Hydrology and Human Impacts

Issues

1. Artificially altered surface flow is most likely the principal problem for steelhead in the Santa Clara River. It is probable that steelhead do not have an adequate opportunity to complete their upstream and downstream migrations.
2. There is no control over wells along the Santa Clara River or its tributaries, or how much water is removed through them. Nor is the total amount of surface water diverted from the river known, in part due to illegal diversions (though the amount is believed to be small).

Potential Research Questions

- How much water is being diverted (rates and timing) and by whom?
- An accurate accounting is needed of the amount of permitted water that is being removed, by both major and minor diverters, and an estimate of how much non-permittees are drawing from the river.
- How could discharges from Santa Felicia be modified to benefit the migration, spawning, and rearing of steelhead in both the Santa Clara River and Piru Creek?

Section I. Santa Clara River

Diverted Water

- UWCD is mandated by the State Water Resources Control Board to divert the maximum flow available for groundwater augmentation and to mitigate seawater intrusion into aquifers on the Oxnard Plain that are pumped for agricultural, industrial, and municipal uses. UWCD can also divert SCR flows during the winter months, notwithstanding requirements to maintain migration continuity, pursuant to approval/agreements with CFG and NMFS. (Matt Carpenter, Entrix, pers. comm. November 2002)
- The UWCD operates Santa Felicia Dam on Piru Creek conjunctively with the VFD. Generally water is only temporarily stored in the reservoir during winter, spring and summer months, and then released during the fall in a manner which allows the released water to either naturally percolate into the Santa Clara River aquifers, or be diverted through the VFD for percolation via the series of percolation ponds at Saticoy. (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)
- The highest average daily amount diverted at VFD for the years shown (Moore 1980c):

Years	Cfs/day
1932 - 1954	32
1955 - 1974	112

- The 1999 water year: 49,591 acre-feet of water was released from Lake Piru. The Piru spreading grounds received 3.5% of the released water. The upper basins of Piru, Fillmore and Santa Paula received 33.6% of the release water, which was naturally recharged, and the remaining 62.9% flowed to the VFD. (United Water Conservation District 2000)

In-stream Flow

- Annual mean outflow at the County Line gauging station has increased from 25,700 acre feet in 1972 (20 year mean) to 35,360 acre feet in 1988 (36 year mean). A difference of 9,660 acre-feet. Most likely all of it is from WRP effluent. (United Water Conservation District and Castaic Lake Water Agency 1996)
- Effluent from the Saugus and Valencia WRPs comprise a majority of the total flow in the upper SCR during summer months. Forty years of stream data indicate that effluent accounts for 40% of total stream flow during the wet season and 90% during the dry season. (United Water Conservation District and Castaic Lake Water Agency 1996)
- No record of streamflow was recorded at Montalvo during 1933 – 1950 (Taylor *et al.* 1977). This was due to the gauging station being inoperative, or non-existent; this time period experienced some record flood flows, e.g., 1938, (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004).
- Five cfs or natural stream inflow to Lake Piru, whichever is less, is required to outflow from Lake Piru (Murrray McEachron, United Water Conservation District, pers. comm. January 2004).
- Generally the channel of the SCR upstream from Bouquet Junction is dry except following storms. Downstream from Bouquet Junction, the combination of shallow bedrock, a reduced cross-sectional flow area and wastewater discharge to the streambed from two water reclamation plants creates a perennial flow condition in the river westward from the Saugus water reclamation plant past the LA – Ventura County Line. (United Water Conservation District and Castaic Lake Water Agency 1996)
- Castaic Dam seems to have little effect in reducing the annual flow at Montalvo due to percolation between Castaic Reservoir and Saticoy Taylor *et al.* 1977).
- Bouquet Dam is used primarily for storage of imported water. It controls less than 1% of the total drainage area and its influence on the streamflow at Montalvo has been considered negligible. (Taylor *et al.* 1977)
- The cumulative effects of the combined operation of Pyramid, Castaic, Bouquet, and Santa Felicia dams on the natural pattern of surface flows (level, duration, frequency, and timing) on the mainstem of the Santa

Clara River has not be investigated, or modeled. (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)

- Opinion differs on the flow available to the mainstem with the construction of the Santa Felicia dam. Taylor et al. (1977) state that all inflow to Lake Piru has been prevented from reaching Montalvo (with rare exceptions such as 1969 water year). UWCD states that on average Santa Felicia has spilled every six years (1969, 1978, 1979, 1980, 1983, 1993, 1995, 1998, and 2001 - essentially during big water years) (Murray McEachron, United Water Conservation District, pers. comm. January 2004).

Groundwater Basins

- The groundwater basins of the Santa Clara River starting in Los Angeles County and moving west into Ventura County are: Acton, Eastern, Piru, Fillmore, Santa Paula and Mound Basins. Moving south from the Santa Paula and Mound Basins are the Montalvo, Oxnard Plain and Pleasant Valley Basins. (United Water Conservation District and Castaic Lake Water Agency 1996; United Water Conservation District 1999)

Rising Groundwater

- Rising groundwater occurs at several points along the SCR. Rising groundwater is an area where groundwater is forced to the surface by some type of flow barrier and thus becomes surface water flow. Rising areas of groundwater are (United Water Conservation District and Castaic Lake Water Agency 1996 United Water Conservation District 1999):
    - At the mouth of Soledad Canyon caused by buried bedrock highs in the alluvium
    - Just west of the Los Angeles/Ventura County line
    - Just east of Fillmore at the Fillmore Fish Hatchery; considered to be the boundary between the Piru and Fillmore groundwater basins.
    - Just east of the city of Santa Paula in the vicinity of Willard Road
    - East of the unincorporated area of Saticoy near the toe of South Mountain.

How groundwater basins get replenished

- Acton Basin – deep percolation of rainfall and infiltration of surface water runoff; lawn and agricultural runoff; septic tank and leachfield system percolation. (United Water Conservation District and Castaic Lake Water Agency 1996; United Water Conservation District 1999)
- Eastern Basin – surface water runoff from SCR; rainfall; tributaries.
- Piru Basin – percolation of surface flows; rainfall; irrigation returns; spreading grounds located adjacent to Piru Creek just upstream of the confluence of Piru Creek and the Santa Clara River; water conservation releases from Santa Felicia Dam by UWCD. (United Water Conservation

District and Castaic Lake Water Agency 1996; United Water Conservation District 1999)

- Fillmore Basin - percolation of surface water from SCR and Sespe Creek and releases from Santa Felicia Dam; rainfall penetration; irrigation returns; effluent from sewage treatment plants. (United Water Conservation District and Castaic Lake Water Agency 1996; United Water Conservation District 1999)
- Santa Paula Basin – percolation of surface flows of SCR (including releases from Santa Felicia Dam), Santa Paula Creek and other tributaries; underflow from the Fillmore Groundwater Basin; agriculture returns. (United Water Conservation District and Castaic Lake Water Agency 1996; United Water Conservation District 1999)
- Montalvo Basin – UWCD's spreading grounds at Saticoy and El Rio; percolation of SCR flows; underflow from the Santa Paula Basin; rainfall; irrigation returns. (United Water Conservation District and Castaic Lake Water Agency 1996)
- Oxnard Plain Basin – Montalvo Basin. (United Water Conservation District and Castaic Lake Water Agency 1996; United Water Conservation District 1999)

Groundwater in the Oxnard Plain

- The Fox Canyon Groundwater Management Agency was established in the 1970s to deal with the problem of high chloride levels in Oxnard Plain groundwater. The solution chosen was additional yield from Vern Freeman Diversion supplied via the Pumping Trough Pipeline, and shifting pumping to the lower aquifer system from the upper aquifer system, which is determined to have 100 years of supply. A moratorium was established on new upper aquifer system wells, meters were installed on wells, rolling cutbacks were implemented of 25% over 20 years, and waivers or credits were established for cutbacks. The cutbacks started in the early 1990's and are in 5% increments every 5 years. If a users pumpage exceeds the cutback amount, there is a tiered penalty structure of up to $600/AF. (United Water Conservation District and Castaic Lake Water Agency 1996)
- Groundwater aquifers in the Oxnard Plain are in critical state of overdraft. Over the last 50 years, groundwater pumping from these aquifers has exceeded natural and artificial recharge. (Lent 2001)

Groundwater Overdrafts

- Annual overdraft = how much more water is taken out than put in during one water year. (United Water Conservation District Groundwater Department 2001)
- Accumulated overdraft = amount of water necessary to prevent seawater intrusion, or subsidence of land. (United Water Conservation District Groundwater Department 2001)

- For the eight groundwater basins that lie wholly or partially within UWCDs jurisdiction, and for the water year 2001, the (United Water Conservation District Groundwater Department 2001):
    - Average annual overdraft for prior 10 years was 600 AF.
    - Annual overdraft for 2002 was estimated to be 0 – 600 AF.
    - Accumulated overdraft is 30,000 – 35,000 AF.
    - Water needed to replenish the groundwater basins is estimated to be 846,000 AF.

Groundwater Usage

- Agriculture was estimated to use 155,300 AF in 2002 (United Water Conservation District Groundwater Department 2001).
- The concept of "safe yield" was discussed with Santa Clara River water agencies during the SCREMP process. Safe yield of an aquifer is the amount of water, usually expressed in acre-feet that may safely be withdrawn annually from an aquifer without causing depletion or long-term harm to the aquifer. However, water agencies would not agree to a safe yield level. (Ron Bottorff, Friends of the Santa Clara River, pers. comm. December 2002)

Geomorphology

- The upper river has typical braided stream deposits and a relatively wide floodplain area. The particle sizes of sediment in the streambed generally range from coarse sand sizes to gravel (pebble, cobble and boulder size). (United Water Conservation District and Castaic Lake Water Agency 1996)
- The SCR along its entire course consists of typical braided stream geomorphological characteristics such as point bar deposits, gravelly stream bottoms, and broad, wide washes. (United Water Conservation District and Castaic Lake Water Agency 1996)
- The SCR has been formed largely by stormwater flows emanating from highland areas caused by storms of short duration but great rainfall intensity. (United Water Conservation District and Castaic Lake Water Agency 1996)
- Where the SCR runs adjacent to South Mountain and has cut into sedimentary formations scour pools have formed with retain water through sub-surface flows during the during periods where continuous surface flows is otherwise non-existent. (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)

Water Use and Availability

- Nearly 10.7 million gallons of water are pumped through the raceways daily from the Fillmore Fish Hatchery's four wells. Some of the water is

cycled back through the facility, and some is piped out and used for crop irrigation. (Whitnall 2003)

- FOSCR is in disagreement with several water agencies over the actual amount of water that is available to cities and those agencies. The agencies and cities claim there is more water available than FOSCR believes there is. (Ron Bottorff, Friends of the Santa Clara River, pers. comm. December 2002)
- There is no enforceable regulatory mechanism over how much water gets pumped out of the SCR aquifers by wells, nor is there monitoring of the level of groundwater extraction. (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)
- Trailer and RV parks along the river engage in unregulated or illegal activities that no agency oversees such as damming the river for swimming holes, etc. (Ron Bottorff, Friends of the Santa Clara River, pers. comm. December 2002; (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004).
- It is unknown how much water is taken from the upper SCR. UWCD has some information on water withdrawals from the lower river.
- The County of Ventura has transferred it long-term State Water Project (SWP) water supply contract for 20,000 acre-feet of water annually to the Casitas Municipal Water District. This water is available to UWCD (5,000 acre-feet), Casitas Municipal Water District (5,000 acre-feet), and the City of San Buenaventura (10,000 acre-feet). Only UWCD has taken delivery of SWP water. (United Water Conservation District and Castaic Lake Water Agency 1996; Ventura County Resource Management Agency 1994)
- Before the drilling of wells and production of underground water, the valley ground water basins were full to overflowing, resulting in a perennial surface flow in the river channel throughout the valley (Henke 1995). Other sources have noted that the flow was in some sections of the river channel, or below the Sespe Creek confluence (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004; Murray McEachron, United Water Conservation District, pers. comm. January 2004).

Urbanization Effects

- Impervious surfaces increase runoff, creating a greater flood hazard.
- Flood control and land drainage schemes may increase the flood risk downstream by concentrating runoff. A flashy discharge pattern results in increased bank erosion with subsequent loss of riparian vegetation, undercut banks and stream channel widening. (Bryant and Lynch 1996)
- Sediments washed from the urban areas and deposited in river waters include trace metals such as copper, cadmium, zinc and lead, as well as pesticides, herbicides, fertilizers, gasoline and other petroleum products. (Bryant and Lynch 1996)

- CSWRCB (1991, as cited in Bryant and Lynch 1996) reported that NPS (non point source) pollution is the cause of 50 – 80 percent of impairment of water bodies in CA.
- Increases in urban development are expected to result in an approximate 10 percent increase in peak discharges in the Santa Clara River (Ventura County Flood Control District and Los Angeles County Department of Public Works 1996).
- Proposed major projects as of 1996 (United Water Conservation District and Castaic Lake Water Agency 1996):
    - Newhall Ranch – 25,000 homes. Includes new wastewater treatment facility. Wastewater will be used to irrigate the golf course and other landscaped areas.
    - Tesoro del Valle – master planned community of 3,000 units. North of the City of Santa Clarita and south of the Angeles National Forest. Castaic Lake is to the northwest of the site. Consumption will be 2,800 AF per year.
    - Chiquita Canyon Landfill Expansion – near city of Santa Clarita. 154 acres. Located on Newhall property and operated by Laidlaw.
    - Reclaimed water system by Castaic Lake Water Assn. That will be used to serve Magic Mountain, golf courses and misc. irrigation uses. 1,700 less gallons of effluent will go into the SCR per year.
    - Aggregate mining and reclamation of a site known as Sycamore Ranch. Would enable continued operation of S.P. Milling's processing plant. Simultaneous agricultural, mining and reclamation activities. North of SCR at confluence with Sespe.
    - Toland Road Landfill Expansion – unincorporated area of Ventura County between Santa Paula and Fillmore. Serves the SC valley, which includes the communities of Santa Paula, Fillmore, Piru and other unincorporated areas of the county. Would increase capacity from 2.5 million tons of solid waste to 15 million tons. Would expand service to Oxnard, Port Hueneme, Ventura, Camarillo and Ojai.
    - Expansion of Valencia WRP

Agricultural Effects

- Citrus and irrigated agriculture in the SCR valley have overtaken earlier crops that required less water. Higher profits and yields come from irrigated crops (Schwartzberg and Moore 1995). Farmers are currently losing money on citrus. Some are switching over to avocado orchards.
- Fields were "tiled" starting at the turn of the century to deal with the problem of alkali accumulation. Tiling provides improved drainage and now underlies a vast portion of the Oxnard Plain and part of the river valley. Many ditches drain into the Pacific Ocean or McGrath Lake but a number runoff into the SCR. The nature/quality of this run-off differs from the river's water. (Schwartzberg and Moore 1995)

- Some agriculture like watercress farming and gathering is done within the riverbed itself. (Schwartzberg and Moore 1995)
- The harvesting of the exotic, invasive species *Arundo donax* is another use of river bottomland. The SCR is reputed to contain the finest reed source in the United States. (Gilday 1994, as cited in Schwartzberg and Moore 1995)
- The area generally referred to as the Oxnard Plain is actually part of a large marine deltaic formation which has been created by the periodic shift of the lower Santa Clara River channel, and the deposition sediments in the river's lower reaches and at its mouth at the Pacific Ocean. The arcuate shaped marine face of the Santa Clara River Delta extends along the coast between the Santa Monica Mountains on the east to the Ventura Foothills on the west, while the apex of the delta extends inland to the area around Saticoy. (Mark Capelli, National Marine Fisheries Service, pers. comm. October 2003)
- Primarily as a result of agricultural return waters there has been a general increase in TDS in groundwater basins. Few groundwaters in the Piru, Fillmore, Santa Paula, and Montalvo basins are now less than 1000 parts per million total dissolved solids, the maximum concentration permitted under United States Public Health Service Drinking Water Standards. (Mann 1975)
- The aquifers for the Santa Clara River Valley are marine deposits so we would always expect to see a certain concentration of TDS. Other potential causes for an increase of TDS could include an increase in the outfall of the sewage treatment plants along the river. (Murray McEachron, United Water Conservation District, pers. comm. February 2004)

Effects of Recreation

- Recreational use has included fishing, duck ponds/clubs, birding, hiking, golf courses, RV parks, ATVs in the river bottom and on surrounding lands, motocross racing at Indian Dunes on Newhall land took place in the river bottom, trail rides, and fishing/boating/camping/swimming at reservoirs. (Schwartzberg and Moore 1995; Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)

Homelessness

- The riverbed has been a de facto housing community for many years for the homeless. (Schwartzberg and Moore 1995)

Aggregate Mining Effects

- The river produces the best aggregate material in the county and much of the county's roads and other structures were built out of materials extracted from the river. (Schwartzberg and Moore 1995)
- Aerial photos of the river in the 1960s demonstrate the extent of mining in the Santa Clara River. Evidence of roads crossing the river bottom is pervasive, trucks are often present in the river bottom and extraction operations are clearly visible. (Schwartzberg and Moore 1995)
- Curtis Sand and Gravel has an in-river mining operation east of Santa Clarita. There is one inactive in-river operation in the Saugus-Newhall section of the Santa Clara River, and eight inactive in-river operations in western Ventura County. P. W. Gillibrand has an active out-of-river mining operation in the Saugus-Newhall area. (AMEC 2003)
- CEMEX, a giant cement company in Mexico recently purchased Southdown Corporation. Southdown's subsidiary Transit Mixed Concrete is planning to open an aggregate strip mine on 460 acres of public land just east of Santa Clarita's city limits in Soledad Canyon. Part of this mine project site is within the 500-year floodplain of the River. The proposed mining operation is planned to span 20 years in its initial phase and process 78 million tons of material. Excavation is planned to be six days a week, sixteen hours a day. Blasting is planned to occur twice a week for 10 years, then double for the subsequent 10 years. Materials transport is an estimated 694 trips per day mostly via the 14 Freeway. Currently there are about 9,600 residential units within a five-mile radius of the site. (AMEC 2003)

Section II. General Information

Habitat and water flow

- In California, diversion and transfer of water has resulted in depleted river flows necessary for migration, spawning, rearing, flushing of sediment from spawning gravels, gravel recruitment, and transport of large woody debris. (Bryant and Lynch 1996)
- It has been reported that 7 inches is the minimum depth required for successful migration of adult steelhead (Thompson 1972, as cited in McEwan 2001), although the distance fish must travel through shallow water areas is also critical.
- A primary characteristic of high quality aquatic ecosystems is an abundance of large pool habitats (particularly important for over-summering juvenile steelhead). Loss occurs by: filling by sediments, loss of pool-forming structures such as boulders and large wood, and loss of sinuosity by channelization. (Stoecker 2002; Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)
- Stream depth provides steelhead with shelter from extreme water temperatures, excessive water velocities, and predation. Southern California streams are often subjected to low flow conditions due to

drought, water extractions, and the annual summer-fall dry season. Survival during dry season stream conditions is believed to be a major limitation to steelhead and adequate depth is essential for survival (Douglas 1995, as cited in Stoecker 2002). Pools provide depth and habitat that is critical to steelhead survival during the dry season. An abundance of large pools has been shown to be an important characteristic in healthy aquatic ecosystems. (Stoecker 2002)

- Warmer water temperatures due to water diversion, water development and habitat modification may affect steelhead mortality from predation directly or indirectly through stress and disease associated with wounds inflicted by pinnipeds or piscivorous predators. (Bryant and Lynch 1996)
- Agricultural practices in general have contributed to the degradation of salmonid habitat through irrigation diversions, overgrazing in riparian areas, sedimentation, loss of riparian vegetation, loss of habitat complexity (Bryant and Lynch 1996).

List of Major Water users along the Santa Clara River

(United Water Conservation District and Castaic Lake Water Agency 1996)

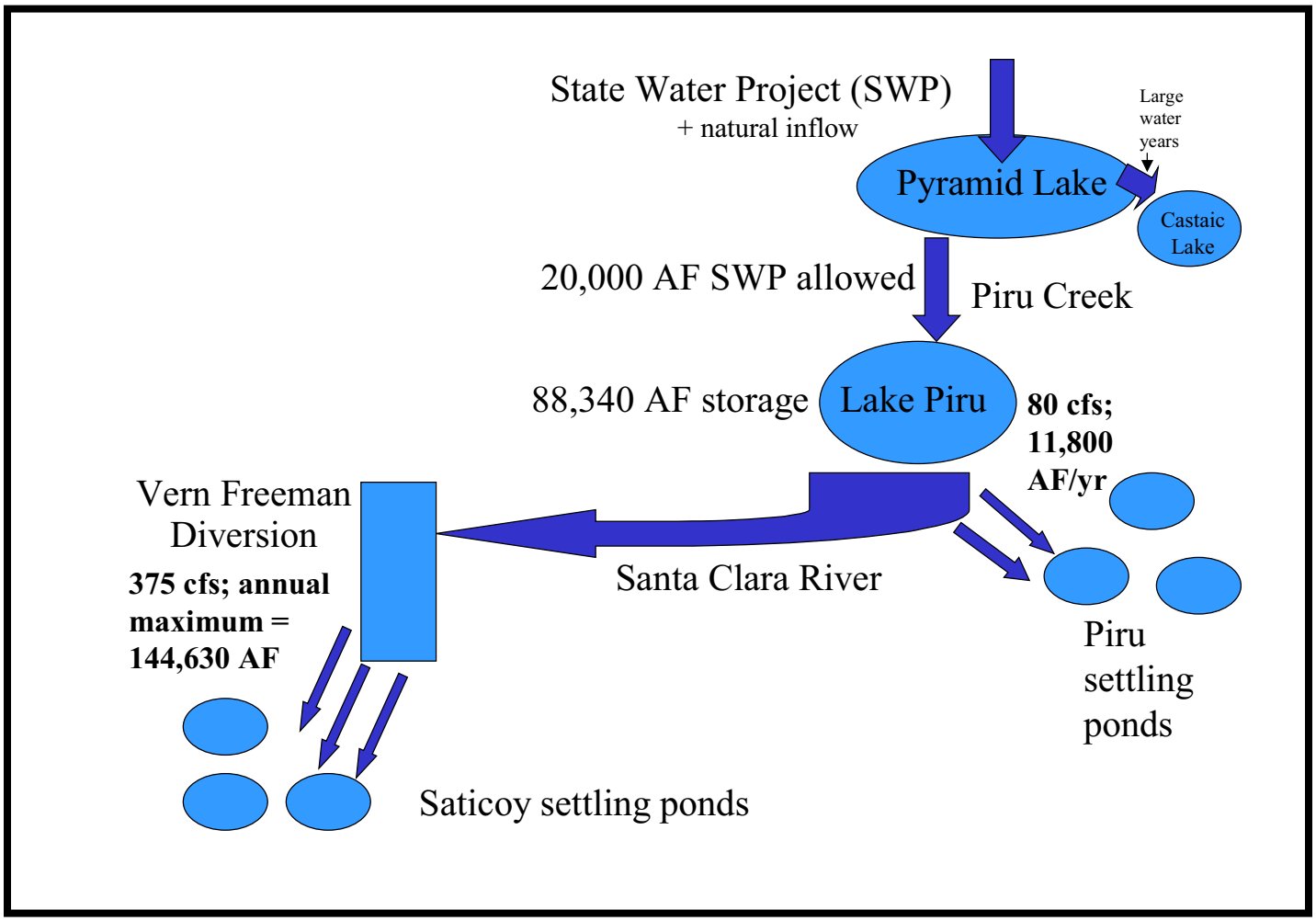
- California Watercress, Inc.
- Camulos Ranch
- Fillmore Irrigation Company
- Newhall Blue Cut and Isola Diversions
- Piru Mutual
- Ray and Elizabeth Billet
- Rio Dulce Ranch
- Santa Clarita Water Company
- Santa Paula Water Works
- Southside Improvement
- Transit Mixed Concrete Co
- Turner/Richardson Ditch
- United Water Conservation District

Smaller Diversions

(United Water Conservation District and Castaic Lake Water Agency 1996)

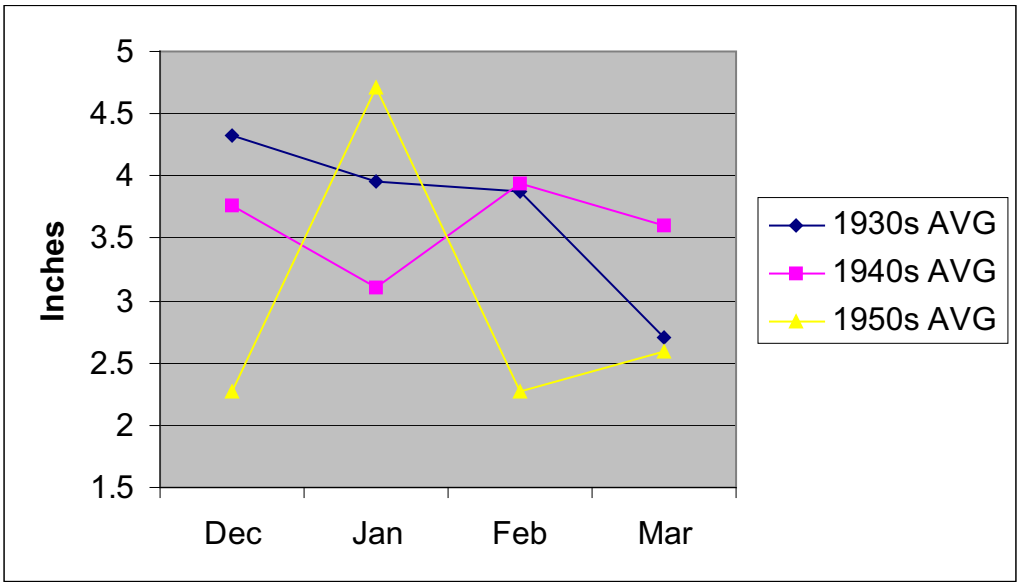
- Alfred and Francis Martinez, Pole Creek
- Central Coast Production Credit Assn., SCR
- CF&G, SCR
- Flying A Ranch, Pole Creek
- Pajaro Partners Inc, Santa Paula Creek
- Robert Asimow, Hopper Creek
- Sanford Drucker, Sespe Creek
- Santa Clara Water and Irr. District, SCR
- Steven and Robin Smith, Santa Paula Creek
- The Nature Conservancy, Hopper Creek

Graphic of Lower Santa Clara Flow of Water



Amount of rainfall in the Lower Santa Clara River

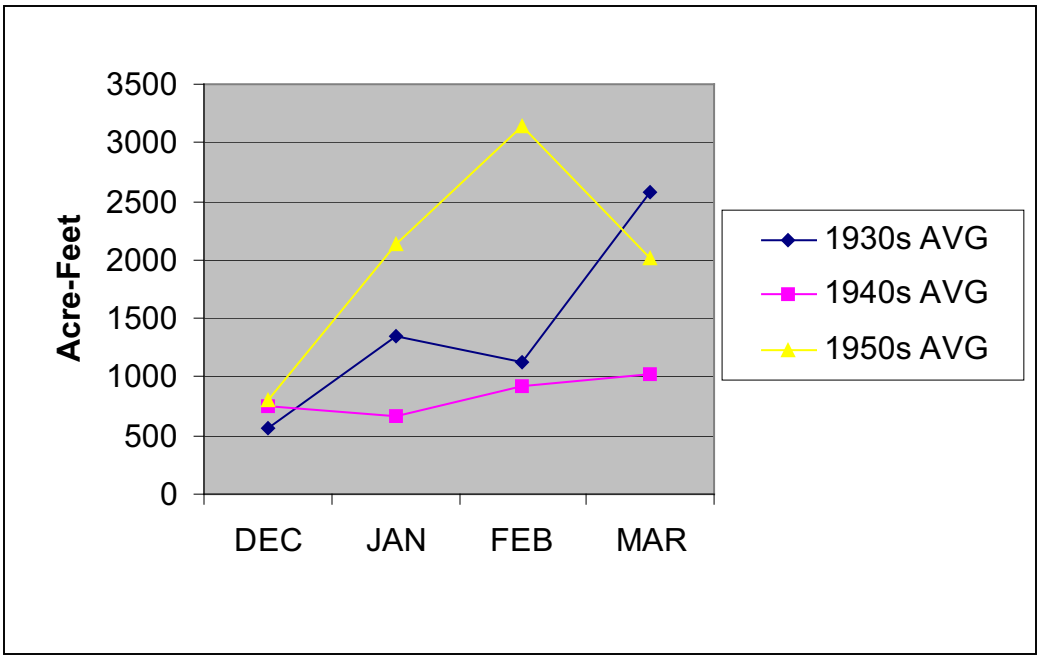
December through March, by decade



*Date source: United Water Conservation District

Amount of water diverted at the Vern Freeman Diversion

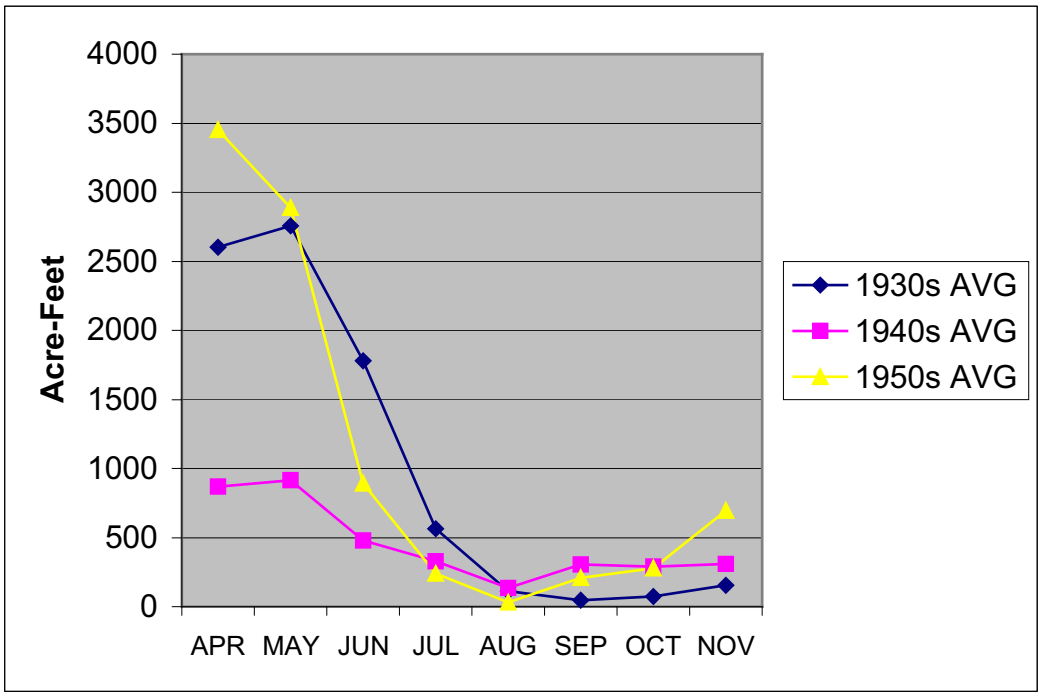
December through March, by decade



*Date source: United Water Conservation District

Average Acre-Feet diverted at VFD

April through November, by decade



*Date source: United Water Conservation District

Fish Passage

Issues

1. It is unclear how steelhead passage into and out of the tributaries from the mainstem is affected by flow regulation, flood control project/activities, or other types development.
2. There is no independent evaluation or assessment of the fish passage structures on the mainstem or tributaries. Opinions conflict regarding how well the fish ladder at VFD operates or how easily fish find the ladder, but the number of adult steelhead detected over the last 10 years since the commencement of the operation of the ladder is extremely low (<10).

Potential Research Questions

- What are the fish passage problems in the mainstem, between the mainstem and the tributaries, into the tributaries, and within the tributaries?
    - Do transverse bars occur in the river? What is the impact of multiple ladders or passage difficulties on reproduction? What can be done to minimize the number of days it takes for fish to get up or down river? In what condition do fish arrive at the spawning areas after passing problem areas?
- For how long after storm flow do Santa Paula and Sespe creeks maintain a passable steelhead connection with the mainstem of the Santa Clara River?

Section I. Santa Clara River

The Vern Freeman Diversion Fish Ladder

- Discharge from VFD in the recent past has been 40 cfs for the 1st 24 hours and 20 cfs for the 2nd 24 hours post-storm. However, the National Marine Fisheries Services has indicated that increased levels and duration of flows are necessary to provide adequate opportunities for steelhead to reach the VFD and pass to upstream spawning and rearing areas. (Mark Capelli, National Marine Fisheries Service, pers. comm 2004.
- The VFD ladder incorporates a denil design, which operates at a maximum flow of approximately 40 cfs, with an additional artificial attraction flow capacity of approximately 80 cfs. As a consequence of these design limitations, the ladder operates over a relatively narrow range of natural river flows (approximately 200 to 1,200 cfs), based upon the attraction flow criteria used by the California Department of Fish and Game and the National Marine Fisheries Service (i.e., attraction flow associated with a ladder should not be less than 10% of the natural river flows). Its design does not allow for good trapping method, and the trap

that was used in the late 1990s caused problems. Currently, velocities can drop out and sediment can get into ladder shutting it down during the most critical time. (Maurice Cardenas, California Department of Fish and Game, pers comm. December 2002; Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)

- There are varying opinions on issues and/or functionality of the Vern Freeman diversion and the location of the ladder. Two of those opinions are:
    - VFD is a wide structure. Main channel tends to stick to opposite side of the river from the ladder. The fish swim up the opposite side and then have to traverse the face of the dam to get to the fish ladder. A second ladder or a fish ramp usable by fish during higher flow events may provide a means of supplementing the limited fish passage opportunities afforded by the current ladder. Problems with installing a second ladder are a productive marsh area that has been established above the VFD. (Rick Rogers, National Marine Fisheries Service, pers. comm. January 2003; Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)
    - The main channel above the Vern Freeman has always been on the fish ladder side. Only storms great than 50,000 cfs have caused water to go to the other side. Downstream of the diversion the main channel was almost in the middle prior to the Freeman, but has since moved to the fish ladder side. (Murray McEachron, United Water Conservation District, pers. comm. January 2004).

Santa Paula Creek

- DFG actively assisted ACOE in development of a fish passage at the transition between the upper end of the Santa Paula Creek Flood Control Project, and the unimproved portion of lower Santa Paula Creek. In general there are adequate jump pools, but the 1st jump pool is too shallow and needs to be fixed. A large boulder could block one of the low flow passage channels. (Mary Larson, California Department of Fish and Game, pers. comm.; Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)
- Harvey Diversion was built prior to 1910, the original fish ladder was built in 1939 and effective until 1969 floods made it unusable. The Canyon Irrigation District built a new fish ladder on the Harvey Diversion in the late 1990s. This second ladder requires a lot of maintenance. The area located directly downstream of the Harvey Diversion has highly erosive conditions and scoured out in 2000 - 2002. To keep the downstream entrance of the fish ladder in place and functioning properly, it has been anchored, and large boulders have been placed along the downstream bank to reduce scouring. “Rock glue”, drill, and cable were used to keep rocks in place. The bank underneath the fish ladder would be undermined

without this. DFG helped design and pay for the diversion ladder. A fish counter was installed on the ladder in 2003. (Rick Rogers, National Marine Fisheries Service, pers. comm. January 2003; Mary Larson, California Department of Fish and Game, pers. comm.; Buck Yedor, United Water Conservation District, pers. comm. December 2002; National Oceanic and Atmospheric Administration and National Marine Fisheries Service, 2000)

- The Highway 150 Bridge near Thomas Aquinas College presents steelhead passage problems. The supports are in a concrete apron. There are steps in the apron, and the modifications necessary are minor. The free-flowing oil seeps need to be channeled around the step pools. Some exposed rebar needs to be removed, an interim step pool needs to be built to correct one large jump, and the shape of another bowl needs to be changed so a deep pool is formed. (Mary Larson, California Department of Fish and Game, pers. comm.)
- DFG wants the city of Santa Paula to develop a restoration plan for the area from the debris basin upstream to the top of the Harvey diversion. (Mary Larson, California Department of Fish and Game, pers. comm.)

Sespe Creek

- Sespe has tremendous potential for steelhead production. There are no dams. The main obstacle is the correct management of the "window of opportunity" (i.e., sufficient duration and volume of streamflow) for adult steelhead to migrate between the estuary and the Vern Freeman Fish Ladder; and the control of introduced aquatic species (fish and amphibians) that prey upon juvenile steelhead. (Rick Rogers, National Marine Fisheries Service, pers. comm. January 2003; Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)
- Surface flow from Sespe Creek doesn't reach the mainstem during normal, baseflow (summer and fall) conditions. Water coming out of the Sespe usually disappears into a porous flood plain before it reaches the mainstem. There is a lack of connectivity between the Sespe and the mainstem, and Santa Paula Creek and the mainstem, except during storm events. (Steve Lee, University of California at Los Angeles, pers. comm. November 2002)
- Fillmore Diversion may impound juveniles in artificial pond, but its significance to adult passage is unknown. (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)
- There is a gravel operator on the lower Sespe who as of early 2003 was interested in extracting from the creek; this operation has the potential to further reduce steelhead passage from the mainstem to Sespe Creek (Rick Rogers, National Marine Fisheries Service, pers. comm. January 2003; Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004). However, this operator would need to obtain a new permit from Ventura County, with adequate CEQA review (Ron Bottoroff, Friends of the Santa Clara River, pers. comm. January 2004).

Piru Creek

- Owner of the lower section, Rancho Temescal, bought the property in 2000 and is developing it for agriculture and other commercial uses, e.g. an Equestrian Center for thoroughbred training and racing. The value of the 5cfs which is currently released from Santa Felicia Dam to protect aquatic resources in the lower two miles of Piru Creek from the dam to the confluence of the Santa Clara River may be compromised by proposed development and related activities. (Rick Rogers, National Marine Fisheries Service, pers. comm. January 2003; Mark Capellli, National Marine Fisheries Service, pers. comm. January 2004)

Section II. General Information

Dams/Barriers

- Dams can result in increased water temperatures, changes in fish community structure, and increased travel time by migrating adult and juvenile salmonids. (Bryant and Lynch 1996)
- Types of barriers include dams, culverts, diversions, flood control channels, flow dynamics, water quality, and natural features such as waterfalls (Stoecker 2002).

Exotic Species Predation and Competition

Issues

1. The impact of exotic species on different life stages of steelhead has been poorly documented.
2. Green sunfish and black bullhead catfish are known to prey on steelhead fry and eggs.

Potential Research Questions

- How many exotic species exist and what are their population numbers?
- What likely impact are they having on the different life stages of steelhead?
- What overall/accumulative effect do exotic species have? What are the impacts of predation and competition?

Section I. Santa Clara River

- Bullheads can be extremely voracious egg eaters. Bullheads are in high abundance in the middle Sespe from Timber to Lion Creeks and appear to be rapidly expanding in population and distribution into the lower Sespe; within the last 5 years black bullheads have spread down through the Sespe Gorge to Devils gate, and now dominate many of the shallow pools. (Blecker *et al.* 1997; Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)

Section II. General Information

Predation

- Low flow conditions in southern California streams can enhance predation opportunities where adult steelhead may congregate at the mouth of streams waiting for high flows. (Bryant and Lynch 1996)
- Most investigators believe that marine predation is a minor factor in steelhead declines. (Bryant and Lynch 1996)
- Two striped garter snakes (a native species) are highly effective predators, taking juvenile salmonids of up to 5 inches in length. Their impacts on local fish populations can be substantial. (Blecker *et al.* 1997)
- Bullfrogs (a non-native species) may also prey upon young trout and steelhead. (Blecker *et al.* 1997)
- During drought years green sunfish densities seem to increase and trout densities decline. Sunfish are better able to withstand higher temperatures and will prey upon large numbers of trout fry if they are crowded into the same habitat. (Blecker *et al.* 1997)

Competition

- Green sunfish are likely competitors with trout and juvenile steelhead, feeding on the limited caddisflies and terrestrial insects. The may also feed on salmonid eggs and very young fry. (Blecker *et al.* 1997)

Water Quality

Issues

1. The Stormwater program has found that copper, lead, nickel, selenium, and fecal coliform exceed allowable limits in the SCR.
2. The LA-RWQCB is establishing TMDLs (Total Maximum Daily Loads) for the Santa Clara River. A chloride TMDL of 100 mg/L, has been established for the upper river. Other TMDLS scheduled are: toxaphene, fecal coliform, and nitrate.
3. Many of the smaller communities in this watershed remain unsewered. In particular in the Auga Dulce area of the upper watershed and near the city of Acton.
4. Increase in urban areas has led communities to build sewage treatment plants along the river, adding flood protection structures and effluent to the river.
5. There are eight Wastewater Treatment Plants (or Water Reclamation Plants) along the river that are releasing at least 25 million gallons per day of effluent into the river or nearby percolation basins.
6. Over time there have been 14 landfills/dumps both legal and illegal associated with the river. It is unknown if contaminants are leaching into the surface or ground water.

Potential Research Questions

- How significant a problem is pollution in the Santa Clara River?
- What is the impact of agricultural chemicals on the river? How much is released into the river?
- Which WRPs are contributing excessive pollution to the river?
- What are the impacts of the WRPs impact on the estuarine environment at the mouth of the Santa Clara River?
- Are there pollutants/runoff in the tributaries?
- How do different pollutants impact steelhead adults, smolts, fry, and eggs?
- Are landfills contaminating surface and groundwater? What and how much?

Section I. Santa Clara River

Mainstem

- In the past LA-RWQCB considered the designation of the SCR as a Significant Natural Resource. This category would be similar to the unique natural resource designation at the federal level that declares a resource unlike any other in the region. A major component of the designation would be limiting the hydrologic and water quality impacts of further urbanization in the watershed. However, the LA Sanitation District said that LA-RWQCB didn't go through sufficient legal processes that such

a designation would require more legal development of the category, and established strong adversarial legal challenge. Continuing this effort is beyond the staffing capabilities that LA-RWQCB has now. To make this happen the category would have to be adopted by the regional board, then the state board. They would also have to go through the process of a new beneficial use designation at the federal level.

Tributaries

- Since 1971, Piru Creek (between Pyramid Reservoir and Santa Felicia Reservoir) has shown improvements in water quality as a result of discharges from Pyramid Reservoir. (United Water Conservation District and Castaic Lake Water Agency 1996)
- Sespe Creek has a lower overall Total Dissolved Solids (TDS) and is a good source of higher quality water. (United Water Conservation District and Castaic Lake Water Agency 1996)

Estuary

- Water quality issues within the estuary are (United Water Conservation District and Castaic Lake Water Agency 1996):
    - Water level management – the estuary has been mechanically breached when it reaches 9 ft above sea level. Questions remain whether natural breaching is sufficient to avoid water quality problems at other times.
    - Eutrophication – high nutrient levels entering estuary from point source and non point source discharges could cause algal blooms and lead to eutrophication [not clear if this has actually happened].
    - Coliform bacteria – bacteria levels exceeding recreational standards have been recorded at receiving stations in the estuary and nearby ocean monitoring stations. High levels appear to be associated with non-point sources.
    - Pesticides – Agricultural activities may result in contamination of sediments in the estuary. Further investigation is needed. Agricultural runoff can alter chemistry of the water and may destroy aquatic life by adding pesticides, herbicides and fertilizers to the water.
- Wastewater treatment plant effluent is not a source of coliform bacteria in the estuary. Populations of native and migrating birds who use the estuary for feeding, resting, and breeding are a potential source of coliform. (Waln 2004)

Surface water quality monitoring occurs

- At the Vern Freeman Diversion for Ventura County Stormwater Program (the SCR receives municipal storm drain discharges from Fillmore, Oxnard, Ventura, Santa Paula and unincorporated Ventura County). (Darla Wise, Ventura County Flood Control District, pers. comm.)
- In the upper SCR by LA Sanitation District for Saugus and Valencia treatment plants. (Los Angeles Regional Water Quality Control Board date unavailable)
- Between Piru and Saticoy by UWCD. (Los Angeles Regional Water Quality Control Board date unavailable)
- At Santa Paula, for mid-river receiving water. (Los Angeles Regional Water Quality Control Board date unavailable)
- At Fillmore when they discharge to surface waters. (Los Angeles Regional Water Quality Control Board date unavailable)

Discharge Permits granted by the Los Angeles RWQCB

(Los Angeles Regional Water Quality Control Board date unavailable):

- 47 NPDES discharges – 33 go into mainstem, 14 go into tributaries
- 4 major discharges (POTWs, one discharging to estuary, one to middle reaches, two into upper watershed.
- 13 minor discharges
- 30 discharges covered under general permits
- 72 dischargers covered under an industrial storm water permit. Largest number of dischargers is located in the cities of Santa Paula and Valencia. Many of these businesses are involved with auto wrecking and food packing.
- 188 dischargers are covered under a construction storm water permit. The majority of these are located in the upper watershed especially within Santa Clarita and Valencia.

Pollution/contamination

- Natural oil seeps discharge significant amounts of oil into Santa Paula Creek. (Los Angeles Regional Water Quality Control Board date unavailable)
- In 1997, ammonium perchlorate was discovered in four Saugus Aquifer wells (Castaic Lake Water Agency 1997). Ammonium perchlorate is an inorganic chemical that is used in solid rocket propellants, fireworks and explosives (Castaic Lake Water Agency 1997). All currently contaminated Saugus wells are located south of the San Gabriel fault, many near the location of the former Whittaker-Bermite site where the perchlorate contamination originated (Castaic Lake Water Agency 1997). The five shut wells are located along San Fernando Road, Magic Mountain Parkway, and Soledad Canyon Road in the Santa Clarita Valley (Worden 2003).

- An oil spill occurred in Lake McGrath in 1993. Subsequent sampling after cleanup revealed no residual oil contamination remaining in the lake. Water sampling has demonstrated however, that pesticides are a problem particularly historically used pesticides such as DDT. California State Parks is the lead trustee agency for restoration planning efforts related to the oil spill settlement from the 1993 spill. (Denise Steurer, U.S. Fish and Wildlife Service, pers. comm. January 2004)
- Nitrates in specific areas (El Rio, Bardsdale near Fillmore and an area west of Fillmore) are in excess of the state drinking water standard of 45 mg/l. (United Water Conservation District and Castaic Lake Water Agency 1996)
- Higher water quality is present with higher in-stream flows, and lower water quality with lower in-stream flows. (United Water Conservation District and Castaic Lake Water Agency 1996)
- Potential sources of water quality problems in the lower Santa Clara River are: natural oil seeps in the Santa Paula Area, impacts from urbanization, impacts from agriculture, and effects of imported and reclaimed water. (United Water Conservation District and Castaic Lake Water Agency 1996)

Stormwater program

- On August 22, 1994 the California Regional Water Quality Control Board (RWQCB), Los Angeles Region, issued a NPDES permit to the Ventura County Flood Control District (VCFCD), the County of Ventura, and the cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, San Buenaventura, Santa Paula, Simi Valley, and Thousand Oaks as Co-permittees, for discharges of stormwater and urban runoff into the receiving waters of the Santa Clara River. (Ventura County Flood Control District 2002)
- The presence of the following constituents are measured as part of the stormwater program (Ventura County Flood Control District 2002). Tables are shown as they appear in the 2003 mid-year monitoring report:

Table 37: Bacteriological Results from the Mass Emission Station (ME-SCR)

Constituent	Units	11/7/2002	12/16/2002	2/11/2003
E. Coli	MPN/100ml	18600	26020	17930
Enterococcus	MPN - 1:100 Dilution	11840	14450	20050
Total Coliform	MPN/100ml	980400	488400	>241920

Table 34: Organics Results from the Mass Emission Station (ME-SCR)

Date			11/7/2002	12/16/2002	2/11/2003
Method	Constituent	Units			
EPA 8081	Endrin Ketone	ug/L	<0.01	<0.01	0.07
SM5310C	TOC	mg/L	6.8	7.6	7.3
Remaining EPA methods 8141/8151A, 8081, 8270C, 547, 418.1 are non-detect.					

Table 28: Conventional and Nutrient Results from Mass Emission Station (ME-SCR)

Date			11/7/2002	12/16/2002	2/11/2003
Constituent	Fraction	Units			
Ammonia-N	Total	mg/L	0.3	<0.2	0.5
BOD	Total	mg/L	6	4.8	5
Bromide	Total	mg/L	0.8 *	0.2	0.2
Chloride	Total	mg/L	75 *	56	44
Conductivity	Total	umhos/cm	1070	1000	797
Hardness	Dissolved	mg/L	565	457	N/A
Hardness	Total	mg/L	675	684	388
Nitrate Nitrogen	Total	mg/L	2.7	1.8	1.9
Nitrate+Nitrite as N	Total	mg/L	3.1	1.8	2
Nitrite Nitrogen	Total	mg/L	0.34	0.1 *	<0.1
Oil and Grease	Total	mg/L	<3	<3	<3
pH	Total	units	7.7	7.8	8
Phosphate	Total	mg/L	0.6	0.9	0.5
Phosphorus	Dissolved	mg/L	1.1	2.5	1.4
Phosphorus	Total	mg/L	3.4	5.5	3
TKN	Total	mg/L	3.1 *	4.2	2.3 *
Total Dissolved Solids	Total	mg/L	1210	870	750
Total Suspended Solids	Total	mg/L	420	2340	990

Table 31: Metals Results from the Mass Emission Station (ME-SCR)

Date			11/7/2002	12/16/2002	2/11/2003
Constituent	Fraction	Units			
Arsenic	Total	mg/L	0.011	0.028	<0.002
Cadmium	Total	mg/L	0.0012	<0.0002	0.0005
Calcium	Total	mg/L	155	157	96
Chromium	Total	mg/L	0.051 *	<0.001	0.018
Copper	Total	mg/L	0.041 *	0.005 *	0.021
Lead	Total	mg/L	0.0147	0.0578 *	0.009
Magnesium	Total	mg/L	70	71	36
Mercury	Total	ng/L	43	122	10.8
Nickel	Total	mg/L	0.035 *	0.003 *	0.015
Selenium	Total	mg/L	0.007	0.008	0.005
Silver	Total	mg/L	<0.001 *	<0.001 *	<0.001
Thallium	Total	mg/L	0.0005	0.0007	<0.0002
Zinc	Total	mg/L	0.12 *	0.04 *	0.09 *
Arsenic	Dissolved	mg/L	<0.002	<0.002	<0.002
Cadmium	Dissolved	mg/L	<0.0002	<0.0002	<0.0002
Calcium	Dissolved	mg/L	139	114	N/A
Chromium	Dissolved	mg/L	0.003 *	0.002	<0.001
Copper	Dissolved	mg/L	0.014 *	0.005 *	0.012
Lead	Dissolved	mg/L	<0.0002	<0.0002 *	<0.0002
Magnesium	Dissolved	mg/L	53	42	N/A
Mercury	Dissolved	ng/L	1.28	1.19	1.44
Nickel	Dissolved	mg/L	0.005 *	0.003 *	0.004
Selenium	Dissolved	mg/L	0.009	<0.002	0.006
Silver	Dissolved	mg/L	<0.001 *	<0.001 *	<0.001
Thallium	Dissolved	mg/L	<0.0002	<0.0002	<0.0002
Zinc	Dissolved	mg/L	<0.01 *	<0.01 *	<0.01 *

Constituents that exceeded water quality objectives under either dry or wet conditions in 2003 are:

Constituent	Most Likely Sources
Copper	WRPs (residential plumbing materials)
Lead and Nickel	Urban storm water runoff, industrial, or domestic wastewater discharges, oil and gas production, mining or farming.
Selenium	?
Fecal Coliform	Unknown. Possible sources include poorly functioning wastewater treatment plants, ranches (with horses, cattle or hogs), dogs, cats, wildlife (raccoons, coyotes, birds, etc.).
Total Dissolved Solids	Can have both natural and anthropogenic sources.
Chromium	Urban storm water runoff, industrial, or domestic wastewater discharges, oil and gas production, mining or farming.
Zinc	Urban storm water runoff, industrial, or domestic wastewater discharges, oil and gas production, mining or farming.

TMDLs

- The LA-RWQCB is establishing TMDLs for the Santa Clara River (Los Angeles Regional Water Quality Control Board date unavailable). A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The schedule for setting TMDLs is listed below though it is subject to change:

Constituent	Area Affected	Standard or scheduled year	Probable Source	Most Likely Cause
Chloride	Upper SCR	100 mg/l	Saugus and Valencia WRPs	Residential water softeners
Toxaphene	Estuary	2007	Historical pesticide	
Fecal Coliform	Upper SCR and Estuary	2006	Unknown	
Nitrate	Upper and Lower SCR	2004	Unknown	WRPs, livestock, fertilizers
Eutrophication, fish kills, algae, trash	Lakes Elizabeth, Hughes, Munz	2004	Unknown	Recreational users. Other.

Sewage

- Sewage alters dissolved oxygen concentrations leading to near anaerobic conditions. (Hager 2001)
- Secondary water source usually sewer treatment plant effluent provide more surface water than was available historically. This water is often detrimental. It is much warmer than natural waters emerging from underground sources. Its high nutrient load encourages a different suite of species and can put the native fauna and flora at a competitive disadvantage. These conditions favor introduced aquatic vertebrates like red shiners, grass carp, goldfish, and clawed frogs. (Swift *et al.* 1993)
- Many of the smaller communities in this watershed remain unsewered. In particular, in the Auga Dulce area of the upper watershed, and near the city of Acton. (Los Angeles Regional Water Quality Control Board date unavailable)
- The effects of septic system use in the Oxnard Forebay area is also of concern. (Los Angeles Regional Water Quality Control Board date unavailable)
- Increase in urban areas has led communities to build sewage treatment plants along the river, adding flood protection structures and effluent to the river. (Schwartzberg and Moore 1995)

- The amount of sewage that plants along the river are capable of treating and releasing as effluent are (United Water Conservation District 2000; pers. comm. with respective facilities):

Location of Plant	Capacity
Saugus	5.43 million gallons per day (MGD)
Fillmore	0.15 MGD
Piru	0.11 MGD
Valencia	10.56 MGD. Expansion planned as of 1996.
Ventura	10.3 MGD. Significant upgrades are underway to increase capacity to14 MGD
Santa Paula	2.55 MGD
Newhall (proposed)	6.90 MGD

- Piru, Fillmore and Montalvo percolate secondary treated effluent into the ground near the Santa Clara riverbed (United Water Conservation District and Castaic Lake Water Agency 1996). Fillmore also has an NDPES permit to discharge directly into the river.
- Saticoy percolates primary treated effluent from a community septic tank. (United Water Conservation District and Castaic Lake Water Agency 1996)
- Santa Paula discharges tertiary treated water directly to the SCR. (United Water Conservation District and Castaic Lake Water Agency 1996)

Landfills/Dumps

- There have been huge landfills associated with the river (see following landfill table).

Table of present and past landfills located on or near the Santa Clara River
(Schwartzberg and Moore 1995; United Water Conservation District 2000)

Name	Present	Historic	Location	Serves/served/notes
Chiquita Canyon	X		Near Santa Clarita	Valencia, Newhall and eastern Ventura County
Elkins Ranch	X			
Toland Rd	X		Between Santa Paula and Fillmore	SC valley: Santa Paula, Fillmore, Piru and other unincorporated areas of the county. Oxnard, Port Hueneme, Ventura, Camarillo and Ojai.
Illegal dump site	X		South Mountain Road	A large amount of trash, including cars, boats and trailers have been found in the river's bed
Illegal dump site	X		Between Bailard Landfill and Ventura Marina	Casual dumping of trash on both sides of the river.
Torrey Rd		X	Piru	Piru
Highway 23		X	Near Fillmore	
12th St. and South Mountain		X	Santa Paula	Santa Paula
Saticoy Avenue		X	Saticoy	Saticoy
Wagon Wheel		X	Wagon Wheel	Oxnard, Ventura
Southern California Coastal landfill		X	Ventura Road to the Victoria/ River Ridge Golf Course	Ventura? Oxnard?
Borchard dump		X	Victoria Ave	Ventura? Oxnard?
Bailard Landfill		X	South of the SCR, approx. 1,500 feet west of Victoria Ave.	Ventura Regional Sanitation District
Sears-Walker		X	Site of Ventura Marina	Sea burn dump where trash was often bulldozed into the ocean.

Sediment Regime

Issues

1. Santa Felicia Dam has had the greatest impact on altering the SCR sediment regime and preventing delivery of sediment to beaches.
2. Total reduction in sand transport to the coast from 1928 – 1975 is estimated to be 15 million tonnes.

Section II. Santa Clara River

<u>*Sediment*</u>

- From 1928 to 1955 suspended sediment delivery to the ocean was reduced by only 6% due to anthropogenic influences. Since 1956 annual deliveries of sand sized material by have been reduce by about 37% or 15 million metric tonnes due to man-made upstream control structures. The Lower River Diversion Dam built in 1929, and Santa Felicia Dam built in 1956 on Piru Creek are the structures whose operations have been primarily responsible for this reduced shoreline sediment delivery. (Taylor *et al.* 1977)
- Total sediment discharge of the basin computed from records of SCR at Montalvo for water years 1968 – 75 was 63.5 million tons of which 59.5 million tons was carried in suspension. (Williams 1979)
- Total reduction in suspended sediment transport to the coast from 1928 – 1975 has been on the order of 50M tonnes. A ballpark estimate of the total reduction in sand transport to the coast during this period can be made as 30% of the suspended load, for a total of 15M tonnes. (Taylor *et al.* 1977)
- The major difference between natural and actual sediment discharges of the Santa Clara River Basin is the sediment intercepted upstream from Lake Piru behind the Santa Felicia Dam. The combined trap efficiency of Lake Piru and Pyramid Lake approaches 100 percent. Sediment deposited in these reservoirs resulted in about a 12 percent reduction of sediment to the SCR basin during the period 1953 – 75. (Williams 1979)
- VFD and the Santa Felicia dam are the main structures that reduce delivery of sediment to the beach. (Taylor *et al.* 1977)
- Sediment losses by gravel mining, diversion of flows and interception of sediment in the Castaic Creek basin resulted in additional reductions of 4 percent during the period 1953 – 75. (Williams 1979)
- Most of the sediment from the SCR was transported during only a few days of floodflow. The long-term average annual sediment discharge of the SCR is estimated at 3.67 million tons. (Williams 1979)

- Development on steep slopes (residential, industrial, and agricultural) can elevate the background levels of fine sediments in tributaries, particularly, Santa Paula, Pole, Hopper, and lower Piru Creeks, affecting steelhead spawning and rearing success. (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)
- Forest fires can have temporary, but substantial effects on sediment regimes in tributaries, particularly the Sespe and Santa Paula Creeks; their frequency and intensity have been significantly modified by forest management practices. (Mark Capelli, National Marine Fisheries Service, pers. comm. January 2004)

Section II. General Information

- Excessive sedimentation alters the entire hydrology of a watershed leading to channel widening, loss of the pool-riffle sequence, reduced pool depth, and decreased stability of substrate and banks. (Barnhart 1986, as cited in Stoecker 2002; Cordone and Kelley 1961; Walters 1995)

A partial list of Santa Clara River Species

Birds

Common Name	*Genus*	*Species*	Native?	Special Status?
California least tern	*Sterna*	*antillarum browni*	Y	Y
Least Bell's vireo	*Vireo*	*bellii pusillus*	Y	Y
Loggerhead shrike	*Lanius*	*ludovicianus*	Y	Y
Southwestern willow flycatcher	*Empidonax*	*trailii extimus*	Y	Y
Western least bittern	*Ixobrychus*	*exilis hesperis*	Y	Y
Western snowy plover	*Charadrius*	*alexandrinus nivosus*	Y	Y
Yellow warbler	*Dendroica*	*petechia breshteri*	Y	Y
Brown-headed cowbird			N	-

Fish

Common Name	*Genus*	*Species*	Native?	Special Status?
Pacific Lamprey	*Lampetra*	*tridentata*	Y	
Pacific staghorn sculpin	*Leptocottus*	*armatus*	Y	
Prickly sculpin	*Cottus*	*asper*		
Rainbow trout	*Salmo*	*gairdneri*	Y	N
Santa Ana sucker	*Catostomus*	*santaanae*	Y but invasive	Y
Southern steelhead trout	*Oncorhynchus*	*mykiss*	Y	Y
Tidewater goby	*Eucyclogobius*	*newberryi*	Y	Y
Unarmored threespine stickleback	*Gasterosteus*	*aculeatus williamsoni*	Y	Y
Black Bullhead	*Ameiurus*	*melas*	N	
Sacramento sucker	*Catostomus*	*occidentalis*	N	
Green sunfish	*Lepomis*	*cyanellus*		
Largemouth bass	*Micropterus*	*salmoides*		
Owens sucker	*Catostomus*	*fumeiventris*		
Threadfin shad	*Dorosoma*	*peteneses*		

Plants

Common Name	*Genus*	*Species*	Native?	Special Status?
Mule fat	*Baccharis*	*salicifolia*	Y	
Nevin's barberry	*Berberis*	*nevinii*	Y	Y
Ojai fritillary	*Fritillaria*	*ojaiensis*	Y	Y
Slender-horned spineflower	*Dodecahema*	*leptoceras*	Y	Y
Ventura marsh milkvetch	*Astragalus*	*pycnostchyus*	Y	Y
Bull Thistle			N	-
Castor Bean	*Ricinus*	*communis*	N	-
Fennel			N	-
Giant Cane	*Arundo*	*donax*	N	-
Pampas grass			N	-
Tamarisk	*Tamarix*	*sp.*	N	-

Reptiles and Amphibians

Common Name	*Genus*	*Species*	Native?	Special Status?
Arroyo toad	*Bufo*	*microscaphus californicus*	Y	Y
California red-legged frog	*Rana*	*aurora draytonii*	Y	Y
South coast garter snake	*Thamnophis*	*sirtalis sp.*	Y	Y
Southwestern pond turtle	*Clemmys*	*marmorata pallida*	Y	Y
Two striped garter snake	*Thamnnophis*	*hammondii*	Y	N
African clawed frog	*Xenopus*	*laevis*	N	-
Bullfrog	*Rana*	*catesbiana*	N	

Current Santa Clara River Studies

Name	Org	Date Begin	Date End	Summary
Watershed Plan	ACOE	Jan-04	Jan-07	Also referred to as the Feasibility study. Approximately ½ of the cost is being paid by ACOE with Ventura and Los Angeles Counties paying the other ½ mostly with in-kind services. Major components of the study include: surveys and mapping of the watershed; hydrologic, hydraulic, sediment, water quality, and coastal investigations; engineering and design analysis to identify flood control, erosion, sedimentation and environmental restoration projects; socioeconomic studies; environmental studies; and cultural resource studies. The six planning steps are: 1) specify problems and opportunities, 2) inventory and forecast conditions, 3) formulate alternative plans, 4) evaluate effects of alternative plans, 5) compare alternative plans, and 6) select recommended plan. The study will take 3 years to complete.
SCREMP	Ventura County			A management plan for the river up to the 500 year floodplain. Covers from the 500 - 25 year flood line for bank improvements and stabilization.
SCR EIR and Mapping	Arundo Task Force			EIR and mapping to match $1.3M Prop 13 funding that was given to the LA portion of the SCR for EIR, mapping and *Arundo* removal.
Steelhead Recovery Plan	NMFS			An endangered species recovery plan that will encompass the Southern California ESU and will address restoring southern steelhead trout.
Regional Wetlands and Watershed Management Plan for Southern California	Environment Now/ Wetlands Recovery Project	Apr 02	Nov 04	Funded by Environment Now. Watershed Coordinators, hired under the Wetlands Recovery Project Local Assistance Program, are focusing on project management and assistance for projects that are already on the Wetlands Recovery Project workplan. They will also promote the contribution of local resources to the development of watershed management planning tools under development by the Wetlands Recovery Project.
Steelhead Habitat and Barriers Assessment	UC Santa Barbara and The Nature Conservancy	Oct 03	Sept 05	Assessing steelhead habitats, populations, and barriers to migration. Evaluating and modeling hydrology as it relates to steelhead migration.

A partial list of potential funding sources

Sources of funding	Title	Contact	Type of funding	Amt	Notes
CA Water Quality Control Board	NPS				Prop 40.
CA Water Quality Control Board	Stormwater				Prop 40. Dry weather flow; diversions, acquisition and development of wetlands, implementation of BMPs
CA Wildlife Conservation Board	Habitat Enhancement and Restoration Program				
CFG	Fisheries Restoration Grant Program	Mary Larson	Barrier modification and removal, fish ladders, monitoring, education, demo projects.		Very competitive. Funding is not provided until the following summer, i.e. approved proposals from May 2003 will receive funds in summer 2004. $$ needs to be spent in 1 - 2 years.
Dept of Water Resources	Flood protection Corridor Program		Buy land, flood control		
National Fish and Wildlife foundation	Bring back the Natives	Don Glaser	Restoration Projects		On the ground habitat restoration projects for natives
National Fish and Wildlife foundation	Challenge Grants	Anna Weinstein	Cooperative parnerships		To conserve fish, wildlife, plants and their habitats.
National Fish and Wildlife foundation	Native Plant Conservation Initiative	Beth deCarolis	Conservation Projects		On the ground conservation projects that protect, enhance or restore native plant communities.
NOAA	Community Based Restoration Program		Cooperative		

Sources of funding	Title	Contact	Type of funding	Amt	Notes
NRCS	Wetlands Reserve Program	Alan Forkey	Wetland restoration		To establish long-term conservation practices and protection. Private landowners only.
NRCS	Wildlife Habitat Incentives Program (WHIP)	Lisa Roberts	Wildlife Habitat		Develop and improve habitat. 75% cost-share assistance. Like to fund multiple partner projects.
USFWS	ARCO oil spill	Denise Steurer	For land acquisition, invasive non-native species control, restoration projects, information and education, and watershed evaluation and monitoring	$7.1M	
USFWS	Private Stewardship		On the ground conservation projects	$10K	
USFWS	Partners for Fish and Wildlife	Kate Symonds	Projects		Conserve/protect fish and wildlife and their habitats

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Symposium

Ecology and Impacts of the Large-Statured Invasive Grasses *Arundo donax* and *Phragmites australis* in North America

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Large-statured invasive grasses (LSIGs) constitute a distinct functional group with characteristic life history traits that facilitate colonization and aggressive growth in aquatic ecosystems, particularly those modified by human activities. These species typically form monocultures in the systems they invade and have wide-ranging and negative impacts on biodiversity and ecosystem processes. In March 2008, a special symposium was held as part of the Western Society of Weed Scientists annual meeting to synthesize our current knowledge of the ecological impacts and management of two notorious LSIGs: *Arundo donax* and *Phragmites australis*. In this volume of *Invasive Plant Science and Management*, symposium participants provide articles summarizing existing knowledge, recent research progress, and research needs for these two taxa. Here, we summarize the basic biology of these species and suggest the use of a more holistic approach to deal with the effects and management of LSIG invasions.

Nomenclature: Giant reed, *Arundo donax* L.; common reed, *Phragmites australis* (Cav.) Trin. ex Steud.

Key words: Biological invasions, ruderal, life form, functional group, invasive species.

Environmental managers, government agencies, and conservation groups worldwide face tremendous pressure to deal with the ongoing threat of invasive species. Restoring native biodiversity and ecosystem function through prevention, control, and eradication is central to most management strategies. However, addressing invaders on an individual species basis might limit our ability to prevent invasions, as well as predict future ones (Smith and Knapp 2001). Rapid response might thus be improved by considering species groups that share life histories, pathways of invasion, and habitat preferences (Aronson et al. 2007; Newsome and Noble 1986).

Grime (1977, 1979) developed a model for grouping species based on traits conferring tolerance to certain environmental conditions rather than on taxonomic similarity. His triangular model hypothesized that varying combinations of disturbance and physiological stress constantly impose selection pressures on plants and are the underlying mechanisms by which plants adapt to the environment. This typological approach has had a strong influence on many areas of ecology because it provides an ecological context for studying plant communities, which taxonomic groupings cannot. Taxonomically related plant species do not necessarily have similar life histories and, therefore, are not amenable to studies at the functional group level. Plant functional group (or type) is a loosely used term in ecology describing the grouping of plants on the basis of shared morphological, physiological, behavioral, or biochemical attributes rather than evolutionary or taxonomic relatedness (Gitay and Noble 1997; Lavorel et al. 2007). Efforts have been made to standardize the concepts and terminology of plant functional groups, but with little success (Rejmanek and Richardson 1996; Tecco et al. 2010).

Predicting who the next invader will be and early detection of invasive species before they spread have been major focuses of researchers and managers. Scientists have recognized that it is essential to identify the functional attributes common to successful invaders to address the problems they pose rather than examine the biology of individual species (Pyšek and Richardson 2007; Rejmanek and Richardson 1996). Here, we introduce the use of a functional group approach to studying a suite of large-statured invasive grasses (LSIGs) with similar morphological and physiological characteristics that cause them to

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colonize and establish in similar environments, resulting in similar ecosystem impacts.

Large-statured invasive grasses constitute a distinct functional group with characteristic life history traits that facilitate colonization and competitive success. We define LSIG as perennial grasses with highly lignified culms, culm heights greater than approximately 1.5 m, and a history of being aggressive invaders outside their native ranges. Vegetative reproduction and rhizomatous proliferation are common attributes of these species and promote their success in ruderal environments. Some of the better known members of this group include *Arundo donax* L., *Phragmites australis* (Cav.) Trin. ex Steud., *Pennisetum purpureum* Schumach., *Phalaris arundinacea* L., *Neyraudia reynaudiana* (Kunth) Keng ex Hitchc., *Saccharum ravennae* L. [=*Erianthus ravennae* (L.) P. Beauv.], *S. spontaneum* L., and *Miscanthus sinensis* Andersson, and these grasses are found across many biomes and continents. Many have practical uses leading to a propensity for human-assisted dispersal, and then escape into natural ecosystems.

Most LSIGs are invaders of riparian and other mesic areas (except for *P. purpureum,* which is considered a facultative wetland species because it often invades grasslands as well). Moisture appears to be an important element in the life history of these species, either because of the high water demands necessary to generate large size and extent rapidly, or as the mode of LSIG propagation. The predominance of wetland cases also makes LSIG invasion a critical conservation concern because these are among the most biodiverse and threatened ecosystems in many landscapes. LSIGs also typically form near-monocultural stands, suggesting broad similarities in the competitive mechanisms by which they achieve dominance; thus, their impacts on infested ecosystems can be strong and generalizable.

In March 2008, a special symposium was convened during the Western Society of Weed Scientists Annual Meeting in an effort to synthesize our current knowledge of the ecological impacts and management of two notorious LSIGs: *A. donax* and *P. australis*. In this volume of *Invasive Plant Science and Management*, symposium participants provide articles summarizing existing knowledge, recent research progress, and future research directions for these two taxa. Although these papers have a North American emphasis, the implications of this symposium could be much broader than the limited taxonomic and geographic coverage would imply, because both of the focal species are considered noxious in other regions of the world (Dudley 2000; Mathieu et al. 2004; Richardson and Van Wilgen 2004) and share traits with numerous other global invaders (Weber 2003). These papers will build on the concept of a functional group-based treatment of these species, and here, we introduce *A. donax* and *P. australis* to set the stage for proceeding authors to discuss the biology and ecological impacts of invasion more fully.

Figure 1. Distribution of *Arundo donax* in North America.

Arundo donax

Arundo donax L. (giant reed) is a perennial, clump-forming hydrophyte that has invaded Mediterranean, subtropical, and semiarid riparian zones worldwide. It is the largest of six species in the genus *Arundo* and is one of the tallest grasses (up to 10 m). *Arundo donax* is considered native to eastern Asia (Polunin and Huxley 1987), but recent data suggests a Mediterranean origin (Dudley et al. 2008).

Arundo donax has been cultivated across Asia, southern Europe, North Africa, and the Middle East for thousands of years (Perdue 1958) and was first introduced to the New World in the early 1800s from the Mediterranean region (Bell 1997). It was extensively planted along ditches for erosion control and around other sites as a visual ''screen,'' including near natural bathing sites, where it is often planted because it tolerates the toxic conditions found at thermal or saline springs (Papazoglou 2007). Plants have been maintained in rural areas for fence material, roof thatching, construction of baskets and other artisanal products, and food preparation (tamale wraps). The plant has been cultivated in plantations in California (now terminated), Argentina, and France for production of reeds for musical instruments, and it is also popularly used to construct informal flutelike instruments. Because of its rapid biomass production, *A. donax* is a proposed candidate for biofuel development in North America (Barney and DiTomaso 2008; Mack 2008) and other warm regions of the world (Seca et al. 2000). Despite the invasive nature of *A. donax*, the species continues to be sold horticulturally throughout the United States, including a ''variegated'' form that is known to have escaped in some areas (Dudley, unpublished data).

In North America, *A. donax* has colonized riparian systems from Maryland to California (Bell 1997; Figure 1) and is considered to have had its greatest impact in southern California (Bell 1997; Dudley and Collins 1995) and along the Rio Grande in Texas and Mexico (Dudley 2000). Invasion of riparian systems in the southwestern United States is generally facilitated by the highly variable hydrologic regimes of these systems (Bell 1997). Heavy rains in the wet winter season lead to flash flooding, causing rhizome fragments to break off and be carried downstream. As a result, reed populations tend to increase with distance from headwaters (Else 1996). Once established, it is highly drought tolerant, and rhizomes deposited at the upper reaches of floodplain terraces often thrive in the absence of supplemental moisture. Plants also tolerate high salinity levels, inhabiting estuarine and coastal strand environments, even colonizing marine islands after flooding that transports rhizomes from rivers across ocean waters.

Arundo donax invasion has many purported ecological and environmental impacts, (Bell 1997; Dudley 2000). It is classified as a noxious weed in Texas (USDA 2009), and the California Invasive Plant Council lists it among the top five invasive species degrading natural ecosystems in the State (Cal-IPC 2006). Invasion in riparian areas alters the native vegetative structure (Herrera and Dudley 2003) and rapid growth after floods or wildfire leads to competitive displacement of native riparian vegetation such as cottonwood/willow woodlands (Coffman 2007). This dominance reduces arthropod diversity and abundance (Herrera and Dudley 2003) and also leads to decline in avian diversity and abundance (Kisner 2004). However, empirical data on the ecological and economic effects of *A. donax* invasion remain sparse, and no comprehensive treatment of this species' ecology in its invasive range is available. The lack of "impacts" data hinders management of *A. donax* and protection of essential riparian habitat for endangered species.

Control measures against *A. donax* have been widely implemented in California, Texas, Nevada, and other states, including herbicidal control, cutting and removing biomass, and prescribed fire (Bell 1997). These control measures often have short-term efficacy and can incur collateral damage on non–target species (Boose and Holt 1999). A biological control program is being developed to suppress *A. donax* (Goolsby and Moran 2009; Moran and Goolsby 2009), but the observation that the agents proposed for introduction are already present in North America could suggest that much work remains to achieve success with biological measures (Dudley et al. 2008).

Phragmites australis

Phragmites australis (Cav.) Trin. ex Steudel is one of the most widespread and productive plants in the world and has a truly cosmopolitan distribution (Haslam 1972; Tucker 1990). This robust perennial grass typically grows in open wet areas, in both brackish and freshwater marshes, and along the banks of rivers, lakes, ponds, and ditches. Its network of emergent stems grows up to 6 m high and emerges from a belowground network of rhizomes that also play a role in clonal spread of the plant.

Reproduction and spread is by seed and rhizome fragments, which are transported by water and human activities. Like *A. donax*, clonal expansion occurs through rapid vegetative growth by rhizomes that can reach a depth of 2 m and can constitute two-thirds of the plant biomass (Haslam 1972). Through this rapid rhizome growth, populations can quickly dominate invaded systems, resulting in near monocultures.

Although the species is native to North America, three distinct genetic lineages are found distributed across the continent today (Saltonstall 2002). The native subspecies, *P. australis* spp. *americanus* Saltonstall, P.M. Peterson, and Soreng is found across much of the North and down into the Southwest. Today it persists throughout its historic range, although its frequency and abundance might have been reduced over the past century (Figure 2a; Saltonstall et al. 2004). *Phragmites australis* ssp. *berlandieri* (Fourn.) Fern. is found across the southernmost states, and its range extends down through Mexico and Central America (Figure 2b; Saltonstall and Hauber 2007). This subspecies is cryptogenic, in that its status as a native or introduced species is not yet determined, but it is not considered invasive over most of its distribution. Finally, an introduced lineage, likely originating from Europe, is found across the continent. Its distribution overlaps that of the other lineages but also invades habitats not historically occupied by the other two subspecies (Figure 2c; Saltonstall 2002).

Introduced *P. australis* invasion has many purported ecological and environmental impacts (Chambers et al. 1999; Hershner and Havens 2008; Marks et al. 1994). It is classified as a noxious weed in six U.S. states (Alabama, Connecticut, Massachusetts, South Carolina, Vermont, Washington; USDA 2009), and several other states are in the process of reclassifying its status. After invasion, introduced *P. australis* often rapidly overwhelms native plant communities, typically transforming them from low- or mixed-statured communities into tall grass monocultures. This can change the quality of the habitat for a suite of species, including fish and other estuarine species (Able and Ragan 2003; Hunter et al. 2006), and birds (Benoit and Askins 1999). It also can affect ecosystem-level processes, such as nutrient cycling (Windham and Meyerson 2003) and sedimentation rates (Rooth et al. 2003).

Control of *P. australis* typically includes restoring tidal flows, herbicide treatment, cutting and removing biomass, and prescribed fire. Because of the remarkable propagation and regeneration capacity of the species, treatments must be carefully timed and control efforts repeated in multiple

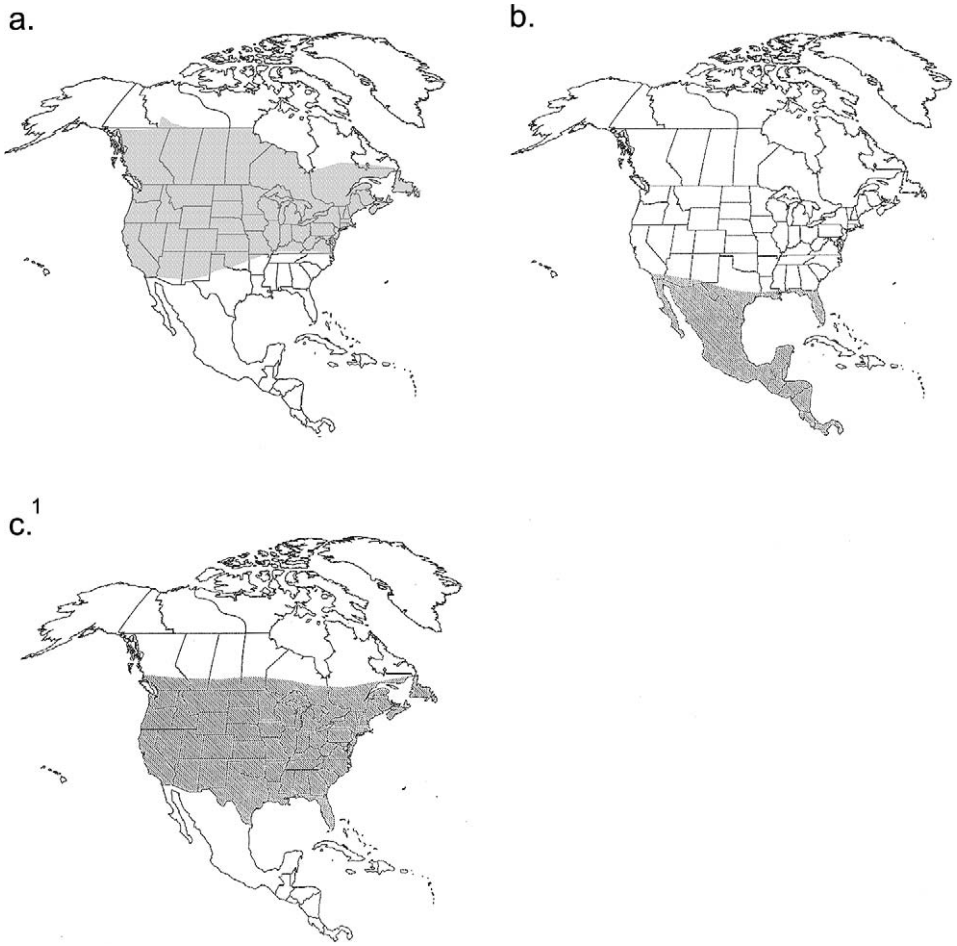

Figure 2. Distribution of (a) native, (b) Gulf Coast, and (c) introduced lineages of *Phragmites australis* in North America. Reprinted from Saltonstall et al. (2004). [1]Although not documented across the Gulf Coast except in the Mississippi River delta (Saltonstall 2002), introduced *Phragmites* might already have invaded these regions and certainly has the potential to spread into them. The distribution of introduced *Phragmites* is not known south of the U.S. border and thus is not included in this figure.

growing seasons to suppress growth adequately. A classical biological control program to suppress *P. australis* has been initiated (Blossey 2003), and host range testing of candidate agents is underway (R. Casagrande, personal communication).

Conclusions

In this special issue, four papers on various aspects of the ecology and impacts of *A. donax* and *P. australis* are brought together in an attempt to illustrate the benefits of studying a functional group/life form of invaders while recognizing the drawbacks of overgeneralizing without acknowledging specific traits. Saltonstall et al. (2010) review the current knowledge regarding reproductive characteristics and genetic diversity in both *A. donax* and *P. australis*. Within *P. australis*, important differences are found between the three subspecies found in North America, which reflect both their means of reproduction and likely their distribution and abundance. Spread of introduced *P. australis* via sexual reproduction in roadway corridors is discussed by Brisson et al. (2010). Analyses show that *P. australis* spread is strongly associated with the expansion of highway infrastructure and transportation-related runoff. Meyerson et al. (2010) describe recent landscape-scale dispersal and invasion patterns of the various *P. australis* lineages into western North America, tying in how reproductive strategies and human disturbance could facilitate or hinder invasion events. Moore et al. (2010) discuss experimental research examining the herbivory effects of two specialist insects on *A. donax*. Feeding by the armored scale, *Rhizaspidiotus donacis* Leonardi, and stem-galling wasp, *Tetramesa romana* Walker, reduces the photosynthetic capacity and transpiration rate of *A. donax*, with the magnitude of the effects being dependent on the insect's population dynamics.

Critical knowledge gaps hinder our ability to address the problems posed by LSIG invasions adequately. For

example, dual reproductive modes (vegetative and sexual reproduction) are recognized as important biotic factors contributing to the success of LSIG; however, the relative importance of these mechanisms and their relationship to human disturbance and transport of LSIGs is poorly understood. Recent evidence suggests that environmental conditions are just as important as biotic interactions in controlling the establishment and success of invasive species (Menke and Holway 2006; Menke et al. 2007). Although a great body of research informs our understanding of the wide-ranging impacts of *P. australis* on natural communities and ecosystems, we have relatively little knowledge of environmental factors that are precursors to invasion by most LSIGs, especially habitat susceptibility (but see Meyerson et al. 2010). Several common garden studies do provide evidence that increased nitrogen loads and climatic factors might promote *A. donax* and *P. australis* growth (Decruyenaere and Holt 2005; Quinn et al. 2007; Rickey and Anderson 2004). In a field study, Quinn and Holt (2008) found that *A. donax* height and survival were correlated with percentage of bare ground and soil moisture, suggesting that environmental factors, especially those modified by humans, are key factors in the success of these species. Further experimental studies are needed to tie the distribution patterns of *A. donax* and *P. australis* and other LSIGs to in situ environmental conditions such as climate, soil conditions, nutrient availability, and moisture requirements. Furthermore, moving past the species-specific treatment of invasive plant problems to a functional group analysis might provide greater insight into the causes of and potential for LSIG invasion and could more accurately portray the ecosystem-level impacts these species are causing.

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Santa Clara River
Enhancement and Management Plan Study

A History of the Santa Clara River

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Patricia A. Moore

April 1995

Summary

This document presents an overview of the historical changes that have shaped the Santa Clara River and its surrounding environment. Three chronological areas are examined. First, the Agrarian Era (1782-1870s) documents the indigenous populations and the arrival of Spanish and Mexican settlers and their interactions with the river. Second, the Commercial Era (1870-1920) describes the intensification of settlement and agriculture in the Santa Clara River valley and the rising competition for use of water. The final section, the Industrial Era (1920-present) demonstrates the rise of conflicting interests, including agriculture, commerce, development and government.

Sources include a wide variety of published accounts, government documents, maps, photographs, and anecdotal information from interviews and other narratives. These sources do not always present a consistent picture of the river, but their inconsistencies are often revealing and noted as such. Scientific records often present data sets that cannot be compared over time due to changing scientific techniques and goals. Because of the wide variety of source material and changing definitions of the river itself, it was impossible to confine the historical study to a particular area such as the river channel or 500 year floodplain. Although many of the events and shifts chronicled in this report affected areas adjacent to the river and not just its floodplain, the historical trends noted here were significant in the natural history of the river. Shifts in agriculture, for example, often began to affect the Santa Clara River valley as a whole earlier than they affected the riverbed in terms of planting, but increased water demands for crops like citrus did have a direct impact on the Santa Clara River itself. Thus, not all the events noted took place directly "in" the river, but they are relevant to the history of the river.

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A HISTORY OF THE SANTA CLARA RIVER, 1770s - 1990s

Section 1

The River and the Agrarian Era (1782 - 1870s)

Historical Overview

The Santa Clara River, typical of Southern and Central California coastal drainages, cuts through a variety of climate zones (*Sunset* 1979), flows intermittently, has a broad sandy bed and shallow depth, and is subject to annual flooding. Humans, birds and plants have incorporated these characteristics into their lifeways differently over time. The first groups of humans to interact with the river involved themselves in trade, small scale agriculture and livestock raising until the 1870s.

The indigenous Chumash and Tataviam people traded food, pelts and plant material for clothing and basketry from their living sites along the river, and from Shisholop, a large Chumash village which may have been a provincial capital, about three miles north of the mouth of the river.

The first major contact with Europeans occurred in 1782 with the establishment of San Buenaventura Mission by Spanish priests. The mission developed land along the Santa Clara River, and most of the local population became involved with the mission's plan for self sufficiency through the raising of crops and livestock.

From the 1820s to the 1860s livestock raising on large ranchos became the dominant occupation along the river. The new Mexican government granted parcels of land to aspiring ranchers. Ranchos adjacent to the river such as San Miguel, San Pedro, Rio de Santa Clara, Santa Clara del Norte, Santa Paula Y Saticoy, Sespe, and San Francisco supported growing populations of cattle and sheep. The hide and tallow trade followed by a demand for meat from the gold miners in the Sierras fueled this demand for livestock. Grazing and watering of livestock and limited irrigation shaped land use adjacent to the Santa Clara River in this period.

This system began to be challenged with the advent of American ownership of the land in 1848. However, ranchers retained much of their pastoral lifeway until the early 1860s when a decline in demand for cattle coupled with natural disasters economically stripped most of them. Gradually land use around the river shifted from ranching to agriculture.

Physical Setting

Natural History

In 1769 Father Juan Crespi recorded his observations of the Santa Clara River from Castaic Creek east to Santa Paula. His notes are consistent with our current day notions of a fully functioning riparian system. Near Castaic he observed vegetation which indicated a consistent source of water. He wrote about "tall and thick cottonwoods and oaks," and an "arroyo with a great deal of water which runs in a moderately wide valley, well grown with willows and cottonwoods." As he moved toward Camulos rancho he saw a "good stream of water ... [its] banks well grown with cottonwoods, live oaks, and willows.... plenty of grass." He remarked about the alkaline soil of the area, "[The] earth was very spongy; insecure and whitish, [and the arroyo flowing with plenty of water [sunk] into [the] sand." Near Fillmore he commented that the "road [was] broken by arroyos and gullies formed by the floods from the mountain ridges... [We] stopped by one of [the arroyos] which had plenty of water." As Crespi's party approached Santa Paula he estimated the width of the arroyo, which he "would call at this point a river," at "fifty varas of sand and about eighteen varas of running water" (Crespi/Bolton 1927). A vara is roughly equivalent to a yard.

In the mid-1850s the United States government commissioned surveys of the region to ascertain the best route for a railroad. Members of these parties also noted indicators of a riparian system. At the east end of the river moving towards San Francisquito Creek, the party had difficulty traveling due to the denseness of the vegetation in the riverbed: "... the growth of timber and willows along the creek, ... filled the whole valley between the ridges on either side ... we were obliged to cut our way out through the thickets and form a road for the wagon." Another member of the party observed a Black-shouldered hawk (*Elanus leucurus*) "hovering over a freshwater marsh" in the same region. This surveying group also found and named the Unarmored Threespine Stickleback (*Gastersteus williamsoni*) near the eastern headwaters of the river, which they called Williamson's Pass (U.S. War Department vol. 7, parts 1, 3 and 4, 1857) Table 1-1 on the following page lists plant species found in the area.

Table 1-1
Plant Species Noted Near "San Buenaventura and the Valley of the Santa Clara River, 1853
n.b. Taxonomic names change over time. Those listed below may not correspond with current designations.

Sisymbrium deflexum
Sinapsis arvensis
Isomeris arborea
Viola peduncula
Polygala cucullata
Oenothera cheiranthifolia
Lithophragma cymbalaria
Peucedanum utriculatum
Gilia micrantha
Gilia inconspicua
Gilia californica
Eriogonum polifolium
Avena fatua
Sidalcea malvaflora var. *humilis*
Solanum umbelliferum var.*trachycladium*

Sources U.S. War Department vol. 7, parts 1, 3 and 4, 1857.

Floods

While official precipitation records do not exist for the early part of the river's history, various historians have been able to use mission crop records to indicate seasonal rainfall patterns. In 1931, H.B. Lynch calculated average rainfall from 1769 to the twentieth century. Vern Freeman (1968) used these estimates and others to calculate historic rainfall records for the Santa Paula area.

Wet weather dominated the decade from 1770 to 1781, with average annual precipitation of almost nineteen and a half inches. The next thirty years from 1781 to 1809 brought a dry era with severe droughts in 1807 and 1809. The wet period from 1809 to 1825 brought major floods to Southern California during 1811, 1815, 1820-1821, and 1824-1825. A five year dry cycle occurred, followed by a wet period from 1832 to 1840, with flooding in that last year. A forty plus year dry cycle averaged about fifteen inches of precipitation annually from 1840 to 1883. However, this period was punctuated by floods, the most devastating in 1861-1862. J.M. Guinn recorded that the flood waters "made an inland sea of the Santa Clara Valley." Reginaldo F. Del Valle, interviewed by Vern Freeman in 1938, claimed that "In the flood of 1861-1862 the Santa Clara River took out quite a lot of land. Acreage planted to a number of crops was taken out.

The chapel located near the adobe [on Camulos Ranch] came near [to] being washed away. It was saved by building sand bag levees around it." It was also reported that the road to Los Angeles, adjacent to the river, was impassable for three weeks. Landslides were also recorded (Freeman 1968, U.S. War Department 1945).

Despite this flood, drought dominated the period. Drought from 1856 to 1860 killed cattle, crops and destroyed the Indian's acorn crop; the drought of 1864 killed two-thirds of the livestock in Ventura County, forcing ranchers to find new sources of income such as sheep (Freeman 1968, U.S. War Department 1945).

Native Uses of the River

The first peoples to settle around the river were Native Americans of two different groups: the Tataviam and the Ventureño Chumash. The Tataviam lived on the upper Santa Clara River west to about Piru. The group settled throughout the drainage area of the river near water and on south-facing slopes (King and Blackburn 1978). Various maps show settlements on the river and its tributaries, especially Piru Creek. The Ventureño Chumash settled near the river from Piru west to the ocean. This group relied more on water and tended to settle at the confluences of the river and creeks such as the Santa Paula, Sespe and Piru (Kroeber 1925, Old Indian Villages n.d., Grant 1978).

Typical of other California Indian groups, the Tataviam and Chumash adapted their lives to available water sources. The rhythm of the river shaped their daily and yearly routines. While they believed in manipulating the environment, they centered their lifestyles around the capacity of the land (Hundley 1992).

Riparian Resources

Both the Chumash and Tataviam relied on the resources of the river for their food supplies, material culture, and transportation. Table 1-2 below lists common riparian plants known to grow in or around the Santa Clara River, and used by the Chumash and Tataviam.

Table 1-2
Riparian Plants Used by the Chumash and Tataviam

Acorns (*Quercus agrifolia and Q. lobata*)

Both groups depended on the acorn mainly from the California Live Oak (*Quercus agrifolia*), and sometimes the Valley Oak (*Quercus lobata*) for a staple food. Water from the river was crucial to leach toxic tannin from the acorns. They did this in two ways: They shelled the acorns, placed them in a basket, buried them in the sand of the river for a year. Alternately they created a sand filter in the bed of the river in which they placed acorns, and poured hot ~~water~~ over them washing out the bitterness. The final product was a meal used for bread and paste. Oaks grew throughout the region where there was a consistent groundwater table.

Carrizo grass (*Phragmites communis*)

Carrizo grass, or common reed, grows in sloughs and marshes and was harvested for thatching houses.

Tule (*Scirpus acutus var. occidentalis*)

Similar to carrizo grass, tule grows in marshes or on stream banks, and was used for thatching, floor covering and wrapping.

Indian hemp (*Apocynum*), Nettle (*Urtica*), Milkweed (*Asclepias*)

The Chumash and Tataviam wove the fibers of these plants into cord. Hemp and nettle grow in moist places near streams and springs. Milkweed grows in arroyos, washes and canyons.

Wild cherry (*Prunus ilicifolia*)

The seeds of the wild cherry, which grows in canyons and on slopes, were leached, ground and made into a soup. The fruits were boiled.

Cattail (*Typha latifolia*)

The Chumash and Tataviam had several uses for the cattail, which grows in marshy areas. The pollen provided flavoring for a bread, roasted roots created the base for a meal, and its young shoots were eaten. Leaves were woven into floor mats and roofing thatch, while the leaves and leaf-sheaths provided a caulking material for use in canoes and houses.

Table 1-2 (continued)

Water Cress (*Rorippa nasturtium-aquaticum*)
This common green grows along streams, springs, marshes and marshes. It continues to be harvested today.

Soap plant (*Chlorogalum sp.*)
The soap plant had several uses. The pulp of the green bulb was used as soap, or the roasted bulb was eaten. Husks from the plant, which grew in open coastal sage scrub, could be made into brushes. As well the plant could be crushed and used as a fish poison. Turkey mullein (*Eremocarpus setigerus*), which grew in disturbed areas, was also used for this purpose.

California Bay Laurel (*Umbellaria californica*)
The berries of this tree, found in canyons, were roasted and eaten.

California Walnut (*Juglans californica*), White Alder (*Alnus rhombifolia*)
The roots of these riparian trees were used to make wooden bowls and plates. Alders grow near permanent streams such as Sespe and Piru creeks, while walnuts live in canyons, or on the margins of intermittent streams in sandy soil.

Source: Balls 1962, Hundley 1992, Jepson 1993, Grant 1978, Faber 1989, Bolton/Crespi 1927, King and Blackburn 1978, Grant 1978, Kroeber 1925.

The indigenous population also used other riparian resources. For example they created a delicacy, referred to by an early observer as a "sweet preserve like little raisins," from eggs deposited by flies on the tules and marsh grass of the river bed (Bolton/Crespi 1927, Cleland 1940). Migratory birds from lagoons and fish from the lower river and creeks rounded out the diet of the Chumash and Tataviam.

Naming of the River and First Spanish Settlement

Father Juan Crespi gave the river its name on his initial exploration of the valley with the Portola Expedition in 1769. Crespi, scouting sites to build missions in early August, designated the valley and river after Saint Clare of Assisi who had an upcoming feast day (Gudde 1969). Table 1-2 notes Crespi's observations of an extensive riparian system from Castaic Creek east to Santa Paula.

After the 1782 establishment of Mission San Buenaventura, the mission administrators used the labor of the Chumash and Tataviam. The Spanish and Mexican priests brought with them different values and technologies regarding water. They viewed water primarily as a resource to be harnessed for the good of the community (Hundley 1992). In this context, the first diversions of the river occurred at Santa Paula. Chumash laborers created a ditch and a reservoir to irrigate mission crops to feed livestock (Triem 1985).

Spanish-Mexican Uses of the River

Following secularization of the missions in the 1830s, Spanish-Mexican law and custom shaped the use of the river. Community rights not only had priority over the environment, but also over individual rights. For example, in communities (such as San Buenaventura), the maintenance of the main irrigation ditch, or zanja madre, fell on the whole population. Private diversion of water for irrigation did not occur unless decrees from the Mexican government specifically allowed it. If an individual, for example a rancho owner, petitioned the government for diversion rights, generally a maximum of ten percent of the land could be irrigated. This system assumed irrigated crops would be used only for the subsistence of the people and animals on the land. On maps of these land grants (diseños) "de riego" indicated irrigated land, and "labor" indicated cropland that could be irrigated if necessary. If an individual without rights irrigated cropland, and no one complained for ten years, legal rights could usually be affirmed. Government authorities increased and decreased the percentage of designated irrigable land when petitioned (Hundley 1992).

However, to survive and support the laborers who worked the ranchos, most owners diverted water for several crops including fruit, corn, beans and potatoes (Hundley 1992). The rancheros along the river also provided food supplies for travelers. A party traveling in 1847 camped near present day Fillmore and "found an abundance of corn, wheat, and frijoles." In the following days they walked about twenty miles up the river, finding two more ranchos with crops. One of the members observed that "there appears to be a larger supply of wheat, maize, beans, and barley in the granaries of the ranchos [further up the river]. More attention is evidently given to the cultivation of the soil here [likely at Camulos] than further [west], although neither the soil nor climate is so well adapted to raising crops" (Bryant 1847).

Evidence from Diseños

A fairly detailed diseño from 1838 confirms a typical pattern of rancho river and land use. Rancho Sespe, located along the river from Timber Canyon to just east of Fillmore, was devoted to cattle raising. Don Carlos Carrillo originally petitioned for the land in 1829 for the purpose of pasturage; therefore the bed of river was not included in the grant because it did not produce pasturage. The map (Becker 1964 map 29) shows several "abrevaderos" or watering places for cattle near the bank of the river. As cattle grazed all year, one can assume the abrevaderos had a constant water supply easily accessible to livestock. An irrigated field appears in the diseño, very small and abutting the north bank of the river. The map also indicates several "cienegas" or marshy areas on the land, perhaps indicating a high water table or poor drainage. On the south side of the bank, across from Timber Canyon, evenly spaced symbols appear to represent trees. This might simply indicate an area of heavy vegetation or intentionally planted trees, although the designation "labor" or "de riego" is absent.

After Carrillo's death the title to the land eventually was purchased by T. Wallace More who increased the amount of livestock on the land. More was known as "one of southern California's great cattle barons," and was active in the hide and tallow trade, as well as providing meat for the crowds streaming to the California gold fields (Becker 1964 map 29). As the livestock trade flourished in the 1840s and 50s, Rancho Sespe maintained between 8,000-11,000 head of cattle, sheep, horses and mares (Cleland 1940).

Another diseño from the Spanish-Mexican era depicts Rancho San Pedro, a small parcel of land later incorporated into the immense Rancho Rio de Santa Clara. The 1852 map (Becker 1969 map 3) locates the land very near the mouth of the river. The map represents a regular strip of vegetation along the bank of the river, either intentional planting to stabilize the bank and dunes or extensive native bank vegetation. Given that floods occurred in 1850 and 1853 (Freeman 1968) the vegetation could have grown fairly densely. Two freshwater lakes, "lagunas agua dulce," appear near the sand dune border with the ocean and near the border of the river. These fresh water lakes could be bits of McGrath Lake or something similar, perhaps drainage ponds. An 1855 map shows McGrath Lake in the same position as it is today, and a sandbar across the mouth of the river. It has been estimated that 870 acres of estuary existed at the mouth of the river in the mid-nineteenth century (Swanson et al. 1990, Map of the Mouth of the Santa Clara River 1855).

The area was mapped again fifteen years later as Rancho Rio de Santa Clara. Surveyors estimated the mouth of the river at fifteen to twenty chains (330 to 440 yards), the sand dunes parallel to the ocean between 100 to 500 yards, and the "swampy land full of sloughs and lagunas [lakes] extending along the whole front of the rancho" between one-half to three-quarters of a mile wide (Cota 1867).

Grazing, Plant Life and Sandstorms

Like most other ranchos, Rancho San Pedro, later Rancho Rio de Santa Clara, was devoted to livestock raising. Two corrals, an old and a new, appear on the first map. Observations from the era confirm large herds of livestock at other ranchos along the river (Coulter 1835, Bancroft 1886 vol. 2, Cleland 1940, Smith 1977). In 1850 two lost travelers stumbled upon Rancho San Francisco, which extended from Soledad Canyon to Piru Creek, and is now part of Newhall Land and Farming. They noted:

> a beautiful meadow ... green as a thick carpet of grass ... and shaded with oaks, wide branching and symmetrical...; while all over the low mountains that bordered it on the south and over the broad acres of luxuriant grass was a herd of cattle numbering many hundreds if not thousands (Newhall 1958).

Grazing livestock did have an impact on the river and its associated riparian habitats. It has been documented that grazing "may lower [plant] reproduction densities in floodplain areas" (Faber 1989). If livestock eat the groundcover it cannot reproduce, and in turn it cannot provide the environment (e.g. shade) for the growth of small shrubs. Increased erosion is one result. Additionally, this loss of vegetation leads to a reduction of food for aquatic animals, and less stable banks. Consequently sediment in the river increases which, along with animal waste, lowers water quality. Given that governments permitted open ranges to 1891, this series of events is a likely scenario. Grazing is also associated with the replacement of native perennial grasses with introduced and less nutritious perennials, and aggressive annuals (Faber 1989, Rowley 1985, *California's Rivers* 1993).

The loosened sediment from erosion probably encouraged the sandstorms that continue on sections of the river today. The sheer quantity of livestock grazing near the river makes this a likely scenario, although sandstorms could be promoted by several factors including drought or Santa Ana conditions. Many travelers in the rancho era noted the intensity of sandstorms. For example, in January 1847 an observer near Saticoy remarked that "The wind has blown a gale in our faces all day, and the clouds of dust have been almost blinding...." And about seven miles up the valley he noted "the wind blowing to almost a hurricane, and the dust flying so as nearly to blind us" (Bryant 1847).

Until the mid 1860s, rancheros invested primarily in cattle. A shift to sheep raising occurred after drought caused heavy cattle losses. Subsequently heightened demand for wool influenced increased investment in sheep in the late 1860s and early 1870s. Rancho Sespe eventually supported 16,000 to 18,000 sheep (Cleland 1940). This shift in production, like many subsequent changes, affected the Santa Clara River. Sheep have different grazing patterns than cattle. Though better adapted to arid climates, they require closer tending and cause more damage as they graze (Rowley 1985). In 1875 a government surveyor noted the impact of sheep grazing near the river: "Sheep have made savage work ... by treading out the natural grasses (principally the annual "filaree") from the root, which, if not properly cared for, must become in a few years arid" (U.S. Army Engineering Department 1875 vol. 1).

Mining

During the end of the Spanish-Mexican era and beginning of Anglo dominance, mining began to occur near the river. The first gold "boom" in California began in 1842 near the river in San Feliciano Canyon, near Piru Creek. From 1842 until the 1848 discovery of gold in northern California, prospectors trickled into the area. Water, mining pans, and picks were the primary tools of early mining. The lack of water in San Feliciano and Placerita canyons limited the capacities of the miners. They mostly employed a method known as "dry-washing," which relied on the wind to separate sand from the heavier gold. More determined prospectors packed their soil on animals to use the water in Piru Creek. In 1842, about 100 miners worked the canyons, while in 1845 an observer noted about three dozen prospectors (Smith 1977). The small number of miners and their methods probably created a negligible impact on the river, although the sediment flowing from Piru Creek into the Santa Clara may have increased.

After the fortunes of the northern California mines declined in the 1860s, the attention of entrepreneurs turned to other river regions in the state, including the Santa Clara River. Maps noted the potential of quicksilver on the north side of the river from Santa Paula Creek to the Los Angeles County line, and silver at the confluence of the river and San Francisquito Creek. East and north in Soledad Canyon prospectors extracted copper at places like the Hancock Copper Mines (Map of Public Surveys 1866, Map of the States of California and Nevada 1869).

Section 2

The Commercial Era (1870 - 1920)

Historical Overview

The second period of the human history of the Santa Clara River, from the 1870s to about the end of World War I, can be characterized by the increasing control of water usage and land to facilitate emerging capital growth. Euro-American immigrants began arriving in the 1860s, and established larger scale agriculture and oil enterprises. Crops of sugar beets, walnuts, lima beans and citrus relied on irrigation from the river and groundwater. For example, it was during this era that Nathan Blanchard and Wallace L. Hardison founded the Limoneira lemon ranch, which developed into the world's largest lemon producer (McBane 1994). Hardison also founded Union Oil with Thomas Bard. This company, like Limoneira, rose to national prominence. As well, the Oxnard Brothers American Sugar Beet factory introduced a new agricultural crop into the county and became another constituent of the river. The growth of these industries served as the impetus for the Southern Pacific Railroad to build tracks linking Ventura County with the rest of California. The builders of the railroad constructed bridges and berms which altered the character

of the river. The combination of growing access to transportation and developing crops and markets anchored Ventura County as a growing center of California industry. Consequently the human uses of the Santa Clara River grew substantially. For the first time floods on the river were measured by the damage done to agriculture and individuals became increasingly concerned with ways to control and use the waters of the Santa Clara River.

Physical Setting

Natural History

Tables 2-1 and 2-2 represent birds and plants associated with the Santa Clara River in the 1870s and 1880s. The introduction and establishment of *Brassica nigra*, an invasive mustard was noted near the western portion of the river. Tule (*Scirpus validus*) was still found abundantly in the swampy areas of the river. The extensive bird list (Table 2-2) indicates species closely associated with riparian habitats. Comments in this table include the birds' frequency and status as either residents, breeders or visitors. The list includes an extensive representation of birds found both in lagoon and freshwater habitats. Several birds widely distributed in the nineteenth century, but rare in the twentieth are listed such as Ross' Goose, Trumpeter Swan, White-tailed Kite, Golden Eagle, Bald Eagle, Peregrine Falcon, and Osprey.

See the maps and text in section 3 for a discussion of changes in the morphology of the river during this era.

Table 2-1
Flora Observed Near The River, 1875
n.b. Taxonomic names change over time. Those listed below were identified in the years noted, and may not correspond with current designations.

Clematis ligusticifolia, Nutt. var. *californica*, Wats. head of Piru Creek
Sisymbrium canescens, Nutt. head of Piru Creek
Brassica nigra, Boiss. "Introduced and has become a most obnoxious weed ... Sometimes growing 8-10' high, as in the Western portion of the Santa Clara Valley.
Isomeris arborea, Nutt. "The common dry ground shrub in portions of the Santa Clara Valley."
Rhamnus californica, Esch. head of Piru Creek, "appears to be var. *tomentella*, Gray
Lupinus luteolus, Kellogg. head of Piru Creek
Trifolium involucratum, Willd. var. *heterodon*, Wats. head of Piru Creek
Potentilla gracilis, Dougl., var. *rigida*, Wats. head of Piru Creek
Epilobium paniculatum, Nutt. head of Piru Creek
Boisduvalia densiflora, Wats. head of Piru Creek
Mentzelia gracilenta, T. & G. head of Piru Creek
Lessingia ramulosa, Gray, var. *tenuis*, Gray. head of Piru Creek
Aster menziesii, Lindl. head of Piru Creek
Tessarea borealis, T. & G. Santa Clara Valley
Helianthus petiolaris, Nutt. head of Piru Creek
Hemizonia ramosissima, Benth. Santa Clara Valley
Achillea millefolium, L. head of Piru Creek
Senecio dougalasii, DC Francisquitio Pass
Stephanomeria exigua, Nutt. head of Piru Creek
Dodecatheon meadia L., var. *alpinum*, Wats. head of Piru Creek
Asclepias mexicana Lake Elizabeth
Gilia virgata, Steud. head of Piru Creek
Nicotiana attenuata, Torr. Santa Clara Valley and head of Piru Creek
Mimlulus floribundus, Dougl. head of Piru Creek
Castilleia minor, Gray. head of Piru Creek
Stachys albens, Gray. head of Santa Clara Valley
Eriogonum nudum, Dougl., var. *pauciflorum*, Wats. head of Piru Creek
Eriogonum fasciulatum, Benth. Camulos Ranch
Eriogonum baileyi, Wats. head of Piru Creek
Salix laevigata, Bebb, var. *angustifolia*. Lake Elizabeth
Scirpus validus, Vahl. "This is the well-known Tule of California, forming dense masses along lake and river shores, from four to ten feet high."
Elymus triticoides, Nutt. head of Piru Creek

Source: U.S. Army vol. 6 1889 353-378

Table 2-2
Birds Observed Near The River, 1872-1873, 1879-1881

n.b. Taxonomic names change over time. Those listed below were identified in the years noted, and may not correspond with current designations.

1. Western Grebe (*Aechmophorus occidentalis*). "Seen occasionally in the bay in winter.... a fine specimen ... was caught December 10, 1880, in the Santa Clara River, above Santa Paula, eighteen miles from the coast."

2. American Eared Grebe (*Colymbus nigricollis californicus*). "Rather common in winter; a few breed in the marshes along the coast."

3. Pied-Billed Grebe (*Podilymbus podiceps*). "Common resident in the lagoons, where they breed sparingly."

4. American White Pelican (*Pelecanus erythrorynchus*). "Often seen among the lagunas in winter."

5. Mallard (*Anas boschas*). "Common during the winter, frequenting fresh water."

6. Gadwall (*Anas strepera*). "A common winter resident. More shy and quiet than most other species, feeding most usually after twilight."

7. Pintail (*Dafila acuta*). "A winter resident; not common."

8. Baldpate (*Anas americana*). "The Baldpate, or Widgeon, is one of the most abundant of our winter Ducks. Few, if any, remain to breed."

9. Green-winged Teal (*Anas carolinensis*). "this is one of the most abundant and generally diffused of our Ducks, it being found during the wet season in almost every little stream or pool."

10. Cinnamon Teal (*Anas cyanoptera*). "... resident in the county, but is most common during the summer."

11. Shoveller (*Spatula clypeata*). "... common winter resident."

12. Wood Duck (*Aix sponsa*). "... found throughout the year in greater or less abundance."

13. Redhead (*Aythya americana*). "... common resident of the county. I obtained ... its eggs in May."

14. Canvasback (*Aythya vallisneria*). "... common winter resident."

15. American Goldeneye (*Glaucionetta clangula americana*). "Winter resident, not common."

16. Bufflehead (*Charitonetta albeola*). "... common winter resident."

17. Ruddy Duck (*Erismatura rubida*). "... common winter resident."

Table 2-2 (continued)

18. Lesser Snow Goose (*Chen hyperborea*). "On November 20, 1880, I secured the only individual of this variety I ever saw in the county.... I was spending a day gunning among the lagunas near the mouth of the Santa Clara River."

19. Snow Goose (*Chen hyperborea nivalis*). "An abundant winter resident."

20. Ross's Snow Goose (*Chen rossii*). "Frequent in winter, associated with *C. hyperboreus nivalis*, from which it can be distinguished by its cry...."

21. American White-fronted Goose (*Anser albifrons gambeli*). "This is, perhaps, the most abundant of all the Geese ... and is usually the first to arrive.... so destructive are its ravages upon the growing wheat crop, that farmers often find it necessary to employ men by the month to hunt and drive them from their fields."

22. Canada Goose (*Branta canadensis*). "A winter resident, but not so common as the preceding."

23. Whistling Swan (*Olor columbianus*). "A frequent winter visitant to the lagunas along the coast."

24. Trumpeter Swan (*Olor buccinator*). "Winter visitant with the preceding species, but more common."

25. White-faced Glossy Ibis (*Plegadis guarauna*). "One specimen gotten near Santa Paula May 14 [1880]. This is the only specimen I ever saw in Ventura County, but on the San Joaquin Plains I found them common in July."

26. American Bittern (*Botaurus lentiginosus*). "Resident; not common."

27. Great Blue Heron (*Aredea herodias*). "A common resident. Several pairs nested in the cottonwoods near the mouth of the Santa Clara River."

28. American Egret (*Ardea egretta*). "Common resident among the marshes near the coast."

29. Snowy Heron (*Ardea candidissima*). "Resident; most frequent near the mouth of the Santa Clara River."

30. Green Heron (*Ardea virescens*). "Summer resident; not common. A few probably winter in the county, but most all go futher south."

31. Black-crowned Night Heron (*Nycticorax nycticorax naevious*). "Probably resident, but not common."

32. Sandhill Crane (*Grus mexicana*). "Occasionally seen during migrations."

33. American Coot (*Fulica americana*). "An abundant winter resident, both on the shore and in the streams and marshes. A few breed in the lagunas."

34. Wilson's Snipe (*Gallinago delicata*). "A rare winter resident, but a common spring migrant."

35. Greater Yellowlegs (*Totanus melanoleucus*). "Seen frequently along the Santa Clara River. Probably resident."

36. Long-billed Curlew (*Numenius longirostris*). "Frequent along the coast...."

Table 2-2 (continued)

37. Hudsonian Curlew (*Numenius hudsonicus*). "A winter visitant; not common."

38. Killdeer (*Aegialitis vocifera*). "Rather abundant resident."

39. Snowy Plover (*Aegialitis nivosa*). "Resident along the coast and rather abundant."

40. California Partridge (*Callipepla californica*). "Very abundant resident. Nests in March and April. Albinism is not infrequent; I have three beautiful cream-colored specimens secured near Santa Paula."

41. Band-tailed Pigeon (*Columba fasciata*). "The only specimen of this bird I ever saw in the county I got February 28, 1880, near the mouth of Santa Paula Cañon. It was a female and was feeding upon the young balls of the sycamore, no less than thirty-five of which I took from its crop. Residents of Santa Paula inform me that it was common only a few years ago."

42. Mourning Dove (*Zenaidura macroura*). "An abundant resident. Nests early in April."

43. California Vulture (*Pseudogryphus californianus*). "Resident among the higher mountains, descending only to the valleys and cañons to feed upon carrion."

44. Turkey Vulture (*Cathartes aura*). "An abundant resident. During the winter more than a hundred roosted in a grove of eucalyptus trees near Santa Paula."

45. White-tailed Kite (*Elanus leucurus*). "A rare resident. I knew of only four or five pairs in the Santa Clara Valley from the coast to the Sespe, -- about twenty miles. I obtained a full set of eggs April 12[, 1880]."

46. Marsh Harrier (*Circus hudsonius*). "Resident; rather common. Nests on the ground early in April."

47. Sharp-shinned Hawk (*Accipiter velox*). "Seen occasionally during the winter."

48. Cooper's Hawk (*Accipiter cooperi*). "Resident, but not common."

49. Western Red-tail (*Buteo borealis calurus*). "An abundant resident. Nests early in March, -- sometimes even in February."

50. Red-bellied Hawk (*Buteo lineatus elegans*). "A common resident. Nests not quite as early as [the Western Red-tail]."

51. American Rough-legged Hawk (*Archibuteo lagopus sancti-johannis*). "A rare resident; most numerous in winter."

52. Bald Eagle (*Haliaeetus leucocephalus*). "Resident; frequent along coast."

53. Sparrow Hawk (*Tinnunculus sparverius*). "A common resident. I have found it nesting in the deserted nests of the Magpie."

54. American Barn Owl (*Strix flammeus americanus*). "An abundant resident .... It most frequents the deeper barrancas, steep cliffs, and the dense foliage of live oaks."

Table 2-2 (continued)

55. American Long-eared Owl (*Asio wilsonianus*). "An abundant resident; found dozing during the day among the live-oaks or the groves of willows along the streams."

56. Screech Owl (*Megascops asio*). "Common resident."

57. Western Horned Owl (*Bubo virginianus subarcticus*). "Resident, common; nests early in February."

58. Belted Kingfisher (*Ceryle alcyon*). "Resident, but does not seem to be common in any part of the county."

59. Harris's Woodpecker (*Dryobates villosus harrisi*). "Resident throughout the year; common. Nests in early March. I have frequently observed a tendency toward albinism among individuals of this species."

60. Gairdner's Woodpecker (*Dryobates pubescens gairdneri*). "A common resident and generally distributed."

61. Nuttall's Woodpecker (*Dryobates nuttalli*). "Resident, but not so common as the preceding."

62. California (Acorn) Woodpecker (*Melanerpes formicivorus bairdi*). "Resident and locally abundant."

63. Lewis's Woodpecker (*Melanerpes torquatus*). "I have taken this handsome Woodpecker at Newhall ... and at Pacheco Pass...."

64. Red-shafted Flicker (*Colaptes cafer*). "An abundant resident."

65. Poor-will (*Phalaenoptilus nuttali*). "Summer resident; not common."

66. Western Nighthawk (*Chordeiles virginianus henyri*). "Common migrant; a few breed."

67. White-throated Swift (*Micropus melanoleucus*). "On February 19, 1881, while on a high mesa near where Santa Paula Creek enters the valley, I saw perhaps a score of White-throated Swifts circling high in air overhead."

68. Black-chinned Hummingbird (*Trochilus alexandri*). "Rather common summer resident."

69. Costa's Hummingbird (*Trochilus costae*). "Summer resident, rare."

70. Anna's Hummingbird (*Trochilus annae*). "A summer resident; more common than either of the preceding."

71. Rufous Hummingbird (*Trochilus rufus*). "... the most abundant species of Hummers found in the county. It is resident, except for a few weeks in midwinter. I found it very common in April and May in the thickets near the mouth of the Santa Clara River."

72. Western Kingbird (*Tyrannus verticalis*). "... common summer resident, arriving last week of March."

73. Cassin's Kingbird (*Tyrannus vociferans*). "Summer resident; more common than *verticalis*."

Table 2-2 (continued)

74. Ash-throated Flycatcher (*Myiarchus cinerascens*). "A summer resident; arrives about the middle of April. Not very common."

75. Say's Phoebe (*Sayornis saya*). "A winter resident; not common."

76. Black Phoebe (*Sayornis nigracans*). "A common resident throughout the year. Nests as early as April 1."

77. Western Wood Pewee (*Contopus richardsoni*). "... summer resident, but not common."

78. Hammond's Flycatcher (*Empidonax hammondi*). "Summer resident; not common."

79. American Crow (*Corvus americanus*). "Common resident."

80. Northwest Crow (*Corvus caurinus*). "An abundant resident."

81. Yellow-billed Magpie (*Pica nuttalli*). "... resident ... and abundant in suitable places. They are most likely to be found in any cañon where sheep or other stock are herded."

82. California Jay (*Aphelocoma californica*). "... one of the most common and generally distributed birds of the county."

83. Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*). "Abundant winter resident."

84. Bicolored Blackbird (*Agelais gubernator*). "Common; resident."

85. Tricolored Blackbird (*Agelais tricolor*). "An abundant resident."

86. Western Meadowlark (*Sturnella magna neglecta*). "Abundant in winter."

87. Arizona Hooded Oriole (*Icterus cucullatus nelsoni*). "... common summer resident arriving about the first of April.... It has never been recorded north of Los Angeles, I believe."

88. Bullock's Oriole (*Icterus bullocki*). "Summer resident; somewhat more common than the Hooded. Arrives last week in March."

89. Brewer's Blackbird (*Scolecophagus cyanocephalus*). "One of the most abundant residents. Nests usually in live-oaks near dwellings."

90. Crimson House Finch (*Carpodacus frontalis rhodocolpus*). "Resident. Perhaps the most abundant bird of the county."

91. American Goldfinch (*Spinus tristis*). "Common. Resident throughout the year."

92. Arkansas Goldfinch (*Spinus psaltria*). "Not common. Resident from April to October."

93. Lawrence's Goldfinch (*Spinus lawrencei*). "Common summer resident. Probably the most abundant representative of the genus."

Table 2-2 (continued)

94. Western Savanna Sparrow (*Ammodramus sandwichensis alaudinus*). "Resident in old fields and meadows. Not common."

95. Belding's Marsh Sparrow (*Ammodramus beldingi*). "Resident; frequent near the coast."

96. Western Vesper Sparrow (*Poocaetes gramineus confinis*). "Resident? Not common."

97. Western Lark Sparrow (*Chondestes grammacus strigatus*). "Common resident. Scarcely distinguishable from the eastern form."

98. Gambel's Sparrow (*Zonotrichia gambeli*). "An abundant winter resident."

99. Golden-crowned Sparrow (*Zonotrichia coronata*). "Winter resident; frequent in the foothills and mountains; seldom seen in the valleys."

100. Western Chipping Sparrow (*Spizella socialis arizonae*). "Summer resident. Rare."

101. Heermann's Song Sparrow (*Melospiza fasciata heermani*). "Resident; not very common."

101. Samuel's Song Sparrow (*Melospiza fasciata samuelis*). "Resident; very common."

102. Rusty Song Sparrow (*Melospiza fasciata guttata*). "Resident; rare."

103. Spurred Towhee (*Pipilo maculatus megalonyx*). "Resident. Common."

104. California Brown Towhee (*Pipilo fuscus crissalis*). "Resident. One of the most abundant and best known birds."

105. Black-headed Grosbeak (*Habia melaocephala*). "Summer resident; common. Arrives about April 23."

106. Blue Grosbeak (*Guiraca caerulea*). "Rare. Perhaps a summer resident...."

107. Lazuli Bunting (*Passerina amoena*). "... rather common as a summer resident."

108. Western Tanager (*Piranga ludoviciana*). "A summer resident; not common."

109. Purple Martin (*Progne subis*). "Summer resident; moderately common, nesting usually in holes in trees."

110. Cliff Swallow (*Petrochelidon lunifrons*). "An abundant summer resident."

111. Barn Swallow (*Chelidon erythrogaster*). "Summer resident, but not common."

112. Tree Swallow (*Tachycineta bicolor*). "Summer resident, abundant. Many breed in holes in the willows near the mouth of the Santa Clara River."

113. Violet-green Swallow (*Tachycineta thalassina*). "... rather common during the spring migrations. A few remain to breed."

114. Bank Swallow (*Clivicola riparia*). "Summer resident; locally abundant."

Table 2-2 (continued)

115. Rough-winged Swallow (*Stelgidopteryx serripennis*). Perhaps a common summer resident, but usually confounded with the preceding."

116. Cedar Waxwing (*Ampelis cedrorum*). "A frequent winter visitant. Often seen in flocks of six to twenty about the peppertrees, upon the berries of which they feed."

117. Phainopepla (*Phainopepla nitrens*). "... found in the valley near Santa Paula [April to October].

118. White-rumped Shrike (*Lanius ludovicianus excubitorides*). "A common resident."

119. Warbling Vireo (*Vireo gilvus*). "Summer resident, but not common."

120. Hutton's Vireo (*Vireo huttoni*). "Not common."

121. Least Vireo (*Vireo bellii pusillus*). "I am not sure that I ever saw this bird, but think I saw a few among the oaks near Sisa [Sespe?] Cañon in January."

122. Yellow Warbler (*Dendroica aestiva*). "A common migrant."

123. Audubon's Warbler (*Dendroica auduboni*). "An abundant winter resident. This is by far the most common species of the family found on the coast."

124. Grace's Warbler (*Dendroica graciae*). "I never saw but one specimen of this beautiful Warbler, -- a male in fine plumage which I shot from a cottonwood tree near Santa Paula, May 3, 1881."

125. Western Yellowthroat (*Geothlypis trichas occidentalis*). "A common resident, nesting in the grass or tules about low marshy places."

126. Long-tailed Chat (*Icteria virens longicauda*). "A common summer resident."

127. Pileolated Warbler (*Sylvania pusilla pileolata*). "Common summer resident in suitable places. Arrives about the first week in April. I found it abundant in the willows near the mouths of the Santa Clara and San Buenaventura Rivers...."

128. American Pipit (*Anthus pensilvanicus*). "An occasional winter visitant."

129. American Dipper (*Cinclus mexicanus*). "Frequent along the mountain streams."

130. Mockingbird (*Mimus polyglottos*). "A common resident."

131. Californian Thrasher (*Harporynchus redivivus*). "A common resident.... Nests as early as February 21."

132. Parkman's Wren (*Troglodytes aedon parkmani*). "An abundant resident throughout the county."

133. Slenderbilled Nuthatch (*Sitta carolinensis aculeata*). "A rare winter visitant."

134. Plain Titmouse (*Parus inornatus*). "Common resident, most frequent among clumps of live-oaks.

135. Oregon Chickadee (*Parus atricapillus occidentalis*). "A rare winter resident."

Table 2-2 (continued)

136. Least Tit (*Psaltriparus minimus*). "A rather common resident."

137. Western Golden-crowned Kinglet (*Regulus satrapa olivaceus*). "With the preceding, a rare winter resident."

138. Blue-gray Gnatcatcher (*Polioptila californica*). "... moderately common resident, nesting usually in the live-oaks, about the middle of May."

139. Black-tailed Gnatcatcher (*Polioptila californica*). "Not so common as preceding. Resident."

140. Townsend's Solitaire (*Myadestes townsendii*). "A very rare migrant. I saw it once or twice in spring 1881."

141. Russet-backed Thrush (*Turdus ustulatus*). "A spring and fall migrant. Not common."

142. Dwarf Hermit Thrush (*Turdus aonalaschkae*). "A migrant with the preceding. Perhaps not so common."

143. Western Robin (*Merula migratoria propinqua*). "An abundant winter resident."

144. Varied Thrush (*Hesperocichla naevia*). "A rare winter visitant. Seen only on one occasion."

145. Western Bluebird (*Sialia mexicana*). "... a common resident."

146. Mountain Bluebird (*Sialia arctica*). "A rare winter visitant. A single individual was seen in December, near Saticoy."

147. Sora (*Porzana carolina*). "...on the marsh at Saticoy."

148. Northern Phalarope (*Phalaropus lobatus*). "A flock was seen in a pond near the seashore in July."

149. Yellowlegs (*Totanus solitarius*). "I saw some of this species in winter, near fresh water streams.

150. Swainson's Hawk (*Buteo swainsoni*). "[observed] chiefly in the West Grove [three to four miles west of Saticoy, along the South bank of the Santa Clara River], where they came in flocks in September.

151. Golden Eagle (*Aquila chrysaetos*). "Not rare during my residence [in Saticoy, 1872 -1873].... Their destructiveness to lambs causes them to be shot without mercy by farmers and they are becoming scarce."

152. Peregrine Falcon (*Falco peregrinus anatum*). "I shot one in the West Grove [three to four miles west of Saticoy, along the South bank of the Santa Clara River].

153. Pigeon Hawk (*Falco columbarius*). "I shot three of this species in winter, all agreeing with the typical form."

154. Osprey (*Pandion haliaetus carolinensis*). "... saw a few near the coast where they were then [1872-1873] more plenty."

155. Yellow-shafted Flicker (*Colaptes auratus*). "I shot one in the West Grove in November, and as it is everywhere rare on this coast, it may be considered a winter straggler."

156. Vaux's Swift (*Chaetura vauxii*). "Migrating flocks appeared April 22, 1873, at Saticoy, but did not remain, seeking the high pine woods at that season."

Table 2-2 (continued)

157. Western Flycatcher (*Empidonax difficilis*). "Arrived at Saticoy March 18, 1873, but none remained near there in summer...."

158. Vermilion Flycatcher (*Pyrocephalus rubineus mexicanus*). "I shot two perfect male specimens of this brilliant subtropical bird in West Grove on October 21 and November 7, [1872]. Seeing no more west of the Colorado Valley, except one near San Diego, I considered it a rare species, but one that probably breeds in the county."

159. Common Raven (*Corvus corax sinuatus*). "The Raven was very common [in 1872 -1873].... I once counted thirty soaring with Turkey Buzzards, above a sheep fold near East Grove [about three miles east of Saticoy where the Santa Clara River runs permanently and a grove of poplars and willows lines its marshy shores for several miles], it is their frequent habit about midday, after feeding on dead sheep when the flocks have gone out for the day."

160. Brewer's Sparrow (*Spizella breweri*). "I shot two from a small migrating flock of this species near East Grove, April 10, [1873], the only time I met with any...."

161. Lincoln's Sparrow (*Melospiza lincolni*). "Not rare about Saticoy Grove in winter."

162. Fox Sparrow (*Passerella iliaca unlaschkensis*). "A few of this species wintered near Saticoy...."

163. Marsh Wren (*Cistothorus palustris*). "A few seen in the Saticoy marsh in winter only."

Sources: Evermann 1886, Cooper 1887, Robbins 1966.

Floods

The flooding of the Santa Clara River continued its unpredictable rhythm between 1870 and 1920. In the floods of 1876, the Santa Clara River "did considerable damage to some of the farmers" living near the Cienega, about one mile east of Fillmore. The deluge swept away grape vines on Camulos Ranch, damaged 1100 acres of T.M. Moore's choicest land, and carried off a house near the river. In response to this particular flood, the Del Valles of Camulos Ranch built flood control structures along the river bank. The Ventura *Signal* recorded: "Señor del Valle is piling his land bordering the river, to prevent any more such encroachments." The *Signal* further recorded that "Sespe farmers are contemplating building a levee on the Santa Clara during the coming summer, thereby reclaiming the lands rendered worthless by the inundation of the water during the winter."

The next wet cycle occurred from 1883 to 1893 with major flood damage in the winter of 1883 and 1884. Lowell Hardison recalled the dry early winter, "the valley was so full of dust that South Mountain was only an outline against the sky. The Santa Clara River became a dry bed of sand." The floods soon ended that. Hardison continued, "High water came out of the canyons to the river with the whole valley from [Piru] to Buckhorn solid water clear across the valley." But that was just the beginning. After the rains and snow, "The whole county was flooded. The railroads and all wagon roads were washed out." Communities became isolated as crossings of both the river and Sespe were halted. Hardison continued, "The banks of the Santa Clara River, the Sespe and Santa Paula Creeks that had been lined with great oak, sycamores and cottonwood trees, that stood for centuries on their banks, had been swept bare. Many buildings had been built in their shade, had kept them company. Many cattle, sheep, horses, and hogs ... drowned or [were] lost in the mud." The February 1884 floods were followed by ten inches of March rains. The Santa Clara River broke out of its channel at El Rio, and headed towards its previous southern channel, although local efforts at flood control diverted the flow. New islands formed in the river, as well. Hardison recalled that "from our cabin window [in Santa Paula] we had a fine view of the Santa Clara Valley below. It looked like one great lake as far as the eye could reach. Clumps of trees could be seen standing in the water and occasionally a stranded house or other things on the shore of the river." Another resident recalled that Ellsworth Barranca was half-full from bank to bank, carrying mud, trees, and rocks along with buildings (Freeman 1968, U.S. War Department 1945).

In the same flood of 1883-1884, the Los Angeles County section of the river also sustained heavy damage. The flood waters were reported to have "swept down Soledad Canyon and carried the Southern Pacific Railroad track out of the canyon down the Santa Clara River to the sea." Observers reported bridge beams, railroad ties and telegraph poles at the mouth of the river. Recorded J.M. Guinn: "The Santa Clara River spread out over the valley and for some time rivaled the Mississippi River during a spring rise."

The next flood year, in 1885-1886, resulted in railroad washouts and halted communications. In 1889, J.E. Borchard "lost a large part of his ranch along with many others whose land adjoined

the south bank of the Santa Clara River near its mouth," according to a letter to the Ventura *Star Free Press* (Freeman 1968). As well, Santa Paula Creek overflowed into the city. The Santa Clara River additionally washed away land and created other damage during 1892-1893 (U.S. War Department 1945).

Drought followed in the next decade from 1893 to 1904, stimulating the use of a large number of water wells and pumps. During this decade, Los Angeles County discovered that its water demands could not be met locally and began to plan for the importation of water from the Owens River via the aquaduct. Plans for water imporation included the construction of the San Francisquito Dam.

The next wet cycle, from 1904 to 1918, brought a number of floods. Railroad damage occurred near Piru, Sespe and Fillmore, with additional tracks washed out at Buckhorn and Castaic in 1904 and 1905 (Freeman 1968). Reports noted that year's flood destroyed ninety acres of land and 1,200 apricot trees, along with other crop damage (U.S. War Department 1945). In 1909, flood water changed the course of Santa Paula Creek. Santa Clara River water flowed down River Street (now Harvard Boulevard). Later that year, floods damaged part of the Saticoy bridge abutment and farm lands near Saticoy (Freeman 1968). 1911 brought floods which destroyed a wing dam on Santa Paula Creek, causing the creek to leave its channel and flood Santa Paula. Along the Santa Clara, the railroad, bridges, and irrigation systems experienced damage (U.S. War Department 1945). Floods in 1914 washed away the homes and farm buildings of "Stringtown," the area near Bardsdale irrigated by the Stringtown Ditch. The floods washed away several hundred acres of fertile bench land below the bluff south of the river, and the land was "practically covered by sand." The flood also damaged railroad trestles and the county bridge across the Sespe. Railroad washouts also occurred in flooding during 1916 (Freeman 1968). Significant silting of agricultural lands was reported in 1913 and 1914 floods (U.S. War Department 1945).

Commercial Agriculture

Commercial agriculture began along the river in the 1860s and 1870s, supplementing and replacing livestock raising. After the devastating flood and drought cycles of those two decades, most investors shifted their interests from ranching to agriculture. Many nineteenth-century framers continued with familiar crops such as grain farming. They cultivated barley, corn, flax, alfalfa, oats and mustard. An economic botanist leading a party across the Oxnard Plain in 1875 described the crops:

> June 22, 1875. ... we crossed the western end of the Santa Clara Valley, and found the farmers engaged in harvesting their barley. Much of it they simply headed, allowing the straw to remain. Large fields of good corn were seen. It was just in tassel and gave promise

> of a heavy crop. it is hardly overreaching the truth to say that on that day we saw thousands of acres actually overrun with wild mustard, which attained the height of eight or ten feet.... In some places, indeed, it might well be doubted as to whether it was a mustard or barley field we were passing, both of which were luxuriant enough.... What more than anything surprised me in the day's march was that no attention was paid to fruit culture. I find recorded in my notes that not a single fruit tree was seen that day. There was no apparent reason for this (Wheeler 1876).

This botanist noted the aggressive and invasive nature of introduced crops such as wild mustard which, when coupled with the grazing of the previous era, outcompeted native grasses which stabilized the soil. Not surprisingly heavy rains washed increasing sediment into the river as single invasive species became dominant in the next decades. The lack of fruit crops mentioned by the botanist can be attributed to the alkaline soil on the Oxnard Plain as well as rudimentary irrigation in areas which would later become productive.

Another member of the botanist's party noted that "With the exception of the Camu[los] ranch, which consumes the waters of Penn Creek in irrigation, but little cultivation is attempted in the valley above Santa Paula" (Wheeler 1876). At that time the main agricultural development existed primarily along the lower fifteen miles of the Santa Clara River. In 1878 about eighty-five percent of crop acreage consisted of wheat, barley and corn. At that time about 8400 acres in Ventura County supported crops (Gidney 1917). Soon after these observations experimentation with new crops began. This experimentation included walnuts, citrus, sugar cane, grapes, malt, hops, mustard seed, and other tree crops like figs, apples and apricots (Gregor 1953, Triem 1985).

Agricultural Practices Intensify

Intensive agriculture began with the introduction of lima beans in 1875. Limas slowly began to displace grain as a major crop in the region, enabling more small farmers to become successful. Crop rotation began in the 1870s, but did not become a regular practice until the twentieth century. In areas like the Oxnard Plain, with its alkali soil conditions, crop rotation became particularly significant. By the late nineteenth century sugar beets, lima beans and barley became the dominant crops in this area. In 1898 farmers discovered the high earnings generated from sugar beets, and the ideal growing conditions provided by the Oxnard Plain, with its high water table and dissolved salts. Sugar beets consume nitrogen while lima beans manufacture nitrogen; thus the crops were complimentary. In areas of high alkali, barley can provide a third crop in the rotation. Sugar beet plantings in Ventura County reached a high in 1919, after which they were eclipsed by other crops such as citrus (Gregor 1953). The increasing agriculture on the Oxnard Plain began the lowering of the water table.

Experiments with citrus cultivation began in the late 1860s (Triem 1985), but did not develop into a profitable crop until the 1890s when the Limoneira Company was founded in Santa Paula. Gradually the Limoneira Company, under the leadership of C.C. Teague, Nathan Blanchard, Wallace Hardison and Charles McKevett, purchased land and converted land once devoted to other crops, such as walnuts, to citrus. Citrus cultivation was a risky and expensive business. It was different from other crops both because it grew only in microclimates specific to areas around the Santa Clara River. Development of citrus along the river was confined to Ventura County as the climate just east of Camulos Ranch became unsuitable. Early citrus ranchers learned by trial and error which areas could support citrus. As well, citrus required irrigation. Teague, Hardison, Blanchard and McKevett planned and engineered some of the first substantial diversions of the river. The Limoneira Company managed 340 acres of citrus in 1905, when the average Ventura County lemon ranch spanned between one to fifteen acres. In succeeding years the business purchased almost 2500 acres of nearby land to convert to citrus production. After World War I, citrus became the dominant crop, surpassing lima bean and walnut production (McBane 1994, Triem 1985, Blanchard 1983, Teague 1944).

Diversions

In the 1860s and early 1870s farmers depended primarily on dry farming techniques, using irrigation during dry seasons only (Triem 1985). An observer noted in 1875 that "The farmers though this region do not irrigate more than they can avoid, for the reason, as they state it, it brings alkali to the surface" (Wheeler 1876). However, with increased settlement and agricultural use of the Santa Clara River valley, dry farming was no longer a reliable option both because of drought and lower crop yields. Thus individuals began to use river water on a larger scale, generally through diversions. These diversions permitted the development of much irrigated land. Early in the 1900s, over 16,000 acres were irrigated by the surface flows of the Santa Clara River (Freeman 1968).

Example of such diversions abound in Ventura County history. In 1869 landowners constructed a sixteen mile ditch (from Santa Paula to Saticoy) which carried 18,000 gallons per minute. This ditch (run by the Farmers Canal and Water Company), also used Santa Paula Creek water. Entrepreneurs built the ditch to attract settlers to the region. In 1871 a local paper praised the development potential of the ditch: "A fine ditch -- the Saticoy-Santa Paula Ditch is slowly winding its way down the valley. It is a capricious waterway, and will suffice to irrigate many thousands acres of as fine lands as can be found in the Santa Clara Valley." The Santa Paula mill relied on water from this ditch to grind its grain (Triem 1985, Freeman 1968). By 1875 a traveler noted "... we passed by a large flourishing mill which was evidently doing a good business. Well-tilled farms became more common, and there seemed to be still more room and water sufficient for a much larger population" (Wheeler 1876).

In 1870, landowners organized the Santa Clara Irrigating Company, which brought river water to parts of Rancho Santa Clara del Norte and Rancho Rio de Santa Clara (also known as the

Colonia). This canal was nearly twelve miles long and twelve feet wide, with an additional two and a half mile branch canal. Water from the Cienega ditch, owned by the South Side Improvement Company, irrigated 1,600 acres in Bardsdale, on the south side of the river near Fillmore. A diversion from the Cienega ditch provided water to the "Stringtown" settlement (near Bardsdale), settled in the 1870s and early 1880s. The floods of 1884 destroyed the settlement and ditch, but developers reconstructed the ditch to serve adjacent farm lands.

Two other canals existed in the Santa Paula area. A small ditch on the north bank of the Santa Clara four miles east of Santa Paula Creek was used until after 1920, when it was replaced by turbine pumps. The River Street Ditch, built in 1887, irrigated Santa Paula farmland via a four and a half mile canal. The Farmers Irrigation Company purchased the River Street ditch, and renamed it Farmers Ditch (Freeman 1968). The Limoneira lemon ranch was the primary client of this river water. On the south side of the Santa Clara, the Turner Ditch or Hyde-Richardson Ditch, was built in 1888. Further east, the Chaffee Ditch ran from Rancho Camulos to Torrey Crossing from 1896 to 1899.

Tributaries of the Santa Clara were diverted as well. Individuals and towns diverted water from Santa Paula, Sespe, Piru, Hopper and Lord creeks in the latter quarter of the nineteenth century (Freeman 1968).

The number of diversions, dams and canals is difficult to quantify accurately. They varied in size and duration, subject to destruction by streamflows. Many structures appeared to have a short history. Other irrigation systems, particularly those established by corporations, survived for long periods.

A map of the Fillmore area in 1894 demonstrates the number and variety of ditches, diversions and other human interventions along the river at the junctions with Sespe Creek. Near the confluence was the diverting dam of the Chormicle and Bennison ditch, with an "old ditch" and "new ditch" indicated on the map. Upstream the map portrayed the old dam for the Kennedy ditch and the new "Bard et. al." dam, feeding the new Kennedy or Williams ditch, directed towards Bardsdale with a series of flumes. Also marked are the dry Stringtown or Cummings ditch (mentioned above) and the dry Sutton ditch. Further downstream, past the confluence, lay at least four additional dams, some with sizable reservoirs indicated. The hydrology of the river, with its fluctuating surface and ground water flow, is indicated by a point which states "water sinks" (Sespe Creek Confluence 1894).

By 1912 ditches appeared in similar areas, but with corporate owners such as Interurban Land and Water, Hardison Ranch Company, Fillmore Irrigation Company, Sespe Land and Water Company and the Southside Improvement Company. In several places on a 1912 irrigation map, pumping plants appear in or adjacent to the river and some of the ditches. These pumping plants indicate water usage beyond the intermittent surface flow. Approximately eighty percent of the level land surrounding the river and adjacent hills supported irrigated crops (Map Showing Irrigation Development 1912).

Further upstream the Camulos ditch, drawing from both Piru Creek and the Santa Clara River, irrigated crops on the north side of the river. The Piru Water Company Pipe Line paralleled Piru Creek and irrigated a section north and west of the confluence of the creek and river. Several pumping stations are represented on the south side of the river (Map Showing Irrigation Development 1912).

As the valley widened downstream from Fillmore, ditches became longer, pumping plants more plentiful, and irrigated lands increased significantly. The Farmer's Ditch had been purchased by the Santa Clara Water and Irrigation Company which operated two other ditches to channel river water to irrigate the Oxnard Plain (Map Showing Irrigation Development 1912).

The two maps (1894 and 1912) show a move from fragmented individual ownership to larger water companies who markedly increased irrigated acreage primarily with river water. During the Commercial Era agriculture became a business. Farmers became entrepreneurs, looking to business consolidation and legal entities such as corporations to increase the value of their product. Water from the Santa Clara River became a component in a complex capitalist system.

The Newhall Example

The property acquired by the Newhall family exemplifies trends in land use and agriculture during the Commercial Era. Henry Mayo Newhall purchased a portion of the immense Rancho San Francisco in the 1870s. Rancho San Francisco had first been sold in the 1860s by the Del Valle family to oil entrepreneurs who sought to explore the oil potential of the region. Newhall bought a parcel from the entrepreneurs that stretched 40,000 acres over eastern Ventura County and northern Los Angeles County. As a rancho, the Newhall farm supported a relatively small amount of livestock because of an uncertain water supply. Newhall continued cattle ranching, and began using some of the oil pipelines left behind for water conveyance. He expanded the irrigation, plowing and planting many acres of the ranch. Down river, Newhall used irrigation to render 4,000 acres of chaparral into agricultural land. As one observer noted:

> At the lower end of the ranch (in Ventura County) Mr. Newhall has made a series of ditches, by which he can irrigate some four thousand acres. Here he grows alfalfa and corn in abundance; while he amuses himself with experiments in sugar-cane, flax, Japanese bamboo, and a large variety of tropical and semi-tropical fruits, all of which are doing well.... Newhall has planted over one thousand five hundred assorted fruit trees, including apples, walnuts, peaches, nectarines, plum ... together with a few oranges (quoted in Rolle 1991).

Newhall, a director of the Southern Pacific Railroad, also built a new town south of the Santa Clara River, to serve as a depot for the SPRR. Newhall thus created a transportation network to ship his products to market and a significant way to increase the value of his land holdings along the Santa Clara River.

Urban and Government Interests

The Railroad

In the mid-1850s the federal government developed plans for the construction of the Southern Pacific Railroad which were not executed until the mid-1870s. The main line, completed in 1876, stretched east from Newhall through Soledad Canyon. By 1887 a branch line extended from Newhall west down the length of the river to Ventura (Triem 1985). Initial plans for the Newhall to Ventura branch proposed excavating the south bank of the river near Saticoy "where the excavations and embankment will nearly equalize each other, and probably not exceed twenty feet in depth." The original plans also called for "two spans of 150 feet each" to cross the river at Montalvo, the site of a popular downstream crossing (U.S. War Department, vol. 7 part 1, 1857). As constructed, the Southern Pacific tracks parallel the river bed for the most part. In narrow places in Soledad Canyon the tracks hug the side of the canyon, barely rising out of the river bed. The original tracks were placed on berms constructed of gravel extracted from the river bed.

As well as creating physical alterations in the river, the railroad brought significant economic change to adjacent areas. Before the 1870s, Ventura was the only town along the river, followed soon after by Santa Paula. Towns such as Piru and Fillmore sprang up to intercept the Southern Pacific. Some towns were intentionally planned. For example, entrepreneur Roys G. Surdam designed in 1887 the community of Bardsdale, just south of the river. He laid out the town to include small plots of citrus, and community buildings such as public schools and churches. Surdam and Thomas Bard spearheaded the formation of the Southside Improvement Company in 1887 to provide water for the new town. They purchased water rights from ditch owners and created their own diversion -- the Southside Improvement Company Gravity Pipeline (Triem 1985, Map Showing Irrigation Development 1912).

The arrival of the railroad stimulated a population boom, spurring the growth of agriculture and new industries such as oil. Each constituency had a need for water which was fulfilled primarily with river water. For example when the Limoneira Company was founded in 1893, its directors also formed the Thermal Belt Water Company to provide their new enterprise with water (Triem 1985).

Industries, Government, Urbanization

With increased population and a growing industrial base, urban areas themselves began to extend to the edges of the river. The new industries needed laborers to support them. With less economic and political power than their employers, these laborers often lived on the floodplains of the river. For example in Santa Paula many of the Mexican families, who picked, washed, sorted and packed the fruit for the Limoneira Company, settled next to the river. Not surprisingly, their neighborhood received extensive damage during flooding (McBane 1994, Triem 1985).

As the region diversified, governmental organizations were formed to promote the area's continued economic growth. For example the mission of the Farm Bureau, founded in 1914, was to provide as suitable an environment as possible for crop growing. As cultivation expanded onto the hillsides, rainwater washed increasing amounts of sediment into the valley and river. To address the problem, the Farm Bureau helped organize storm water districts to manage runoff into the river (Gidney 1917).

Roads

Before the extensive development of paved roads in the late 1910s and early 1920s, denizens of the area often used the river bed as a road due to the lack of improved routes. Annual rains turned the river into a place of treacherous quicksands, not only at the mouth but upstream as well. Before the bridging of the river, numerous accounts exist of horses and wagons becoming mired in the quicksand. Thomas Bard was known to dodge the river crossing by waiting at the mouth of the river to "catch the flood tide on the turn and plung[ing] across before the frothing conflict between river and receding waves churned the hard-packed sand into a quivering entrapment" (Hutchison 1965).

Farm families recall crossing the river in special wagons with especially large wheels and wagon beds high above the river's waters (Dickenson 1994). Ventura County helped maintain local roads. A resident of the Oxnard Plain at the turn of this century remembered traveling across the river bottom with her mother who was taking eggs to sell in Ventura. The county had placed hay on the wheel tracks in the sandy bed so the carts would not sink (Olin 1983).

Crossing the upper Santa Clara River provided numerous challenges as well. A local resident recounted a colorful example of a journey through Soledad Canyon in 1905. He accompanied a party of three cars on a trip from Los Angeles to the Owens Valley on an expedition organized by William Mulholland to show the mayor and other Los Angeles city officials his plan to construct an aqueduct. The resident recalled:

> For forty miles we had to fight the railroad for a trail to get through this narrow and wild mountain pass. This put us in the creek bottom most of the time with no sign of a road or trail. The water was running about one foot deep. If a car slowed, as one did, it immediately sank into the quicksand. This necessitated all hands in the caravan to shed shoes and socks and wade in, push, shove, dig and haul for an hour until the car was on solid ground (Strasburg 1994, Heyser n.d.).

Until 1910, the two primary roads connecting the Antelope Valley with Los Angeles were through Soledad Canyon and San Francisquito Canyon. The Mint Canyon Highway, also known as Sierra Highway, was completed in 1921. In 1918 the Sierra Highway bridge over the river was completed (Strasburg 1994).

Section 3

The Industrial Era (1920 - 1990)

Historical Overview

The years from 1920 to the present day reflect the ever-more complex demands upon the Santa Clara River. Agriculture has moved toward agribusiness which has increased water demands on the river and its associated groundwater. As the population of Ventura County and Los Angeles County expanded numerically and geographically, urban development has encroached upon the floodplains. Subsequently residential demands and recreational uses of the river have multiplied. Further, the development of more sophisticated government bureaucracy at the city, county, state and federal levels has had a significant impact on the history of the Santa Clara River Valley. With increased demands on the waters of the Santa Clara River and the lands surrounding the river, efforts to protect natural resources as well as develop human uses have shaped government actions.

Physical Setting

Natural History

Evidence about the changing physical setting of the Santa Clara River comes from a variety of maps, photographs, and reports. The detailed species lists and environmental analysis that goes

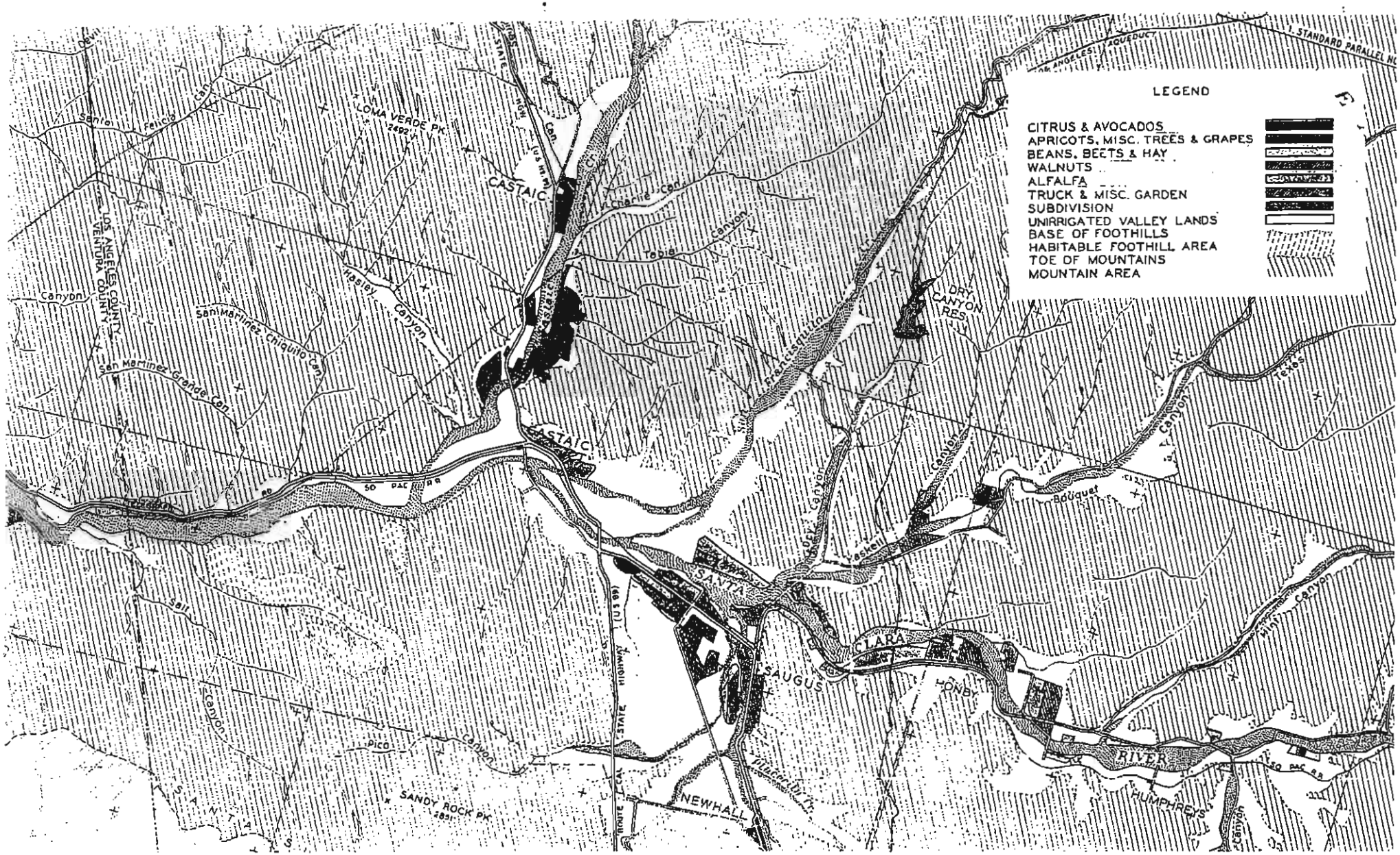

FIGURE 3-1 Mint Canyon 1933 (DWR

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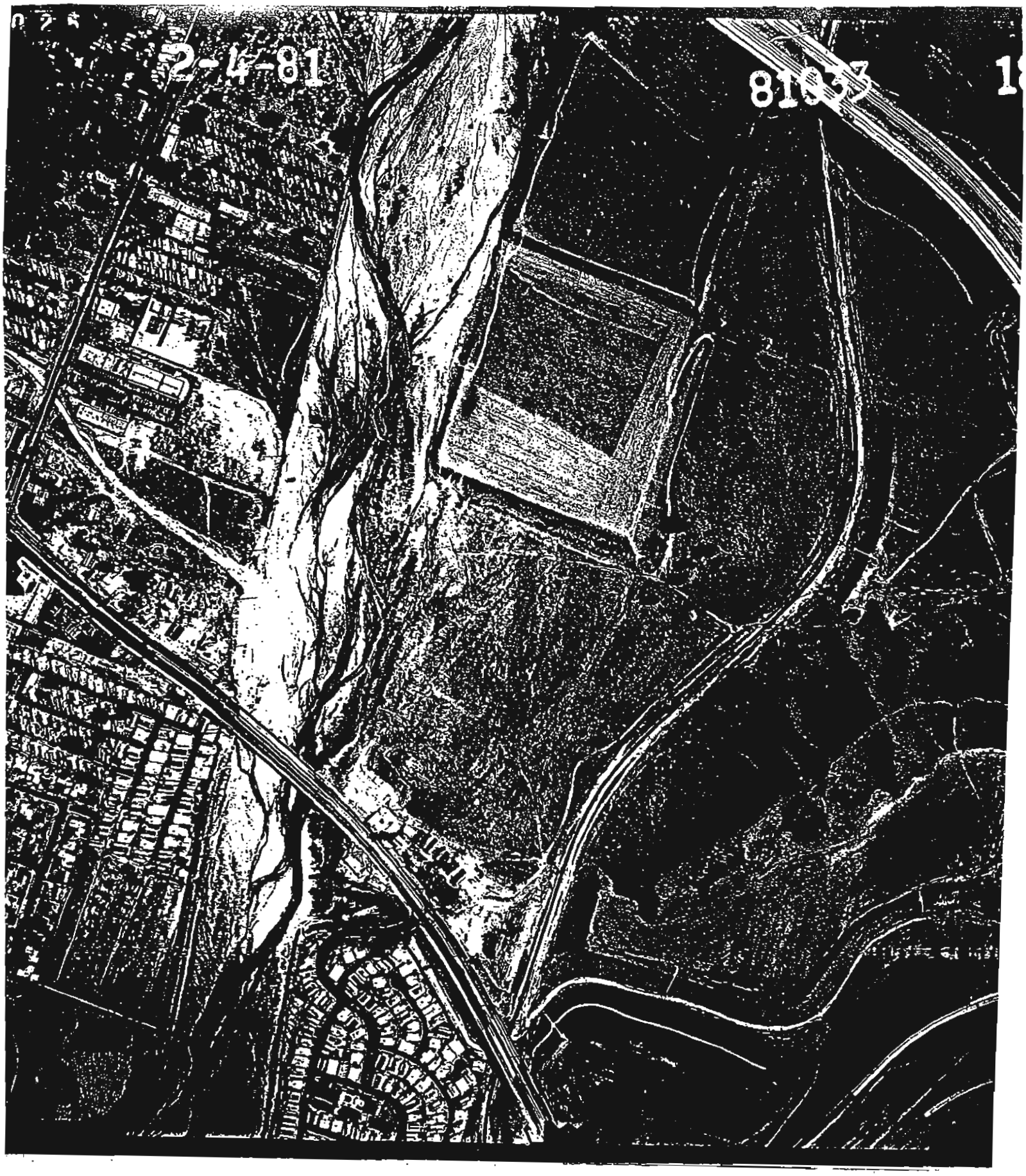


FIGURE 3-2 Mint Canyon/Sierra Highway 1981
(Los Angeles County Aerial Photo 1981)

By 1992 this same area on the Santa Clara River between Sespe and Piru Creeks sustained riparian vegetation only along the banks of the river and creeks. These areas consisted primarily of brush sparsely distributed near the channel, followed by wide expanses of sandy riverbed and pockets of riparian associated woodlands (County of Ventura Overlay Series 1992). According to aerial photographs, the major change in vegetation from the 1930s to today is the loss of riparian thickets, once characteristic of the entire riverbed, along gravel bars and floodplain. The lack is noticable especially near aggregate extraction operations downstream, because of lowered water tables from mining and natural scouring (Faber 1989).

Three additional key points along the river were chosen for comparison on the basis of maps and photos available. These include: the Mint Canyon region at Sierra Highway; the confluence of Sespe Creek and the Santa Clara River at Fillmore; and the region below Montalvo Crossing (Highway 101 and SPRR bridges).

For the Mint Canyon region, six sources were compared: USGS maps dated 1900 (San Fernando), 1940 (San Fernando), and 1960 photorevised in 1988 (Mint Canyon), a Division of Water Resources map dated 1933 and aerial photographs from 1968, 1977 and 1981. The 1900 map indicates the railroad following the contour line at the southern bluff of the river. There was no development between the railroad and the north bank, except for unpaved roads. The 1933 map (Figure 3-1) indicates plantings of alfalfa just west of Mint Canyon. By 1940, some structures appeared in the undeveloped area in the plain of the river and the river was bridged at Sierra Highway. In 1968 there appeared to be manmade borders to the river's plain, additional structures and substantial urban development to the north. A 1977 aerial photograph (Figure 3-2) shows a substantial narrowing of the river channel with urban development defining manmade limits on the river (apparently by levee or another structure). A trailer park abuts this apparent levee in an area that appeared to be riverwash on earlier maps. 1981 aerial photographs also clearly display the manmade confines to the channel on both north and south banks just west of Sierra Highway. U.S. quadrangle maps from 1960/1988 confirm development as well as construction of an additional bridge on the new Antelope Valley Freeway. This example shows how regions of the river have become constricted by urban development.

The second example at Fillmore includes a 1838 diseño, a map from the 1860s, two local surveyor's maps from 1894, maps from 1912, 1921, 1923, 1942 and 1951 (photorevised in 1969 and 1974), and aerial photographs from 1993. These maps show the changing morphology of the Santa Clara River as well as the variability of map detail and quality available. In 1838 a crude diseño demonstrated the Sespe flowing in a single channel into the Santa Clara River, although more modern maps show a double channel. Marshy areas at the river's banks were shown in a 1860s general map of the area.

Two maps from 1894--one dated "July and August" (Barry and Isham, Figure 3-3) and the second dated "August" (H.J. Stocker, Figure 3-4)--demonstrate how local farmers altered and made use of the Santa Clara River in this region. In both, the south bank of the Santa Clara dips further south after the confluence with the Sespe, but this bulge in the river's width varies in shape and

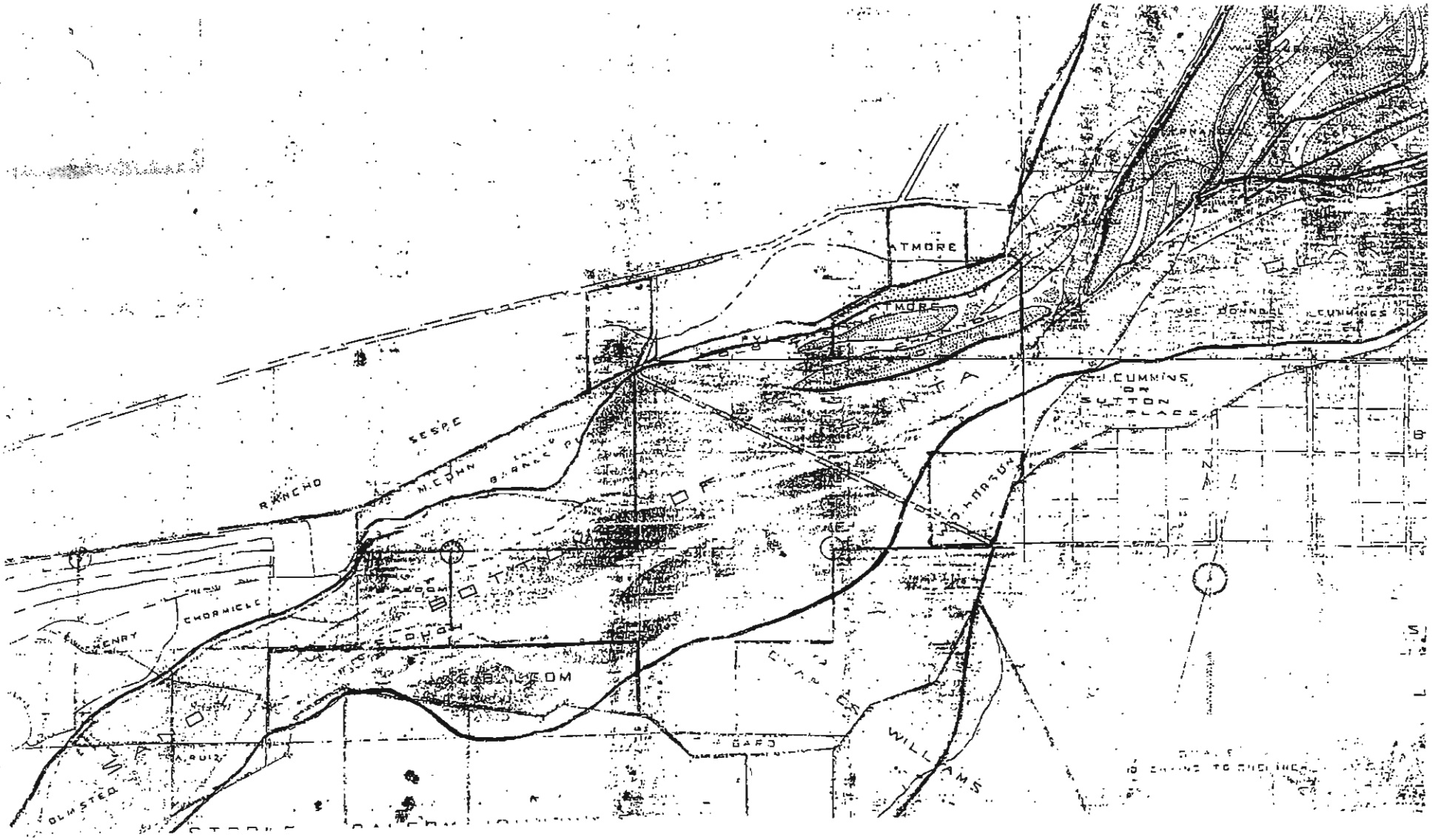


FIGURE 3-3 Sespe Creek/Santa Clara River, Barry and Isham, 1894 (Sespe Creek Confluence 18

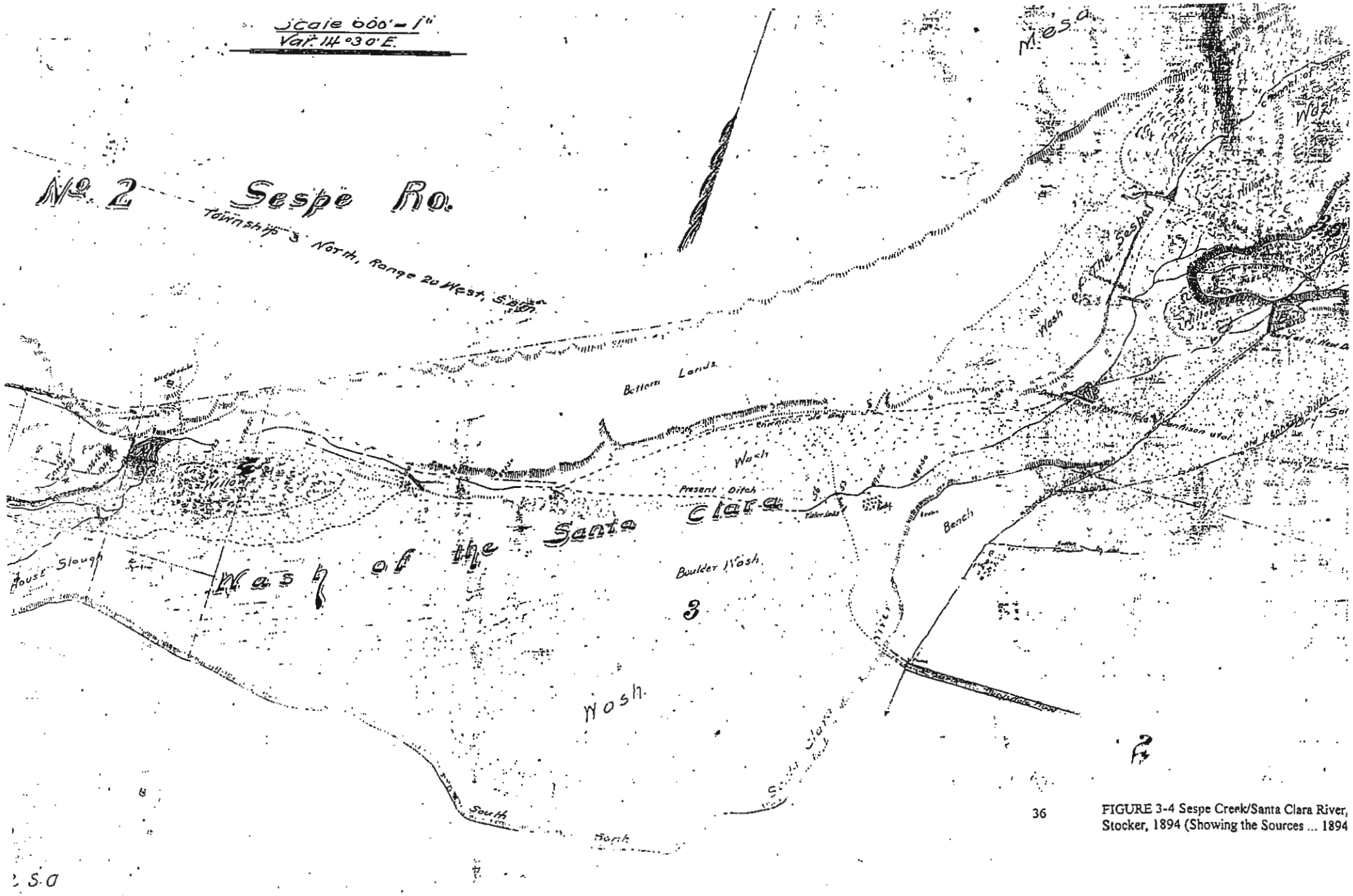
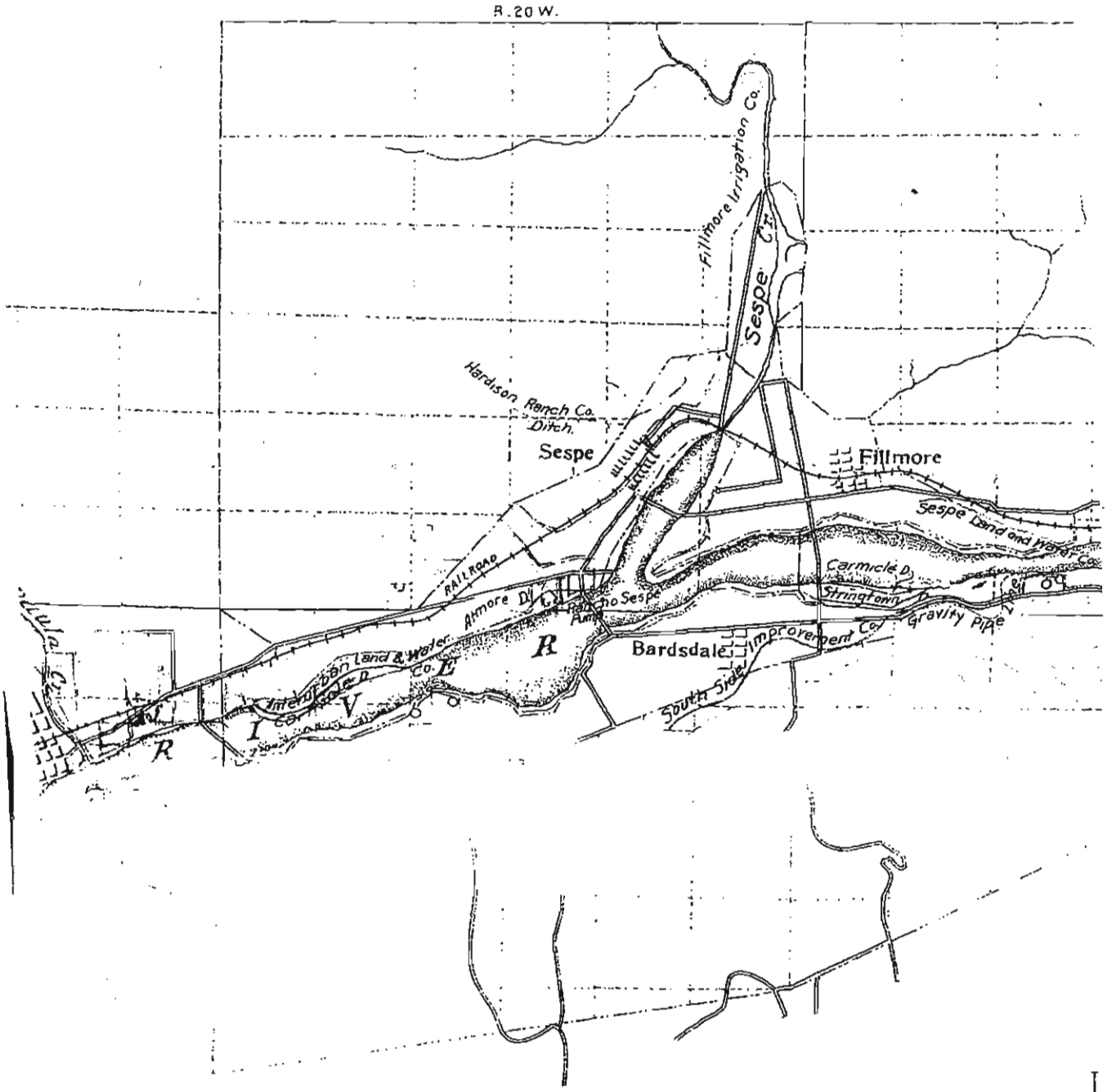


FIGURE 3-4 Sespe Creek/Santa Clara River, Stocker, 1894 (Showing the Sources ... 1894



LEGEND

IRRIGATION CANALS

PUMPING PLANTS.

FIGURE 3-5 Sespe Creek/Santa Clara River, (Map Showing Irrigation 1912)

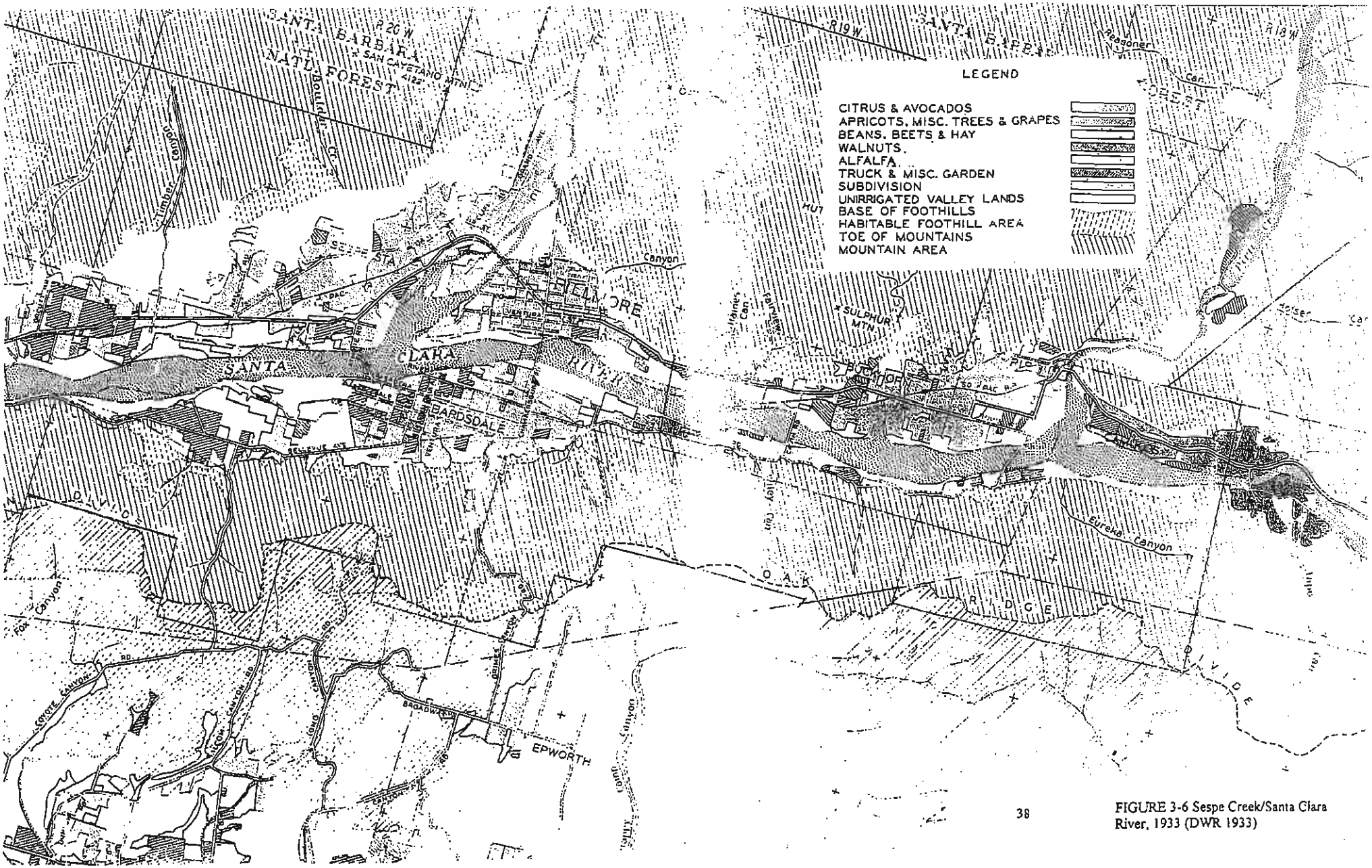


FIGURE 3-6 Sespe Creek/Santa Clara River, 1933 (DWR 1933)

FIGURE 3-7 Sespe Creek/Santa Clara River, 1993 (Ventura County Aerial Photo 1993)

the bank lines are different despite the close dates of the two maps. The Barry and Isham map shows islands and sloughs in the river at places that vary from the Stocker map. The Stocker map shows a number of private dams, reservoirs, irrigation canals and diversions in the river. Further, it indicates large stands of willows downstream from the merger of the Sespe and the Santa Clara. A 1912 map (Figure 3-5) of the same area shows irrigated lands extending to the river banks with a large wide area (comparable to that shown in the Stocker map of 1894) just below the confluence. In 1921, structures appeared in that wide part of the river, and the river bed appeared narrower. The 1933 DWR crop map (Figure 3-6) shows citrus planted to the river's edge in Bardsdale, but mostly unirrigated crop land and some alfalfa adjacent to the widened section of the river to the south. The Santa Clara River appears about half as wide in this area as it did in the 1894 maps. USGS maps dated 1951, 1969 and 1974 show the reappearance of that large wide sandy area, with cultivated lands extending to the edge of the southern river bank. By 1993, an aerial photograph (Figure 3-7) revealed flood protection structures east of the once wide area of the Santa Clara River and the river channel is narrowed.

The third example at Montalvo shows the continuous shifting of river banks and gravel/sand bars within the river. Sources include maps from the 1860s, 1904, 1912, 1914, 1929, 1943, 1947, 1967 and aerial photographs from 1993. The nineteenth century map indicates that a crossing was used where the SPRR and Highway 101 bridges were later built. The map dated August 1914 (Figure 3-8) shows how the bank of the river shifted from 1911 to 1914 (maps from 1904 and 1912 confirm these shifts). The 1914 map also shows human intervention in the river in the form of pilings from the SPRR bridge downstream in the middle of the river channel and some early bank work. The 1929 map (Figure 3-9), made after the St. Francis dam disaster, shows several southern banks of the river and a large amount of manmade interventions such as pilings, groins, jetties and levees along the south bank and in the river itself. Land in the river bottom is marked as pasture land, with some areas that appear to be contained within the 1914 banks marked as cultivated. The Santa Clara Rock & Sand Co. plant is visible on the Ventura side.

Later USGS maps of the Montalvo region show constant shifts between wet and sandy areas within the river's banks. By 1947, a south bank levee is clearly visible on the USGS maps, confirmed by aerial photographs. This levee narrowed the river channel and the south bank was pushed far north from its 1911 and 1914 boundaries. The 1967 map shows a golf course (River Ridge) in an area that appeared to be within the river's banks in historic maps from 1904, 1912, 1914 and 1929. The shifting banks of the lower river can be seen in many historical aerial photographs from Saticoy to the ocean, which show "scarring" of agricultural land left by earlier braiding of the river channel. These variable banks are confirmed by the maps of the Montalvo area described here. The 1993 aerial photographs (Figure 3-10) show a river channel substantially narrowed by levee.

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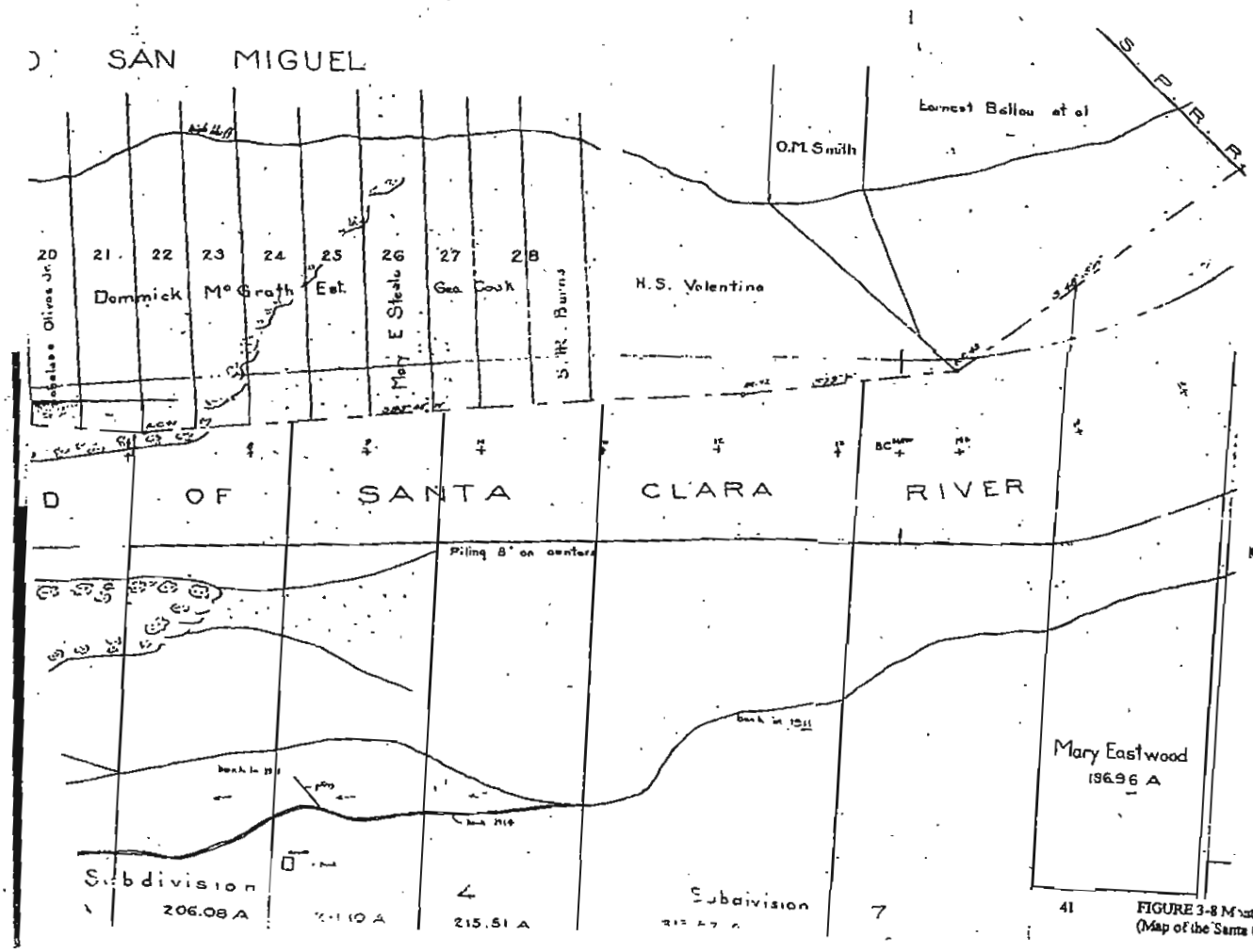

FIGURE 3-8 Montalvo 1914
(Map of the Santa Clara River 1914)

FIGURE 3-9 Montalvo 1929
(Los Angeles DWP [1929])

FIGURE 3-10 Montalvo 1993
(Ventura County Aerial Photo 1993)

Floods

Flooding before 1920 is discussed in the earlier sections of this report. The next dry phase ran from 1918/19 to 1933/34. This era saw the increased use of ground water in the Santa Clara River Valley. With the drought and ground water development came decreased water levels in underground basins (Freeman 1968).

Medium flooding in 1932 resulted in the undermining of the several bridge piers in Montalvo, the flooding of a rock and gravel plant on the Piru Creek, and other damage (U.S. War Department 1945).

While not a naturally-occurring flood, the St. Francis dam disaster wrought flood havoc on Los Angeles and Ventura Counties. The dam, begun in 1924, was built by the city of Los Angeles as a storage reservoir for the Los Angeles Aqueduct. As noted in the "Government" section of Part 3, some Ventura County residents protested the dam because of its possible effects on the Santa Clara River watershed. No one anticipated, however, how the dam was to affect the river valley. On March 12-13, 1928, parts of the St. Francis Dam gave way, sending a huge surge of water down the river valley and creating one of the worst disasters in California history. The dam gave way just before midnight on March 12 and by 4 a.m. floodwaters reached the Saticoy bridge.

The exact loss of human lives will never be known, but at least four hundred people died. Property damage was massive, with water destroying or moving homes, other buildings, orchards, bridges, farms, roads, irrigation lines and canals. In Los Angeles County, valley land was stripped bare. "The forests of river growth--willows, creek alders, and cottonwoods--were either gone or crushed and buried with debris" (Outland 1977, 154). At Blue Cut, the narrowing of the river valley created a near "whirlpool" and washed out a camp of Edison workers, killing over 80.

In the citrus and walnut groves from Camulos to Fillmore, trees were flattened or covered with silt. Aerial photographs, panoramic photographs, and maps demonstrate the extent of damage and the flood line. The force of the floodwaters diminished downstream, but still were quite destructive. Nearly 8000 acres of agricultural land was flooded within Ventura County, with over a third of land being pasture. The unusual breadth of the flood covered agricultural lands that were normally well protected from routine annual flooding, so some citrus and other tree crops were lost and fields crops damaged as well. Photographs taken from the ground and air clearly demonstrate the severe silting that covered farm land. A series of maps that indicate plans for flood control measures (drawn by the Los Angeles Department of Water and Power in 1929) also indicate where severe damage and sedimentation took place in Ventura County.

The dam disaster was a unique event that had a profound effect on the river valley and its residents. Local farmers still point to places where they believe the floodwaters reshaped the topography of farmlands adjacent to the river bottom and created new benches (Taylor 1994).

The dam disaster was not a part of the "natural history" of the river in that it was neither a natural feature nor a repeated response to a manmade intervention. It does clearly demonstrate, however, the potential side effects of manmade structures. After the flood, the Santa Clara was no more "fixed" a river as it had been in the past. Yet for the first time, government began to provide significant flood control assistance to individual landowners.

Table 3-1
Estimates of flooded agricultural land (Ventura County), St. Francis Dam disaster 1928

Crop	Acres
Citrus	1554
Walnuts	367
Apricots	287
Beets, beans, hay	1289
Alfalfa	675
Vegetables	505
Pasture Land	2915
Grapes	17
Vacant land "that could be used for vegetables"	293
Total	7902

Source: Teague 1944

The 1938 Floods

The wettest phase on record followed from 1934/35 to 1943/44. The massive floods of March 1938 resulted in great damage throughout Southern California, with Ventura County costs estimated at $2.5 million. Homes were destroyed and several hundred acres of productive agricultural lands were damaged or destroyed. The Fillmore Herald recorded that "many ranches located in the path of the flood waters suffered heavy damage from flooding of trees, especially in the lowlands near the rivers" (ACE 1972). The Saticoy bridge lost two spans, and the Newhall Ranch bridge east of Piru was destroyed (War 1945). At the mouth of the river, the Bard Beach Road bridge was damaged. Castaic Bridge was damaged and the state highway was closed east of Camulos Ranch. Camulos Ranch lost its intake concrete pipeline. The Herald reported that "Many majestic oaks and sycamores could be seen floating on top of the mad waters" (ACE

1973).

In Santa Paula, flood waters of the Santa Clara reached "automobile flood board level" at Eighth and Harvard Streets, and bridge approaches were washed out at a variety of Ventura County locations (ACE 1968). Some Santa Paula homes were moved from their foundations, the city sewage plant was destroyed, and the channel of Santa Paula Creek filled with debris. Railroad damage--the most extensive since the building of the Southern Pacific line in 1876--was most significant above Saugus, with 7 of 11 Soledad Canyon bridges moved off their foundations and the remaining buried under debris and silt or with destroyed approaches. Most highway damage was above Piru, but most agricultural damage occurred downstream of Piru. About "3,900 acres of improved farm lands were inundated and 360 acres were destroyed by bank erosion" (U.S. War Department 1945). The 1938 flood was comparable to the 1914 and 1916 floods and probably not as major as the 1862 and 1884 flooding.

The Floods of 1969

From 1944/45 to 1964/65 ran a drought period. 1969 brought the worst recorded flood on the river, with damage accelerated by the river bed degradation caused by gravel mining (VCFCD 1983). Upstream, the Sespe washed out the SPRR trestle and washed over fields, orchards, and a housing tract. At least 3000 acres of orchards were flooded, and other lands damaged from mud slides. Fillmore's sewage plant was damaged. 1969 also brought damage or destruction to a number of bridges, including the Saticoy bridge. The Army Corps of Engineers-designed flood control levee from Saticoy to the 101 Highway barely contained the river's flow toward the Oxnard Plain. In the second major set of floods for the year, the river's mouth turned northwest and flooded the Ventura Marina. While there is no single good map of the flood, aerial photographs clearly show the extent of the flooding.

Fires

Fires have regularly affected the vegetation in the Santa Clara River watershed and increased the load of silt and debris carried by the river. For example, the Matilija fire of 1932 damaged 139,000 acres of cover on Sespe and Santa Paula Creek watershed and resulted in silting that closed down the Santa Clara Water Conservation District's water spreading efforts for that water year. Although this report does not provide a comprehensive fire history for the watershed, it should be noted that fires have had an effect on the river's flow and morphology.

Government

Government control over the river became much more extensive in the years after 1920, and came in a variety of forms. Local, state and federal interests overlapped and mixed with private interests. Two major "public/private" uses of the river--bridges and landfills--are discussed in separate sections below.

Government control began with the need to resolve conflicting demands on the water resources of the Santa Clara River Valley. In 1920, the federal government supported the view that the Santa Clara River could clearly meet the demands placed upon its waters. In a U.S. Department of Agriculture soil survey report published in 1920 the Bureau of Soils announced, "The supply of water for irrigation is ample for the present needs of the area..." (USDA 1920) Yet that view was not to hold for long, as landholders in the watershed began to fear encroachment by the demands of outside users and became aware of increased local usage as well.

The 1920s and 1930s

Local Government: Irrigation and Drainage

Starting in the 1920s, local and regional bodies exerted the most government control. Increased agricultural and urban development led to new forms of government intervention, often in support of ranchers and business interests. Local irrigation districts, created under laws authorizing special district formation, took over from individuals the tiling and drainage work that private citizens demanded as improvements on agricultural land. (The significance of these districts is discussed in the "Agriculture" section of this report.) Many of the early local government interventions in the river were directed by the same agricultural interests and significant individuals that peopled the boards of local irrigation companies and municipal governments.

Water Rights

Water rights on the Santa Clara River reflect the complex evolution of water rights doctrine in California. Water rights issues are settled by the state. Appropriative rights were essentially created by early gold miners. Some users along the Santa Clara River had (and continue to hold) riparian rights, which recognize preference in water use to landowners along the stream. Other users began to apply for appropriative rights. (The conflict between these two types of rights was settled by the California Supreme Court in 1886 in *Lux vs. Haggin*, which generally favored riparian rights. Riparian rights that went unused, however, were subject to change. In 1928, the state constitution was amended to reflect the principle of reasonable use, applying to riparian rights as well.) Some users of surface water from the Santa Clara River continue to hold riparian rights.

Competition for Santa Clara River Water

The early twentieth century is remembered in California water history mainly for the drive for water resources to support the growth of the Los Angeles area. Representatives of the Santa Clara River Valley, which is shared by both Ventura and Los Angeles counties, were players in this political forum. One early proposal was to export Piru Creek water to the Antelope Valley, for example; this plan never came to fruition.

By the mid 1920s, however, the state of California had received applications for use of the Santa Clara River drainage basin from five organizations, some from outside the Valley itself. For example, the Ventura Power Corporation wished to appropriate surplus water from Sespe and Piru Creeks, as did the Sespe Light and Power Company. Applications were also filed on the Sespe Creek by the proposed Ojai Irrigation District and the Moorpark-Conejo Irrigation District, and on San Francisquito Creek by the City of Los Angeles (Freeman 1968).

Private Intervention

Alarmed by the potential for these increased demands and possible exportation of Santa Clara River water resources, the Santa Clara River Protective Association (SCRPA) was formed in January 1925. C.C. Teague, one of the most significant economic and political figures in Ventura County history, was elected chairman.

The Protective Association was a private organization supported by agricultural interests and was not supported by the three municipal governments in its purview. It received additional support from local oil and refining companies and gravel/aggregate manufacturers. The association funded itself with a 25-cent-per-acre contribution by owners of over 49,000 irrigated developed agricultural land in the region. Members were appointed from Piru, Fillmore, Bardsdale, Saticoy, Oxnard, Ventura and Santa Paula, and the committee was "empowered to act for water-rights owners at hearings of the Ventura Power Corporation before the State Division of Water Rights" in February of that year (Freeman 1968, 85). In essence, the water-rights owners who demanded representation were the same individuals as those who formed SCRPA. Nonetheless, the SCRPA had no legal standing, so protests were filed by organizations that tied into the interlocking networks of agricultural interests in the valley: the Santa Clara Water and Irrigating Company, Alta Mutual and Community Mutual Water Companies, and Farmers' Irrigation Company.

Water Supply Investigation

The SCRPA also commissioned C.E. Grunsky to investigate the water resources of the valley. By August 1925, Grunsky's report stated that "there will be no surplus water available for diversion away from the main valley and Oxnard region" except in times of heavy rain, and that even those surpluses could not be used "without detriment to the interests of the Santa Clara River region." (Freeman 1968, 88)

Grunsky also reported that 84,000 acres would require irrigation for cultivation, with 40,000 of these acres in the Oxnard Plain. Local irrigating and canal companies reported irrigation of 35,000 acres with use of 2.46 acre feet of water per acre annually (over 28 billion gallons per year). While the drainage basin's average production was nearly twice the demand, much of the production was flood waste. During dry seasons, however, water production would not meet the demand for irrigation.

The association also requested the California Department of Public Works undertake a water resources survey, and the State Division of Water Rights agreed to postpone decisions on the existing water rights applications until the survey was completed (Freeman 1968). This survey became the Ventura County Investigation, which was published by the Division of Water Resources in 1933 and became the guiding force behind local and state policy in the Santa Clara River Valley for many years.

Releasing Stored Waters

Meanwhile, the City of Los Angeles applied to more than double the water requested in its application for surplus waters of San Francisquito Creek. The SCRPA and the Newhall Land and Farming Company worked to have the City of Los Angeles agree to release water from the St. Francis Dam (completed in 1925 before hearings on the protests were held).

In a famous test intended to show that 50 second-feet of water from the reservoir would flow down the San Francisquito Creek to the Santa Clara River, Los Angeles Power and Water Division's chief engineer William Mulholland organized a release from the St. Francis Dam. All of the water percolated beneath the stream bed and none of the 775 acre-feet released in the test ever reached the Santa Clara River channel as surface flow. The results of this test, which were far from what Mulholland predicted, led to further delay of water-rights litigation (Outland 1977).

However, the issue of water rights on San Francisquito Creek was obviated in 1928 with the collapse of the St. Francis Dam. Although the result of this dam failure is not considered a natural flood event, it will be considered with other floods in the sections following.

Public Intervention

The 1928 St. Francis Dam disaster, besides significantly altering the physical contours of the river valley, prompted local government agencies to intervene in the river. The City of Los Angeles worked quickly with representatives and landowners of Ventura County to settle claims. Maps from the City of Los Angeles Department of Water and Power, showing the extent of flooding, also indicate plans for the construction of protective levees and groins. Many of these structures throughout Ventura County, such as structures at Fillmore and downstream of the Montalvo (Highway 101) bridge, were apparently built by the City of Los Angeles. They are among the earliest public works along the Santa Clara River, besides bridge protection, built by government

to protect landowners along the river and control flood flows. The Ventura County Flood Control District has repaired some of these levees and groins in the years since 1960.

Percolation Basins

A final interest of the voluntary organization known as the Santa Clara River Protective Association was the spreading of water to replenish groundwater supplies. As no state law enabled the creation of a district to accomplish such a task, the committee instructed an attorney to draft a bill. Assembly Bill No. 233 was passed by the state legislature and became the Water Conservation Act of 1927. Under authority of this law, the Santa Clara Water Conservation District was formed in 1927. The SCWCD included 110,000 acres in the Ventura County's section of the river valley and the Oxnard Plain, excluding incorporated Oxnard, Santa Paula and Fillmore. Directors included members of local agricultural families such as Donlon, Petit and Teague. Later directors included members of these families and other leading Ventura County ranchers (Freeman 1968, UWCD clippings files).

The district's first operations included water spreading, which had been practiced in other regions of Southern California since the 1890s. The SCWCD began its spreading at the Saticoy Spreading Grounds because of lowered well levels in the Oxnard Plain. In 1928-29, the district began diverting Santa Clara River water from near Saticoy, although the St. Francis dam failure delayed the start of operations until 1929. Presumably, the dam and reservoir indicated in the flood damage maps located at the Ventura County Historical Society represent the SCWCD's earthen dam and intake operations on the river, which used the Santa Clara Water and Irrigating Company canal to carry river water to the spreading grounds.

In 1930 the SCWCD began diversion of water from Piru Creek to the Piru Spreading Grounds, and in 1931, the district began diverting water from Santa Paula Creek to the Santa Paula Spreading Grounds. The district also carried out other operations in the Santa Clara River bed itself. "In a number of locations the river channel was scarified and small contour ditches plowed to induce percolation" after rains. (Freeman 1968, 99) There are photographs of this scarifying of the river channel with heavy machinery near the Saticoy bridge in the early 1930s.

Concerns About Appropriations

In 1930, reacting to an the announcement that Los Angeles planned to build a dam in Bouquet Canyon, the district raised questions about the use of Santa Clara River watershed water resources and the safety of another upstream dam. The Los Angeles Department of Water and Power assured SCWCD's directors that the construction of the dam would be safe and that the dam would not claim any rights to the watershed's water but would be used for storing waters of the Owens River Aqueduct. The two parties negotiated a water release contract, which continues to exist between the Department of Water and Power and SCWCD's successor, United Water Conservation District.

Dam Proposals

During the 1930s, the SCWCD investigated dam sites along Piru and Sespe Creeks and expressed concern about potential sea water intrusion into wells on the Oxnard Plain. SCWCD expressed interest in dam sites at French Flats and Los Alamos (now Pyramid Dam) when the state highway division planned to extend Highway 99 across both sites. From the mid 1930s to mid 1940s, a combination of wet years and major water releases (beyond those required by agreement) from the Owens River Aqueduct into the Santa Clara River basin quieted public demand for water conservation (Freeman 1968).

State Involvement

In 1933 the California Division of Water Resources published Bulletin 46, the Ventura County Investigation. Besides providing basic geological information on the river basin, Bulletin 46 described the projected water demands for the region and suggested a variety of development plans. Rejecting reservoir sites as excessively costly, DWR suggested additional spreading grounds and the creation of underground capacity in the Santa Paula Basin by extracting water. The Ventura County investigation suggested the removal of willows from the riverbed to conserve water. Water levels in the river valley, suggested the report, were so high that they supported 3700 acres of willow even after several years of drought. Reported the Division of Water Resources: "The willows are wasting about 40% as much water as is being beneficially consumed in the valley" (Division of Water Resources 1933).

Other state agencies were involved in river-related issues during these years as well. The California State Department of Fish and Game issued a fisheries report for the river in 1938, and in the early 1940s the State Fish Hatchery at Fillmore was opened. The fishery initially used surface water but by 1948 had to resort to the use of well water (Wolf, in Freeman 1968, 24-25).

Government Involvement Increases

During these years, other government agencies began to regulate and control the river. On the federal level, the War Department (and then the Army Corps of Engineers) developed plans for a levee between South Mountain and Highway 101 by the end of World War II. On the local level, flood protection work and "channel changes" apparently were carried out from the turn of the century to the 1930s by the county. The Ventura Country Flood Control District was established in 1944 and the Ventura County Board of Supervisors authorized the development of a comprehensive water control and conservation plan. The Zone 3 report, published in 1946, suggested that water for the Calleguas Creek basin be imported from the Sespe Creek. The Zone 2 report, which covered the Santa Clara River area, said that Zone 2 had no need of surface storage because of sufficient groundwater supplies, but that a Sespe Creek dam, specifically at Topa Topa, was crucial for the Zone 3 and that Zone 2 may need to supply future needs of Zone

1 in the Ojai and Upper Ojai Valleys. The Zone 2 report further suggested that control of the Sespe Creek might result in improvements in water quality particularly helpful for citrus crops.

The Santa Clara Water Conservation District vigorously fought the recommendations of the VCFCD reports. The SCWCD commissioned Harold Conkling to write on "The Water Supply of the Santa Clara Water Conservation District." This report emphasized the overdraft of groundwater supplies and the increase in local demand for water. Conkling recommended construction of storage reservoirs on the Santa Clara's tributaries. In 1947 SCWCD filed applications to appropriate waters of the Santa Paula, Sespe and Piru Creeks and Santa Clara River; there were applications for municipal use, domestic use, irrigation, and industrial uses. In 1949, the Ventura County Flood Control District Zone 2 filed a similar set of applications for water appropriation, but withdrew the applications in 1955. The Calleguas Municipal Water District (VCFCD Zone 3) also filed on Sespe Creek in 1949 and in 1952 requested the federal Bureau of Reclamation to begin investigations for dams.

In 1949, SCWCD's Vern Freeman suggested to that agency's board that Oxnard city water system be changed to a variable rate system to save water, that ranches on the Oxnard Plain use concrete pipe rather than open ditches to transport well water to fields and that duck clubs along the Santa Clara River used significant and unjustifiable amounts of water. Despite considerable political controversies, some changes were made: Oxnard installed water meters and duck clubs reduced their use of water (Freeman 1968).

New Dam and River Projects

The Santa Clara Water Conservation District was succeeded by the 1950 formation of a new special district, United Water Conservation District, under the California Water Conservation Act of 1931. UWCD continued investigations of dam sites and water conservation measures and unlike SCWCD was authorized to secure funds for the construction of major projects. After considering sites on Sespe and Piru Creeks, UWCD decided to build dams at the Topa Topa site on Sespe Creek and the Santa Felicia Dam on Piru Creek. However, a bond issue to finance both dams failed (UWCD clippings files).

A more limited bond election approved the funds for a single dam, and UWCD built the Santa Felicia Dam on Piru Creek. The dam was completed in 1955. At the same time, UWCD continued to develop the Lower River Project, built from 1954 to 1956. The Lower River system included an improved diversion at Saticoy, new spreading grounds at El Rio, a Pleasant Valley diversion line and reservoir and a pipeline to Oxnard and Port Hueneme. UWCD continued operations of its spreading grounds and Saticoy diversion. Increasingly, however, the bulldozed earth diversion was washed out by heavy rains, thus allowing water that UWCD intended to store in groundwater basins to flow to the ocean instead. Repair work restored the earthen dam but often at a high annual cost.

Flood Control Projects

The Army Corps of Engineers issued final reports and plans for the levee from South Mountain to the freeway in 1958. In 1961, construction of the rip-rap (stone revetted) levee was completed with federal funds, and an earthen berm was extended downstream to the present site of the Victoria Avenue bridge between Ventura and Oxnard. (After the construction of the Victoria Avenue bridge in 1976, that berm was developed into a levee.) That the levee blocks the river from places where water historically flowed can be seen from aerial photographs, which show evidence of past river braiding in the region south of the structure. The levee is maintained by the Ventura County Flood Control District. At about the same time as the major Santa Clara River levee was constructed, the Saticoy Auxiliary Dike, protecting Cabrillo Village, was planned and built. VCFCD also maintains dikes along the lower portion of Santa Paula Creek (VCFCD 1983).

Pilot Channeling

Ventura County Flood Control District also restructured the river in a variety of ways. Pilot channeling, or the excavation of stream channels within the river bed, was a regular practice in the river. For example, the Ventura County Department of Public Works report to the Board of Supervisors published in June 1959 recorded that 1950 linear feet of river bed was affected by pilot channels, which moved 42,300 cubic yards of riverbed materials (DPW 1959a). The following quarterly report, from July to September 1959, indicates that upstream from the UWCD headworks, a channel one mile in length with "a cross-section about 300 feet in bottom width" was completed. This channel was intended for flood control as well as assisting diversion operations at Saticoy (VCDPW 1959b). In addition, the same report recorded that VCFCD was at work on a three-mile pilot channel upstream of Willard Bridge in Santa Paula. The annual report for 1959 indicated that 24,215 linear feet of channeling was carried out in the Santa Clara River, with removal of 529,400 cubic yards of materials. Additional pilot channels were dug in Sespe and Santa Paula Creeks. The 1960 report indicated that pilot channels were created or redug in a variety of places, including in the Santa Clara River from Willard Bridge to Balcom Canyon Road, approximately 13,000 linear feet (VCDPW 1960). Annual reports clearly mention pilot channel work throughout the early- to mid-1960s. Aggregate extraction companies were apparently given permits to maintain pilot channels as well. Other specific projects were carried out in the late 1960s and 1970s.

Drainage

Ventura County Flood Control District controls a number of significant drainage outlets into the river. It maintains all drainage districts in the county, whether urban or agricultural, with flows over 500 cfs. The VCFCD also placed concrete linings in a number of barrancas and drainage areas over time.

Additional Flood Control Projects

The Ventura County Surveyor's Office houses plans of work done by VCFCD. Projects include repairs to rock groins at the river banks (such as those near Briggs School, the Santa Paula Airport, Sycamore Rd., and behind the Ventura municipal golf course on Olivas Park Drive, dated 1973). Work to repair and augment existing levees includes construction of rock groins at the south bank of the river at Bardsdale and upstream of the confluence with Sespe Creek (dated April 1973). Plans for similar work were drawn in 1969 (after major flooding) although records of construction do not accompany the plans.

Permits and Aggregate Extraction

VCFCD is one of several county agencies issuing permits for work in the Santa Clara River. The earliest permits were issued in the early 1960s and included permits for pipeline crossings, construction of haul roads, sedimentation ponds and storm drains, and removal of borrow from the riverbed. The majority of permits for work in the river allow removal of riverbed material and alluvium. County permitting of the sand and gravel mining industry accelerated in the early 1970s, and state and county intervention in aggregate extraction is a prime example of government involvement in the Santa Clara River. Gravel mining in the Santa Clara River changed forever with the studies and conditional use permit reports of the 1970s and 1980s. In 1975, California passed the Surface Mining and Reclamation Act, intended to protect access to significant mineral resources and require reclamation of lands used in aggregate extraction. State law required that operations extracting over 1000 cubic yards must reclaim areas through grading and planting. In 1980 Ventura County began its Mineral Resource Management Program, with the State Division of Mines and Geology conducting a resource survey. Ventura County created a "red line" to limit mining in the river. At first, the line followed from the top of the footings at the Santa Paula Bridge to the top of footings at the Montalvo Bridge; more sophisticated studies and projections have resulted in the modification of that level (Collart 1994; VCFCD 1993).

Local Conflict: Sespe Creek Appropriations

Conflict with the Calleguas Municipal Water District over use of Santa Clara River watershed resources for the eastern section of the county continued through the 1950s and 1960s. In 1956 UWCD rejected Calleguas's proposal for a joint project, and later that year UWCD filed protests to Calleguas's application to appropriate Sespe Creek waters. UWCD eventually filed protest to the State Water Rights Board decision favoring Calleguas, Calleguas moved to import Metropolitan Water District water in 1960, and in 1963 the State Water Rights Board denied Calleguas's application to appropriate Sespe Creek waters. Meanwhile, some municipalities moved to solve the demands of increased urban water use by using resources outside the Santa Clara River watershed. As Calleguas Municipal Water District had done in the early 1960s, Oxnard began importing Metropolitan Water District water in 1965.

In 1957, UWCD announced plans to develop additional dam sites on the Sespe and Piru, and continued to promote dam proposals with the approval of its application by the State Water Rights Board. The Bureau of Reclamation produced a reconnaissance study of the Sespe Creek Project in 1964 and a feasibility report in 1966, but public controversy about the project and particularly about potential damage to California condor habitat mounted. In 1966, plans for UWCD dam development on the Sespe were halted by voter rejection of the proposal.

Environmental Regulation

Environmental concerns became an important facet of government involvement in watershed policy during the 1970s. A proposed Quality Management Pipeline was protested by the State Department of Fish & Game and local environmentalists. Plans for the QMP drawn up by UWCD in the early 1970s were dropped by the end of the decade. Concern over seawater intrusion in the Oxnard Plain in 1969 led the California State Water Resources Control Board to threaten a lawsuit if local agencies could not agree on a plan for groundwater protection. By 1980, UWCD drew up plans to meet the seawater intrusion problem through the creation of the Pumping-Trough-Pipeline and the new, permanent Freeman Diversion. The Bureau of Reclamation and the State of California financed the construction of the Freeman Diversion with multi-million dollar loans. Again, the Department of Fish & Game played a significant role in demanding a fisheries study on the lower Santa Clara River (UWCD clippings files).

In 1986, Santa Clara River watershed politics again appeared on the national level with proposed designation of parts of the Sespe Creek as a wild and scenic river. The U.S. Forest Service had suggested a plan in its draft land management plan for the Los Padres National Forest. The bill to designate 31.5 miles of the Sespe as "wild and scenic" was approved by Congress and signed in 1992.

Permanent Structures on the Lower River

The construction of the Freeman Diversion was necessitated since the original earthen structure washed out almost every year. As river bed lowering occurred, especially after the 1950s and the rise of intensive sand and gravel extraction in the riverbed, the UWCD diversion had to be moved upstream about three-quarters of a mile and also was frequently damaged by storm flows. It was rebuilt, sometimes yearly, and often located further and further upstream because of riverbed degradation. Downstream erosion and increased flood water velocities caused by a sharper river gradient also affected UWCD's diversion (VCFCD, 1983).

After years of costly rebuilding, UWCD secured funding from the Bureau of Reclamation, the state of California, and local sources to help construct a permanent diversion, with groundbreaking taking place in 1988 and completion of the roller-compacted concrete dam and related structures in 1991 (UWCD clippings files).

Planning

Local and state planning efforts as well have had some impact on the river. Versions of the Ventura County general plan and city plans like that of Oxnard have projected a variety of projects along the river, from lakes to recreational trails. In its 1969 general plan, for example, Oxnard proposed the creation of a Santa Clara Bay, an inland waterway that would connect the Channel Islands Marina with the Ventura Harbor. While few of these recreational projects have come to fruition, local zoning has affected the agricultural, residential and industrial uses of the river area. For example, land reserved for agriculture under Williamson Act (Land Conservation Act) contracts has kept parts of the region surrounding the river as farming regions.

Additionally, local ordinances continued to monitor land use in the Santa Clara River Valley and the Oxnard Plain. While the creation of interurban greenbelts, for example, may not seem to directly affect the river, patterns of land use and the control of those patterns by government have historically had a very significant effect on the river.

Other structures in the watershed include Pyramid Lake and Dam and Castaic Lake and Dam, which store imported water from the State Water Project.

Bridges

The need to bridge the Santa Clara was a major concern as local population increased in the late nineteenth and twentieth centuries. Local government began intervention in the river with the planning and building of bridges. As noted before, hazardous crossings in the rainy winter season and the danger of quicksand in many regions led to a demand for the bridging of the river. Squabbling between local interests over the location of the first bridge led to delays and failed bond elections until the Board of Supervisors authorized construction of a bridge at Montalvo (near a popular early crossing) in 1897. A highway bridge was constructed. The Southern Pacific Railroad bridge at the location, built in 1898, connected Montalvo to the Oxnard sugar refinery; its wooden structure has never been damaged by flooding. Other bridges followed, some built by the state, others by the county and yet others by private users. Still, travelers have persisted in crossing the river itself in dryer regions and seasons, and river crossings like the Torrey Road crossing near Piru are still used and maintained despite frequent washouts in flood conditions. Similar crossings in Santa Paula were still used before 1920, despite dangerous quicksands, although there was also reported to be a pontoon bridge in use at that city. The vastly increased amount of highway mileage after population grew in the region in the mid-twentieth century created a demand for additional safe river crossings. A Bard Beach or Beach Road bridge existed in the 1930s, but faced frequent washouts. The present Harbor Boulevard bridge, slightly upstream of the old beach bridge, was constructed in 1955. Before construction of the Willard Bridge, many Santa Paula area residents believed that such a structure was impossible to build (California DPW 1953). The Willard bridge, first constructed in 1919 by public subscription was washed away in 1928 by the St. Francis dam failure, then rebuilt. In 1939 the bridge was

damaged again and in 1953 it was rebuilt by the state. (It is clear that there was a levee at the new bridge site in 1953, and that it was built of large boulders and filled with earth.) The Willard bridge was again damaged by flood in 1969, when two spans were lost.

As time passed, larger government entities became involved in bridging the Santa Clara River. Caltrans was involved in the construction and repair of five state highway bridges on the Santa Clara River, often in the aftermath of flooding. The Highway 101 bridge was built by the state, which constructed the first bridge in 1938 and a second in 1966 when the road was widened and northbound and southbound traffic were located on separate bridges. The Saticoy bridge (State Highway 118) existed before 1938 but was destroyed in the flood of that year and was rebuilt in 1939 by the state. In the 1969 floods, six spans of the bridge failed, and in 1978, two pilings were exposed though no spans failed due to earlier repair work (VCFCD 1983). That bridge was recently replaced by a new bridge, which opened to traffic in 1994. On Highway 23 at Bardsdale, Caltrans is construction a new bridge adjacent to a truss bridge built in 1928, which is due to be removed. On Interstate 5, two bridges were built in 1964. Notes on bridges may also be found in the Physical Setting portion of Section 3 of this report.

Other local bridges have followed the growth of subdivision and residential development. The Victoria Avenue bridge between Ventura and Oxnard was completed in 1975, accompanied by the levee work noted above. Other bridges are visible on USGS maps. See Table 3-2 on the following page.

Table 3-2
Bridges indicated on USGS quadrangle maps

Map	Date	Bridges/other crossings
Oxnard	1967	Harbor Boulevard bridge
		SPRR bridge
		Highway 101 bridges (north and south)
Saticoy	1967	Highway 118 bridge (Los Angeles Ave.)
Santa Paula	1967	Santa Paula bridge (Willard/12th St.)
Fillmore	1988	Bardsdale/Chambersburg Rd.
Piru	1988	no bridges (two crossings, including Torrey Rd.)
Val Verde	1988	bridge two miles west of county line
		crossing from 126 to Potrero Canyon
		crossing from 126 to Tapo Canyon
Newhall	1988	Bouquet Junction bridge
		bridge from 126 (Saugus-Ventura Rd.)
		I-5 bridge
		I-5 frontage road bridge
Mint Canyon	1988	Sierra Highway bridge at Solemint
		Antelope Valley Freeway bridge near Mint Canyon
		Sand Canyon Road
		crossing near Honby
		crossing near Lang
Agua Dulce	1988	bridge at Agua Dulce
		several unbridged crossings
Acton	1974	several dry crossings

Source: USGS quadrangle series indicated above

Landfills

A number of landfills exist nearby or along the river. The Chiquita Canyon landfill in Los Angeles County, in a canyon, handles waste from Valencia, Newhall and eastern Ventura County. Old dumps exist at Torrey Rd. in Piru, on Highway 23 near Fillmore (south of the river). At the Elkins Ranch, adjacent to the golf course, a dump receives some trash, including oil and chemical waste. The VRSD has a "live" dump up in the hills at Tolland Rd. below Fillmore, on the shoulder of San Cayetano Mountain. Santa Paula had a burn dump south of the river, west of 12th St. and South Mountain, in operation until the early 1970s. The river itself is the dumping site at an informal, illegal dump off of South Mountain Rd., which the county has cleared a

number of times, most recently for a cost of $300,000. A large amount of trash, including cars, boats and trailers have been found in the river's bed.

The end of Saticoy Avenue housed the old Saticoy burn dump, adjacent to the river, slightly upstream of the present Cabrillo Village levee. Further down the river are the "big three" dumps; there had been eight smaller dumps. At the Wagon Wheel area, a series of smaller dumps dating from the 1940s and forward are now closed. The Southern California Coastal landfill (from Ventura Road to the Victoria/River Ridge Golf Course) now covers the site of five older burns dumps. Across Victoria Road, an older burn dump, the Borchard dump, has been removed by the developers of the California Cove housing development. From 1982-89, the Coastal Landfill was in operation and created the hill near Victoria Ave. The Ventura Regional Sanitation District maintains the Bailard Landfill, with engineered levees built by the Ventura Regional Sanitation District and maintained by the Ventura County Flood Control District.

Between the Bailard Landfill and the Ventura Marina, "casual" dumping of trash on both sides of the river occurs. Near the river mouth, at the site of the marine, was the old Sears-Walker by the sea burn dump, where trash was often bulldozed into the ocean. Behind the levee built to protect the Olivas Park golf course, the city of Ventura dumped street or green waste, but they are working to clean up this project (Gilday 1994).

AGRICULTURE

Santa Clara River Valley agriculture has changed significantly in the years since 1920. Remnants of the cattle ranching days remain, with some cattle operations continuing near Piru and in Los Angeles County, with occasional cattle drives crossing the river. The demand for dairy products increased with the upswing in Southern California's urban population, and related development of alfalfa fields for cattle field took place early in the century. Pasture lands adjacent to the river are marked on a number of maps from the 1920s and oral histories recount grazing of cattle and horses in the river bottom.

Intensification

Yet the story of agriculture in the Santa Clara River valley and Oxnard Plain has strayed far from the days of cattle ranching. Early in the century, a variety of crops, including sugar beets, beans and truck crops, spread over the region. Today, agriculture continues to be vital, especially to the Ventura County economy, and citrus and irrigated agriculture has overtaken earlier crops that required less water. In the region of the lower river owners have shifted to smaller farms. As Ventura County and particularly coastal population increased throughout the twentieth centuries and farm areas have decreased, farmers in the Oxnard Plain have sought higher profit and increased yields. Many of these intensive crops require irrigation, often from groundwater

supplies. High revenues also served to increase land values, thus further favoring small farms. For example, by the late 1940s many farms were under 100 acres. The switch to intensive crops has been particularly linked to the growth of urban Oxnard over former agricultural areas (Gregor 1953).

The Rising Significance of Citrus

The most significant and famous shift in Santa Clara River Valley agriculture occurred as ranchers realized the higher profits of valuable citrus crops, which came to overshadow earlier types of planting. Yet other crop patterns shifted as well. Increased urban demand for dairy products in the 1920s and beyond led to an increased planting of alfalfa for cattle feed. Before the 1920s, vegetables like tomatoes, peppers, lettuce and green limas (truck crops) were insignificant, but improved transportation and population shifts led to higher production of these row crops and seeds (Gregor 1953).

Water Demands

As discussed in Section II, increased agricultural demands tapped first into the surface water supply. In 1912, surface flows supplied irrigation to almost 17,000 acres. By 1965, that number would drop to 2,500 acres, not because of reduced demand but because of reduction of surface flow (Freeman 1968). Groundwater supplies became increasingly significant. The first artesian wells on the Oxnard Plain were drilled in the 1870s. Not until after the establishment of the town of Oxnard and the building of the sugar factory in the late 1890s, however, did water demands of the Oxnard Plain reached levels high enough that water pressure in the Oxnard Basin was reduced and pumps had to be installed. Water companies established at the start of the twentieth century continued to deliver groundwater deliveries. They were joined by new corporations like the Citrus Mutual Water Company (1929), serving 305 acres of irrigated agricultural land, and the Hardscrabble Mutual Water Company (1920). Individual farmers and ranchers also dug their own wells. Various water companies, local governments, and ranches had steam or electric pumping plants to deliver water for irrigation and other uses. It was this increased dependence on not only surface flows of the Santa Clara River but the rich but potentially threatened groundwater supplies in the Santa Clara River watershed that led individual ranchers to join together in the 1920s, when they saw the water supply threatened by users outside the watershed and increased use within the watershed.

Drainage

As discussed in Section II, before 1920 lowlands in the Oxnard Plain had a high water table, and alkali accumulation prevented successful production of certain crops. However, significant tiling provided these areas with improved drainage. Starting at the turn of the century, fields used for sugar beets were "tiled" and local drainage districts were formed to assist with the process. Tiling now underlies a vast portion of the Oxnard Plain and part of the river valley. Many ditches

drain, eventually, to the Pacific Ocean or McGrath Lake, but a number of agricultural drains from this tiling contribute their runoff to the Santa Clara River itself. The character of such run-off water differs from the river's water.

With the growing desire for tree crops, farmers became interested in increasing their irrigated acreage. Lemons, in particular, are sensitive to a high water table and alkaline conditions, but have been planted in reclaimed areas (Gregor 1953). From 29,000 acres in 1917, orchard land in Ventura County increased to 66,000 acres in 1950. Overall, irrigated acreage in Ventura County increased from 31,700 acres in 1919 to 107,689 in 1949, and by the late 1940s, only 4,900 of the original 74,800 dry-farmed acres in the Oxnard area continued to be farmed without irrigation (Cuevas 1973).

Crop Variety: The 1920s

A detailed map of the Santa Clara River from the Southern Pacific Railroad Bridge below Highway 101, dated from the late 1920s, indicates the variety of crops in the lower river reaches. Even very close to the high water line at the beach (in the area that is now McGrath State Beach) alfalfa was planted. Pasture land lined many sections of the river and extended to the brush or sandy river bottom (LADPW 1929). Recollections by area farmers include mention of cattle and horse grazing in this region of the river bottom throughout the twentieth century. Throughout the 1920s, hay and alfalfa were grown near the river, with beans and barley grown on the river banks. Brushy areas were scattered throughout cultivated lands. A lemon grove was located on the north bank above the railroad and highway bridges, while potato and alfalfa fields were located above the river bank to the south (LADPW 1929).

Detailed topographic maps of sections of Rancho San Francisco from 1922 indicate that citrus crops were protected by other less valuable crops. This land owned by Newhall Land and Farming (NLF) featured oranges, lemons, alfalfa and peaches. In addition, a pump house existed in the river bed. Other NLF property, such at that at the county line, were marked "tillable" but were at that time unplanted. On the rest of the maps, which indicate the Del Valle Ranch (Camulos), walnuts and olives were planted closest to the river, along with a protective grove of gum trees, and alfalfa fields and apricot orchards also provided a buffer between citrus groves and river land. Some unplanted lands were clearly marked "overflow bottom land," indicating consistent flooding.

Crop Variety: The 1930s

In 1933, when the Division of Water Resources issued the Ventura County Investigation, the principal crops of the coastal plain were beans, beets, alfalfa and truck. Bulletin 46 projected that 5400 acres of additional land in the Oxnard Plain would come under irrigation in future years. The report notes that citrus trees used more water than beans, beets and truck, and that water use would probably increase with increased plantings of citrus. Within the Santa Clara River Valley,

DWR estimated 23,500 acres irrigated or using domestic water in 1933, while 10,000 to 13,000 additional acres were feasible for irrigation. However, the best irrigable land had already been used, and DWR predicted that progress in irrigating other lands "should be slow and should depend to a large extent on what lies in the future for citriculture" (DWR 1933). Aerial photographs reveal progressively more significant plantings of citrus along the river valley.

The crop map accompanying Bulletin 46 demonstrate a variety of land uses along the river. To Saticoy, most of land surrounding the river bottom was unirrigated, with sections of alfalfa near the south side of the river outlet, and with walnuts and beans, beets and hay up the river to Saticoy. Near Saticoy Road were the first citrus groves adjacent to the river, along with truck gardens and continued plantings of walnuts and beans, beets and hay. Between Saticoy and Santa Paula on the south side of the river were several citrus or avocado orchards at the base of South Mountain, with walnuts, alfalfa and truck gardens on the north side. Some citrus was planted to the south of Telegraph Rd., but the closer to the river, the more likely plantings were in walnuts, truck crops or alfalfa, with unirrigated valley lands interspersed throughout the area. The same pattern continued from Santa Paula to Fillmore, with major citrus plantings on the south side of the river at Bardsdale, large stretches of unirrigated valley land, and scattered plantings of truck, alfalfa and walnuts. Upstream from Fillmore lay unirrigated lands and citrus plantings on the north bank, scattered with alfalfa. On the south bank citrus predominated with plantings close to the river banks. At Buckhorn and Camulos, citrus and avocado dominated, with the lands next to the river varying between citrus plantings, alfalfa and unirrigated land. On the south river bank near Tapo Canyon lay additional citrus/avocado plantings, with unirrigated valley farm lands indicated to the county line and beans, sugar beets and hay plantings around Telegraph Rd. (Highway 126) at the north side of the river at the county line. Within Los Angeles County, unirrigated farm lands predominated through Castaic Junction and further upstream, with additional riverside plantings of alfalfa and beans/beets/hay near Saugus and Honby. With the exception of occasional orchards and alfalfa patches, unirrigated agricultural land predominated upstream to the end of the map at the community of Lang (DWR 1933).

Continued Agricultural Shifts

The crops of major landholders like Newhall Land and Farming shifted in type and quality after 1920, as well. Tenant farmers worked much of the Newhall property until the 1920s and 30s when the company retook control and planted more profitable citrus crops. After 1945, the ranch cut back its sheep and hog production, in part because of the increased value of irrigated crops. While in 1913, the Newhall Ranch had 150 acres of oranges planted, by the 1930s citrus filled nearly 600 acres. Between 1948 and 1955, walnut acreage on land not suitable for citrus due to a colder climate (Rolle 1991).

DWR Bulletin 46-A, which provided statistical information to support the Ventura County Investigation, noted the acreage of different crops in the various regions of Ventura County in 1932. In the Piru Basin, of 3658 acres planted, over 2600 acres were in citrus. A similar pattern

existed in the Fillmore Basin, where over two-thirds of cultivated land, 6100 of 8863 acres, was planted to citrus. In Santa Paula, out of 10,756 acres, citrus also predominated (4700 acres) but walnuts ranked a close second (4000 acres). Oxnard South Basin, the largest agricultural region, had 25,750 acres planted with only 1500 in citrus, and over 16,000 acres of beans and beets, with alfalfa and truck crops using an additional 5000 acres (DWR 1933).

Changes in local agriculture have included a shift toward smaller farms, especially on the lower river. As population increased in the late twentieth century and farm area has decreased in certain regions, farmers have looked toward higher-priced crops. Many of these intensive crops need irrigation, often using ground water supplies. High revenues also served to increase land values, further favoring small farms. By 1949, over 62% of the grain, row, or tree crop farms in the Ventura Lowland region were under 100 acres. The switch to intensive crops has been particularly linked to the growth of urban Oxnard (Gregor 1953).

Subsequent DWR investigations have highlighted the continued shifts in agriculture. The Oxnard Plain has lost some fields used for truck crops to both urban uses and field crops. In general, farming has become more intensive, with alternation between field and truck crops in different seasons. While truck crop acreage declined 12% from 1969 to 1980, field crop acreage increased 30%. In the Santa Clara River Valley itself, acres devoted to truck, field and alfalfa declined from 1969 to 1980, but citrus, deciduous, grain, and pasture lands increased (DWR 1981). See Tables 3-3 and 3-4 below.

Table 3-3
1980 Agricultural Land Use

	Oxnard Plain Subunit	Santa Paula Subunit	Sespe Subunit	Piru Subunit	Upper Santa Clara River Subunit
Irrigated:					
Alfalfa	0	10	0	120	180
Pasture	80	50	260	370	380
Citrus/ subtropical	11,230	10,340	11,740	5,370	20
Truck	28,790	820	380	40	1,680
Field	2,180	20	0	0	430
Deciduous fruits/nuts	20	60	20	30	690
Small grains	0	350	0	0	690
Fallow	180	60	0	30	80
Nonirrigated agriculture	2,760	330	250	1,510	110

Source: DWR 1981

Table 3-4
Shift Between 1969 and 1980 Agricultural Land Uses,
Ventura County and Los Angeles County Study Area

Irrigated Agriculture

Ventura County	1969	1980	% change
Alfalfa	420	470	+ 12
Pasture	1,770	2,210	+ 25
Citrus/Subtropical	54,170	62,850	+ 16
Truck crops	39,570	34,500	- 13
Field crops	2,030	2,640	+ 30
Deciduous fruit and nuts	2,650	1,890	- 29
Small grains	530	1,870	+253
Total	101,140	106,480	+ 5

Los Angeles County (study area)	1969	1980	% change
Alfalfa	860	180	- 79
Pasture	460	460	0
Truck crops	1,470	1,680	+ 14
Field crops	180	440	+144
Deciduous fruits and nuts	460	470	+ 2
Others	150	0	n/a
Total	3,580	3,230	- 10

Source: DWR 1981

Agricultural Alterations of the River

Just as agricultural interventions in the riverbed were noted in the commercial period (1870-1920), so they continued into the modern era. A survey of aerial photographs and USGS topographical maps indicates the presence of large numbers of levees and other structures built to prevent and repair flood damage. For example, maps from the 1920s indicate the presence of a row of pilings or "breakwater" below the Montalvo bridge. This structure, sometimes known as the McGrath piling, ran down the middle of the riverbed, and is also visible in aerial photographs. Along the banks in the same area are a series of small jetties or groins for flood control. Some of these structures existed before the St. Francis Dam failure, which others were created after that event. Nearly every map or set of photographs of the river in the modern era shows evidence of some form of bank control. For example, photos with the Army Corps of Engineers flood plain

reports show distinct manmade rock and brush buildups along the bank at river mile 35.0 and 35.5 (near the Ventura/Los Angeles County line).

In general, the aftermath of floods has created a desire on the part of farmers to repattern the river into familiar configurations, controlling storm flows and preventing bank erosion. Thus, where Hopper Creek enters the river below Piru, a new jetty was built in the aftermath of the 1969 flood (Taylor 1994). Other structures work together with public works projects to create more unified flood control measures. The "farmers' levee" built at Coultas Ranch along the lower river in the mid 1980s is one example of such a structure. While it was built with permits from the county, its history followed the pattern of numerous other structures, many of which were clearly not controlled by any regulatory agencies. The levee is constructed of riverbed material, extracted from an "island" in the middle of the river above the Harbor Boulevard Bridge. It essentially continues the levee separating the Bailard landfill from the river itself.

Other levees and similar structures, intended for agricultural and urban protection, can be identified at various sites from aerial photographs and maps.

Surface Flows

The use of Santa Clara River water for irrigation, which began in earnest in the second half of the nineteenth century, continued throughout the twentieth. Diversions and other structures (pipelines and ditches) permitted the development of irrigated agriculture in the river valley and the Oxnard Plain.

Early in the 1900s, over 16,000 acres were irrigated by the surface flows of the Santa Clara. But agricultural and other uses and the building of dams changed these early patterns. By the 1960s, surface flow had diminished and use of groundwater replaced earlier sources. By 1969, only 2,500 acres were irrigated by surface flows (Freeman 1968).

Agriculture and the River

While most agriculture has taken place outside the river's "banks" much agricultural land has been vulnerable to flooding and agriculture continues to encroach upon lands adjacent to the river. Some water-intensive crops have been planted close to the river. Some agriculture, like watercress farming and gathering, is done within the riverbed itself (in some cases, in former recreational duck ponds). The harvesting of *Arundo donax* or giant reed within the river is another use of the river bottom land, although not a result of agriculture per se. Although this plant is an exotic, and many desire its eradication, it does have limited commercial use. A private firm harvests the wild plant from farmers' river bottom land for use in the manufacturing of reeds for woodwind instruments. Indeed, the Santa Clara River is reputed to contain the finest reed source in the United States (Gilday 1994).

Using any sort of borders for the river, such as flood plains, as landmarks has limits in this sort of historical study, since those lines have changed with time. Indeed, aerial photographs and historic maps make clear that what surveyors have called the "banks" of the river have shifted even over short periods of time. Aerial photographs, particularly from 40-60 years ago, clearly show scarring from former river flows as well as revealing the past braiding so characteristic of rivers like the Santa Clara.

URBAN IMPACTS

Since 1920, urbanization has continued to affect the Santa Clara River and adjacent floodplains. Since the 1950s, especially in the Upper Santa Clara River region, development has had a significant impact. Urban and industrial uses of the river and surrounding areas are many and varied. Some of these uses--such as bridges, flood control and landfills--are discussed in the "Government" section of this report. Others are private efforts closely linked to the residential and industrial boom in Los Angeles and Ventura Counties since the 1920s, in what this report terms the "industrial era." The major industrial use of the river itself has been sand and gravel mining, an industry that is closely related to the increasing urban development, including building and road construction, in the Santa Clara River valley.

Resource Extraction

Sand and gravel mining is the best known form of resource extraction in the history of the Santa Clara River. Indeed, the river produces the best aggregate material in the county, and much of the county's roads and other structures were built out of materials extracted from the river. With the growth of the county in the early 1900s and the construction of paved roads, local farmers and landowners were asked by construction companies for permission to extract aggregate from the river. Some of these farmers entered the mining business themselves; the Swift, Donlon, Borchard business, which maintained a small rock plant, near the Montalvo bridge, is one example. A number of farmers have attempted to lease out river land for mining but have found their aggregate resources were inappropriate; Newhall Land and Farming, for example, has tried to lease out riverbed land but without success (Elliot 1994). Maps from the late 1920s clearly show the location of at least one rock plant at Montalvo, surrounding by agricultural lands. City directories from the late 1920s for the first time list the existence of several sand and rock producers and distributors.

Larger companies generally bought out the local businesses. In 1939, L.R. Howard leased the property of the Swift, Donlon, Borchard extraction business and took over the rock operation, operating it until the early 1950s, when Southern Pacific Milling bought out the operation. Southern Pacific Milling, which since 1885 had based its business on warehouses and lumber along the route of the Southern Pacific Railroad, changed its emphasis to mining, concrete and

asphalt production when it was bought in 1947 by H.K. Porter Company. Also near Montalvo, El Rio Construction and the Woolsey/Hertel partnership participated in sand and gravel extraction, although their extractions from the river were less significant (Elliot 1994). Near the Saticoy bridge, Saticoy Rock Company did a great deal of mining during World War II. Their operation was acquired by Conrock (Calmat), which did most of the deep channel digging below and above the bridge until 1986. Upstream at Peck Road near Santa Paula, Mission Rock operated aggregate extraction until in 1955, Livingston-Graham took over operations. This mining dug extensively and deeply into the river bed (Elliot 1994).

Gravel and sand extraction also occurred in other areas above Saticoy. At Santa Paula, as in lower reaches of the river, mining has occurred since the 1920s. O.P. Barker bought Santa Paula Rock in 1945 and Southern Pacific Milling in turn purchased the operation in the early 1950s. Below 12th Street, the company operating milling had been Santa Clara Rock. Above 12th St., Owl Rock began digging in the 1960s, and aggregate production has continued on and off since then, with Granite being the latest company to dig. Other operations have taken place in Los Angeles County, although the quality of aggregate is much lower. Calmat, in the late 1980s, mined sand in the upper river area (Elliot 1994).

Some smaller mining operations have been carried out on Sespe Creek and Santa Paula Creek. In addition, unpermitted "outlaw" operations have taken place over the years. Other county government agencies have obtained permission for other uses below the red line. Ventura County Flood Control District is one of the agencies that issue permits for aggregate removal. For example, 350,000 cubic feet of fill was taken from the river bed near Coultas Ranch as landcover on the Bailard landfill. This digging eliminated a brushy island from the lower river and altered the river channel (Coultas 1994).

Aerial photographs of the river in the 1960s demonstrate the extent of mining in the Santa Clara River. Evidence of roads crossing the river bottom is pervasive in photographs and maps. Trucks are often present in the river bottom, and extraction operations are clearly visible. Deep basins and scarring of the river channel itself are present in aggregate extraction areas (Mark Hurd series, 1960-62).

As discussed in the government section above, permitting processes changed the nature of gravel extraction from the river. The first county permit for gravel mining was issued in the early 1970s. Gravel mining in the Santa Clara River changed forever with the studies and conditional use permit documentation of the 1970s and 1980s. A "red line" was created to limit mining in the river. At first, an imaginary line from the top of footings at the Santa Paula Bridge to the top of footings at the Montalvo Bridge limited the depth of mining; this line has subsequently been revised to reflect more sophisticated projections (Collart 1994).

In 1975, California passed the Surface Mining and Reclamation Act, intended to protect access to significant mineral resources and require reclamation of lands used in aggregate extraction. CUP restrictions also required aggregate companies to create reclamation plans after the early 1970s.

State law requires that extractions over 1000 cubic yards required reclamation, such as grading and replanting. In 1980, Ventura County began its Mineral Resource Management Program, with the State Division of Mines and Geology conducting a resources survey (Ventura County Resource Management Agency 1993, Collart 1994).

While other activities, like dams and levees, can contribute to channel degradation, but there is "no evidence to indicate that these potential effects actually occurred." Most reports about aggregate extraction along the river agree that "the loss of riverbed material and accompanying channel degradation is primarily, if not totally, the result of gravel mining from the channel" (Ventura County Environmental Resource Agency 1979). Erosion caused by deep gravel and sand mining in the river was blamed for many problems. Erosion of the pilings of the Saticoy Bridge led to that bridge's washout in the massive floods of 1969. Until the construction of the concrete, engineered Vern Freeman Diversion in 1988, the dirt Saticoy Diversion maintained by United Water Conservation District was destroyed and rebuilt repeatedly, generally being moved farther and farther upstream from the toe of South Mountain to maintain sufficient gravity flow. Material for the rebuilding of that diversion usually came from the river bed itself. As the river bed degraded, the diversion was moved upstream to ensure sufficient gravity flow to the spreading grounds.

Urban Developments

A major part of the development along the Santa Clara River has come in Los Angeles County. One significant step in the urbanization of the upper Santa Clara River area came in 1964 when the state purchased a large strip of land from Newhall Land and Farming for construction of Interstate 5. The once remote lands of Rancho San Francisco became linked to urban Los Angeles, and Newhall Land and Farming began work to develop their property holdings. Plans began in the 1950s when the company hired architects to plan home locations and in 1964 Newhall Land and Farming announced plans to create a new community, called Valencia. The company further boosted development with the donation of land for an arts center, the creation of several golf courses, and the development of Magic Mountain, which was operated by Newhall Land and Farming from 1972 to 1979 before being sold to another company (Newhall 1992).

The DWR in 1980 estimated that urban water uses in the Upper Santa Clara River Drainage Area and in Ventura County were greater than agricultural uses by a narrow margin of 51 to 49 percent. By comparison, urban uses demanded only 39 of local water service in 1969. The number of urbanized acres in the DWR study area increased by over two-thirds, from 72,600 acres in 1969 to 121,870 acres in 1980. The greatest gain was in industrial use (136% increase), with significant gains in residential (68%) and commercial (64%) acreage as well. Population of these areas also increased significantly, although not at as great a rate as predicted by early planning studies in the 1960s. In the Los Angeles County portion of the study, residential land uses took a large jump (156% increase) from 1969 to 1980. Changes in agricultural land uses are discussed above, but it is worth noting that the LA County section of the study showed a 27%

decrease in irrigated acreage between 1969 and 1980, from 5,330 acres to 3,900 acres (DWR 1981).

Table 3-5
Population Statistics 1930-1980

Year	Ventura County (total)	Upper Santa Clara River Drainage Area (Los Angeles County)
1930	54,976	3,287
1940	69,685	5,620
1950	114,647	10,269
1960	199,138	18,362
1970	378,497	52,700
1980	532,700	93,600

City Population Statistics

City	1940	1950	1960	1970	1980
Oxnard	8,519	21,567	40,265	71,225	115,797
Ventura	13,264	16,534	29,114	55,797	83,084
Santa Paula	8,986	11,049	13,279	18,001	20,522
Fillmore	3,252	3,884	4,808	6,285	9,538

Source: DWR 1981

As urban areas have grown, communities have built sewage treatment plants along the river in Los Angeles and Ventura counties, thus adding structures that demand flood protection and that can contribute effluent water to the river.

Recreation

Recreational uses along the river have varied widely. Fishing was an intermittent pasttime possible along the Santa Clara at least in the early part of the twentieth century and before. The continued presence of steelhead in the river and in the Sespe Creek has been a source of environmental controversy in the past two decades. Areas along the river have also been maintained as duck ponds, and a number of duck clubs were located near the mouth of the river in the first half of the twentieth century. Private families also maintained duck blinds as well. Some extensive maps of these areas exist in the plans for a beach road bridge at the mouth of the river, drawn up in 1935 and 1936 (County Surveyor's Office).

Some of the earliest "grand plans" for the watershed involved recreational use, although none of these plans were carried out. An "electric road" to accompany a massive hydropower project on

the Sespe was proposed in the early 1900s. A monorail to the Sespe Hot Springs was suggested in the 1920s but despite a grand groundbreaking ceremony the project was never built (Freeman 1968).

A number of golf courses, public and private, are adjacent to the river. Some of these, apparently, are irrigated by river water, using existing claims on water rights from the Santa Clara (Taylor 1994). Recreational vehicle parks also are scattered along the Santa Clara upstream from Piru and into Los Angeles County.

At the same time, increased recreational demands directly affected the river. All-terrain vehicles and other motor vehicles have been frequent and illegal intruders on the river bottom and surrounding lands. More formal recreational facilities on private lands followed a similar path. A motor sports park known as Indian Dunes was run by Newhall Land and Farming. At Indian Dunes, which apparently operated in the 1960s and through the early 1970s, motocross racing in the river bottom was a popular sport. Some of this land, apparently, was used for motion picture filming in subsequent years. Other entrepreneurs have run recreational activity centers such as trail rides through the Upper Santa Clara River bed. The reservoirs at Piru, Pyramid, Bouquet Canyon, and Castaic dams provide recreational activities ranging from fishing and boating to camping and swimming.

Municipalities have included river plans in their general recreational plans since the 1960s, but few of the extensive plans have come to fruition. The City of Oxnard, for example, drew up plans for an inland waterway in one of its general plans. Along the upper river area, some communities have used the river as a center for recreational areas.

Other Human Uses

There are other human uses of the river on a much smaller scale. The riverbed has provided a de facto housing community for many years. Stories of the St. Francis Dam failure describe how hobos who lived under local bridges were warned of the coming flood. Hobo encampments persisted throughout the middle of the century and the homeless continue to reside in the river bottom of the Santa Clara. Probably more than one semi-permanent housing structure (trailer, e.g.) is or has been illegally located in the riverbed area.

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Santa Clara River Parkway Floodplain Restoration Feasibility Study

FINAL REPORT
July 2008

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Cover photographs:

Top - Scarlet monkeyflower, *Mimulus cardinalis.*
Upper Middle - Example of riparian vegetation in the lower Santa Clara River corridor.
Lower Middle – Santa Clara River estuary.
Bottom – Juvenile steelhead.
**All photographs by Stillwater Sciences*.

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SUMMARY

The 116-mile-long Santa Clara River flows from the San Gabriel Mountains in Los Angeles County, through Ventura County, and eventually into the Pacific Ocean near the City of Ventura. The lower 33 miles of the river and its floodplain have been significantly altered in the recent past due to flood protection infrastructure, including reinforced levees, water diversions and flow regulation, roads, agriculture, aggregate mining, and urbanization. These structures have constrained or disrupted natural geomorphic and hydrologic processes, often causing riparian and aquatic habitat loss or degradation.

Despite the historical alterations to the riparian system, the lower Santa Clara River presents a unique opportunity to conserve and restore riparian functions and ecosystems compared with other coastal southern California rivers, most of which are highly degraded. There are several reasons why this opportunity is both significant and unique. First, the climate gradients and dynamic hydrology and geomorphology of the Santa Clara River watershed support a variety of natural aquatic and terrestrial communities and native species. Second, the Santa Clara River is one of the least altered rivers in southern California, with relatively intact patches of riparian and floodplain habitats in the lower reaches, particularly when compared to many of its dammed and channelized neighbors to the south. Third, the watershed's position provides a regionally important north-south connection between protected terrestrial wildlife areas in the southern California coastal ecoregion, and the river itself provides an important aquatic habitat linkage from the coast and estuary to upstream habitats in the mainstem and its tributaries, including the wild and scenic reaches of Sespe Creek. Together, these watershed attributes provide critical habitat for several rare and endangered species, and a movement corridor for a number of native species that require access to large areas to survive.

The Santa Clara River Parkway project seeks to ameliorate historical impacts in the lower Santa Clara River and conserve existing riparian habitats by acquiring and restoring existing habitat and flood-prone property from willing sellers. The Santa Clara River Parkway Floodplain Restoration Feasibility Study was undertaken to assist with the acquisition, management, and eventual restoration of lands within the Parkway. This report summarizes previous studies and analyses to: 1) provide an understanding of physical processes, habitat dynamics, and biological resources; 2) assess opportunities and constraints to property acquisition and restoration implementation; and 3) describe strategies for acquiring, managing and restoring the Parkway that are technically and scientifically sound, feasible to implement, and support long-term Parkway objectives.

The primary actions of the Santa Clara River Parkway project—acquisition of high-quality habitat and flood-prone lands, and active and passive process-based floodplain restoration—are intended to partially ameliorate the impacts and constraints from development within the lower Santa Clara River, and to enhance the river's capacity to provide a number of human and ecological benefits within current and foreseeable future land uses, water supply needs, and other policy constraints in the river corridor. The benefits expected from process-based floodplain restoration include:

- Increased length and width of riparian and in-channel aquatic habitat, and greater connectivity between habitats along the mainstem, in upland areas, and along major tributaries.
- Reduced flood risk outside the Parkway area and reduced levee maintenance and other public works costs associated with damages during flood flows, by allowing high discharges to spill onto acquired floodplain areas.
- Expanded and protected open space areas and natural habitats that provide recreational and educational opportunities for the community.
- Stream bank stabilization and food web contributions by riparian vegetation.
- Improved water quality by restoring and conserving stands of riparian and wetland vegetation that filter nutrients and sediment from runoff.
- Improved water supply through groundwater infiltration and recharge during floodplain inundation.

For the purposes of this study, acquisition and restoration strategies were evaluated based on several criteria to ensure that implementation would be feasible and appropriate for the lower Santa Clara River. Consequently, each recommended strategy needed to meet the following criteria: 1) be considered feasible and effective at achieving the ecological objectives of the Parkway project; 2) be technically appropriate given the physical and biological attributes and human uses of the river corridor; 3) work within current and foreseeable constraints, such as the legacy of historical impacts to the fluvial system, land use and zoning, water resource development and management, flood control requirements, infrastructure, impaired water quality, and environmental regulations; 4) offer specific opportunities, such as the presence of existing high-quality habitat, on which to base acquisition and restoration in the lower river corridor; and 5) work toward the flood control objectives of the Parkway project.

These criteria were used to screen potential acquisition and restoration efforts, which resulted in six primary restoration strategies:

1) acquisition from willing sellers of threatened and/or high-value habitat that is currently prone to regular flooding;
2) levee setback and removal, floodplain recontouring, and floodplain infrastructure modification;
3) active and passive revegetation;
4) non-native invasive species removal;
5) creation of a network of water-quality treatment wetlands; and
6) aquatic habitat enhancements focused on fish passage improvements.

These strategies seek to restore physical functioning and improve ecological conditions, given that watershed-wide impacts of grazing, urban development, instream mining, infrastructure, and surface and groundwater regulation preclude a return to presumed historical conditions.

The objectives of the restoration strategies are as follows:

- The land acquisition strategy will provide long-term, protected and sustainable venues for restoration strategies to be implemented in a cost-effective and environmentally optimized manner;
- The levee removal and setback and infrastructure modification strategy will assist in improving physical functioning of the river to naturally create and sustain riparian and other riverine habitats, and providing lateral connectivity between the river and floodplain habitats;
- Revegetation will increase riparian habitat quantity and quality in currently degraded or newly restored areas and contribute to ecosystem functions;
- Non-native species removal will also improve riparian habitat quality as well as directly remove some limitations to special-status species populations;
- Ecosystem-based placement of water-quality treatment wetlands will maintain a range of chemical parameters that support healthy native species assemblages and meet water quality criteria; and
- Aquatic habitat enhancements will increase instream habitat quantity, quality, and connectivity.

1 INTRODUCTION

1.1 Genesis & Goals of the Santa Clara River Parkway

In 2000, the California State Coastal Conservancy (Coastal Conservancy) proposed the establishment of the Santa Clara River Parkway. The primary goal of the Parkway is to create, protect and restore 25 miles of continuous river and floodplain corridor from the mouth of the Santa Clara River to the Sespe Creek confluence. The Parkway is being created through the acquisition of river channel, floodplain, and agricultural lands vulnerable to flooding, and conversion of those lands back to riparian and upland habitats. Initial funding of $9.2 million was provided by Governor Gray Davis, as appropriated by the legislature, to the Coastal Conservancy for land acquisition and planning. Land acquisition is being conducted on a willing seller basis and is focused on the lower river, where a number of parcels have already been acquired (approximately 3,250 acres covering 11 miles of river). The Coastal Conservancy has partnered with The Nature Conservancy's LA-Ventura Project to acquire, manage, and restore Parkway lands. Future management of Parkway lands is expected to be carried out under a joint powers agreement between the Coastal Conservancy, Ventura County and the cities of Oxnard and Ventura.

Other goals of the Parkway project are to: 1) conserve and restore aquatic and riparian habitat for native species, 2) provide enhanced flood protection, and 3) provide public access and environmental education within the Parkway. Habitat restoration will focus on allowing and/or providing self-sustaining natural physical and biological processes and will be guided by historical reference conditions, to the extent appropriate, and focal species habitat requirements. Flood protection will be improved by relocating vulnerable infrastructure to reduce or remove flood hazards, increasing flood attenuation where possible, and by minimizing future encroachment of urban development into the floodplain by acquisition of flood-prone lands from willing sellers. Public access, which is not a part of the focus of this study, will be provided through a continuous public trail system, and permanent interpretive panels installed at key locations will provide opportunities for environmental education.

1.2 Purpose of the Floodplain Restoration Feasibility Study

The Santa Clara River Parkway Floodplain Restoration Feasibility Study was designed to assist the Coastal Conservancy and its partners with the acquisition, management, and eventual restoration of lands within the Santa Clara River Parkway. The Feasibility Study synthesizes several previous water-

shed assessments and restoration and management planning projects, but expands upon these previous efforts with in-depth research on current and historical watershed function from both geomorphic and ecological perspectives. The goals of the Feasibility Study are to develop:

1. an understanding of the historical, current and potential future geomorphic and ecological processes within the lower Santa Clara River system; and
2. a strategy for acquiring, managing and restoring the Parkway that is technically and scientifically sound, feasible to implement, and supports long-term Parkway objectives.

To achieve these goals, the Feasibility Study has included:

- an assessment of hillslope, fluvial, and estuarine geomorphic processes (Stillwater Sciences 2007a),
- a water resources investigation including land use, infrastructure, hydrology, hydraulics, and water quality (URS Corporation 2005);
- detailed vegetation classification and mapping (Stillwater Sciences and URS Corporation 2007);
- an analysis of riparian vegetation dynamics (Stillwater Sciences 2007b); and
- an analysis of focal species habitat conditions (Stillwater Sciences 2007c).

This report summarizes these and previous studies and analyses to provide an understanding of physical processes, habitat dynamics, and biological resources (Chapter 2), to assess opportunities and constraints to property acquisition and restoration implementation (Chapter 3), and to describe acquisition and restoration strategies, priorities, and feasibility within the Parkway area (Chapter 4).

Through the acquisition and restoration efforts described in this report, the Parkway project is eventually expected to result in: (1) a 10,000- to 12,000-ac continuous protected riparian corridor along the lower 25 mi of the river[1] (3,250 ac have already been acquired); (2) an associated increase in riparian and adjacent habitat potentially ranging from 3,000 to 5,000 ac; and (3) a decrease in flood stage in the lowest reaches of the river potentially ranging from 6 to 7 ft. It is hoped that the information provided in this report will be used throughout the lower Santa Clara River watershed to support informed river management and restoration solutions.

[1] 6,000 ac was a previously reported acquisition goal for the Parkway project but has been expanded based on the findings of this Feasibility Study.

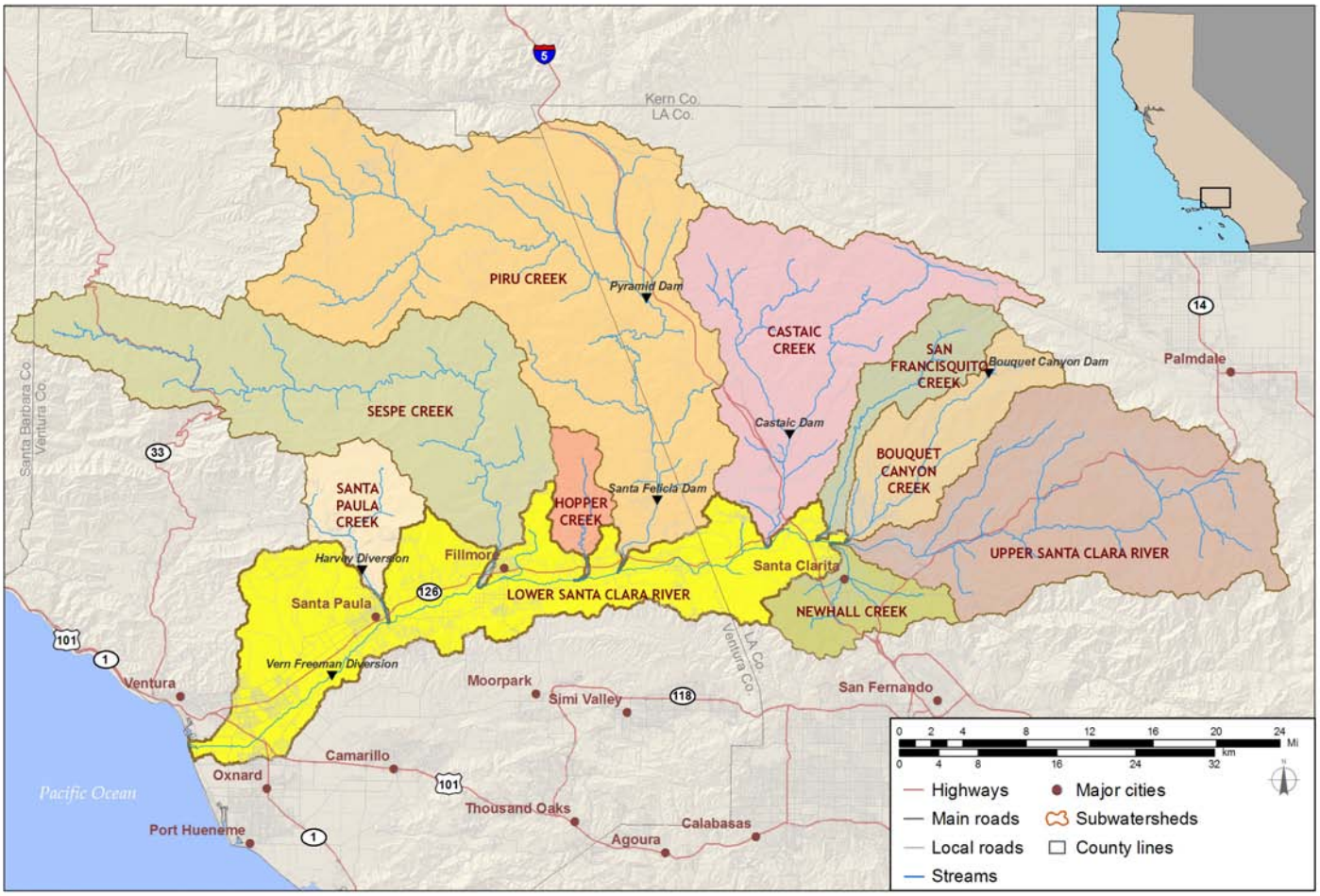

Figure 1-1. The Santa Clara River watershed.

1.3 Study Area

The 116-mile long Santa Clara River flows in a westerly direction from headwaters on the northern slopes of the San Gabriel Mountains in Los Angeles County, through the Santa Clara River Valley and the Oxnard Plain in Ventura County, and finally empties into the Pacific Ocean near the City of Ventura (Figure 1-1). The river is one of the largest watersheds on the southern California coast, draining an area of 1,626 mi^2, with elevations from sea level to 8,832 ft.

Many large coastal southern California rivers (*i.e.*, the Los Angeles, Santa Ana, and San Gabriel rivers) have been confined to concrete channels in their lower reaches to provide flood protection for surrounding urban areas. This has eliminated riparian vegetation and crippled the fluvial geomorphic processes that maintain a functioning riparian-floodplain ecological system. The Santa Clara River is therefore significant in the region because it retains many natural attributes no longer exhibited by the other large coastal south-

ern California rivers, including patches of high-quality aquatic and riparian habitats capable of sustaining threatened and endangered species such as arroyo toad (*Bufo microscaphus californicus*), southwestern willow flycatcher (*Empidonax traillii extimus*), least Bell's vireo (*Vireo bellii pusillus*), slender-horned spineflower (*Dodecahema leptoceras*), and southern California coast steelhead (*Oncorhynchus mykiss irideus*).

While the Santa Clara River presents a unique opportunity to conserve and restore riparian functions and ecosystems compared with other more highly degraded coastal, southern California rivers, its river channel, floodplain, and habitats have been significantly altered in the recent past. Flood protection infrastructure including reinforced levees, water diversions and large dams, roads, agriculture, aggregate mining, and urbanization have constrained or disrupted natural geomorphic and hydrologic processes, often causing riparian and aquatic habitat loss or degradation. The Parkway project seeks to partially ameliorate these impacts in the lower Santa Clara River by acquiring and restoring existing habitat and flood-prone property from willing sellers in a 25-mile reach of the lower river from the mouth to the Sespe Creek confluence (Figure 1-2).

This Feasibility Study includes the Parkway project extent as well as the reach from Sespe Creek upstream to the Los Angeles/Ventura County line (for a total of 38 river mi) (Figure 1-2). The Feasibility Study area of analysis is defined by the extent of the 500-year floodplain (*i.e.*, the area inundated by a 500-year recurrence interval flood as defined by HEC-RAS hydraulic modeling), also referred to as the riparian corridor. This area includes the lower portions of the three major tributaries: Piru, Sespe, and Santa Paula creeks.

To describe the wide variety of physical and ecological conditions that occur in the river, it is useful to subdivide the lower Santa Clara River into 12 reaches (numbered from downstream to upstream), based on physical and biological criteria such as tributary junctions (where flow and sediment supply can change dramatically), degree of channel confinement (or its inverse measure, active channel width), land use history, and dominant vegetation (Table 1-1). These reaches range in length from approximately 1.5 to 6 miles and range in 500-year floodplain width from approximately 720 to 1,870 ft. Riverwash and riparian herbaceous and scrub vegetation types dominate the 500-year floodplain of most reaches, suggestive of the flashy hydrology and dynamic channel morphology of the lower river. Available habitat for focal species (discussed in Section 2.4.2) typically increases with channel width, which also tends to be greater in the more downstream reaches of the river.

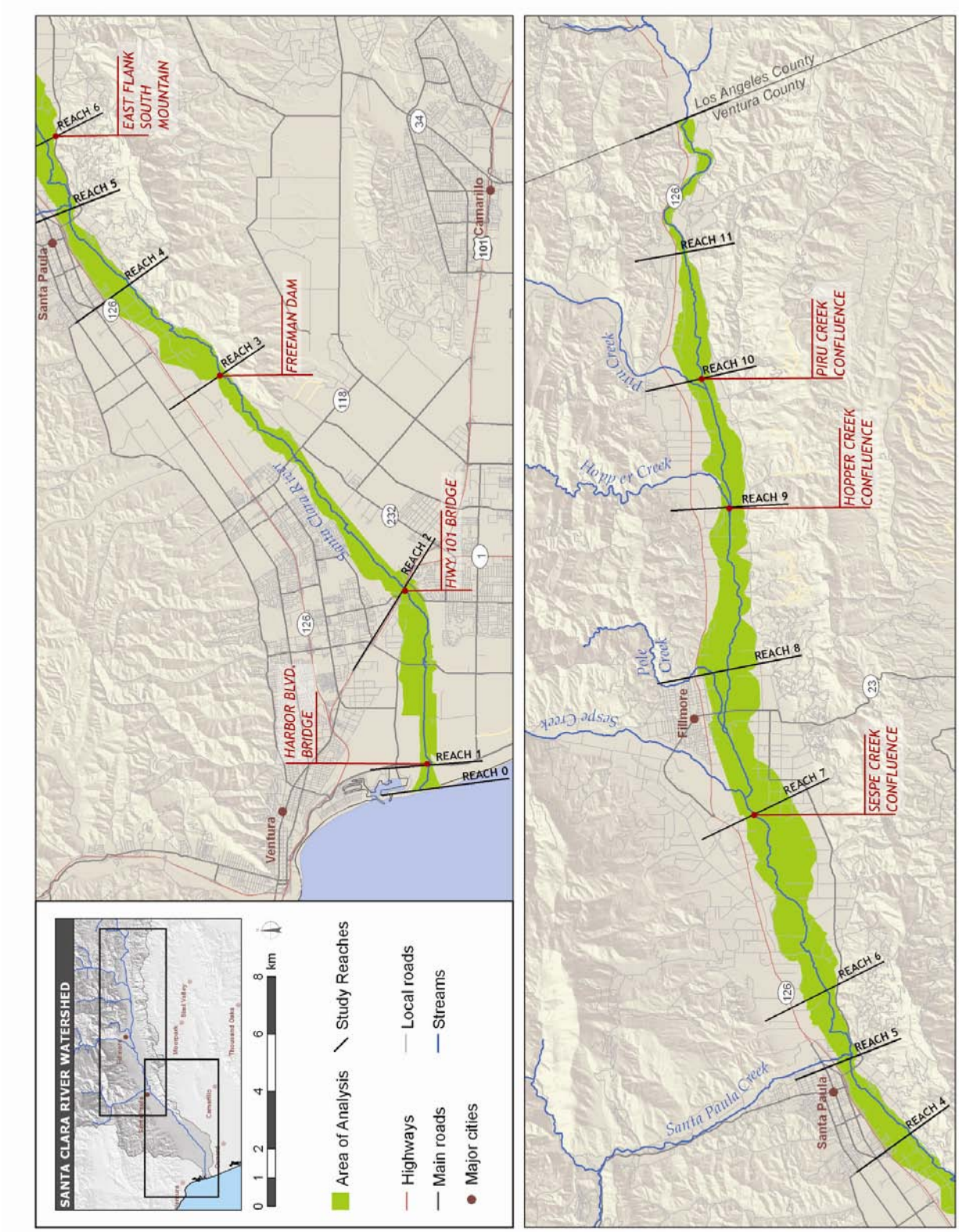

Figure 1-2. The Parkway project and Feasibility Study areas of analysis.

Table 1-1. Lower Santa Clara River reach characteristics.

REACH NUMBER Reach Name	River mile[1] Start	River mile[1] End	Reach-average slope[2]	Active channel width[3,4] (ft)	1.5-yr recurrence interval flow (cfs)[4]	Reach type[4, 5]	Dominant land use[3]	Dominant vegetation type[3]	Available focal species habitat (acres)[3]	Local characteristics
REACH 0 Estuary Reach	0 *[Pacific Ocean]*	0.5 *[Harbor Blvd. Bridge]*	<0.0010	2,600	6,569	gaining	Developed	Open water	856	Lagoon/estuary of the river, dominated by salt marsh and beach habitats. Levees along both banks. Receives treated effluent from waste water treatment plant on right bank. Mouth is open 70% of the year on average.
REACH 1 Hwy 101 Reach	0.5 *[Harbor Blvd. Bridge]*	4.6 *[Hwy 101 Bridge]*	0.0025	728	6,569	gaining	Developed	Cotton-wood-willow forest	4,412	Wide floodplain; part of natural distributary area for the river. Largely straight channel. Levee on left bank, with urban development behind.
REACH 2 Below Freeman Reach	4.6 *[Hwy 101 Bridge]*	10.8 *[Freeman Dam]*	0.0027	1,148	6,569	gaining	Developed	Riverwash	3,188	Wide floodplain, part of natural distributary area for the river. Levees on left bank, and portion of right. Urban development to channel edge along most of the right bank. Gravel mining occurred until 1988. Highly regulated flows downstream of Freeman Dam.
REACH 3 Above Freeman Reach	10.8 *[Freeman Dam]*	13.5 *[Shell Rd.]*	0.0025	869	6,569	losing	Agriculture	Herbaceous (non-native)	1,456	Left bank impinges on South Mountain. Gravel mining occurred throughout the reach until 1988. Freeman Diversion Dam provides grade control at the downstream end.
REACH 4 Below Santa Paula Reach	13.5 *[Shell Rd.]*	15.7 *[Santa Paula Ck.]*	0.0039	1,260	6,569	losing	Developed	Arundo donax	1,237	Left bank close to South Mountain; urban development to edge of right bank. Some revetment on right bank. Gravel mining occurred until 1986. Receives unregulated inflow from Santa Paula Creek.
REACH 5 Above Santa Paula Reach	15.7 *[Santa Paula Ck.]*	17.5 *[East flank South Mtn.]*	0.0031	1,496	6,569	gaining	Agriculture	Mixed riparian scrub	768	Left bank impinges on South Mountain.

REACH NUMBER Reach Name	River mile[1] Start	River mile[1] End	Reach-average slope[2]	Active channel width[3,4] (ft)	1.5-yr recurrence interval flow (cfs)[4]	Reach type[4, 5]	Dominant land use[3]	Dominant vegetation type[3]	Available focal species habitat (acres)[3]	Local characteristics
REACH 6 Below Sespe Reach	17.5 *[East flank South Mtn.]*	22.1 *[Sespe Ck.]*	0.0036	1,555	6,569	losing	Agriculture	Cotton-wood-willow forest	2,939	Wide floodplain, with sinuous and braided channel. Levee on left bank opposite Sespe Creek confluence. Receives unregulated inflow from Sespe Creek.
REACH 7 Above Sespe Reach	22.1 *[Sespe Ck.]*	25 *[1 mi. east of Chambers Rd.]*	0.0048	1,870	3,178	losing	Agriculture	Arundo donax	2,319	Levee on right bank, with urban development behind.
REACH 8 Hopper Reach	25 *[1 mi. east of Chambers Rd.]*	28.5 *[Hopper Ck.]*	0.0055	1,385	2,154	gaining	Agriculture	Herbaceous	1,728	Wide floodplain, with sinuous and braided channel. Received unregulated inflow from Hopper Creek.
REACH 9 Below Piru Reach	28.5 *[Hopper Ck.]*	31.6 *[Piru Ck.]*	0.0053	1,778	2,154	losing	Agriculture	Riverwash	1,088	Wide floodplain, with sinuous and braided channel veering towards left bank mountains. Receives highly regulated flow from Piru Creek.
REACH 10 Above Piru Reach	31.6 *[Piru Ck.]*	34 *[2.5 mi. east of Piru Ck.]*	0.0062	1,821	1,907	losing	Agriculture	Riverwash	1,186	Wide floodplain, with centered channel. Highly regulated flows due to upstream dams on several tributaries.
REACH 11 County Line Reach	34 *[2.5 mi. east of Piru Ck.]*	38.4 *[LA County line]*	0.0055	479	1,872	gaining	Agriculture	Cotton-wood-willow forest	513	Last narrow valley segment (from upstream). Heavy agriculture use adjacent to floodway. Highly regulated flows due to upstream dams on several tributaries.

1 River miles represent the distance along the river channel upstream from the Pacific Ocean. Source: AMEC (2005), supplemented by 2005 LiDAR data where necessary.
2 Source: URS (2005)
3 Within the 500-year floodplain
4 Source: AMEC (2005)
5 Gaining reaches are areas of rising groundwater, losing reaches are areas of where discharge from upstream infiltrates during low flow conditions.

1.4 Concepts & Rationale for Floodplain Restoration

Impacts to the physical and biological resources of the Santa Clara River, assessed through a number of studies and analyses, have been used to provide the rationale for Parkway acquisition and restoration. Impacts include:

- Continuing encroachment of urban and agricultural land uses into the riparian corridor, construction of reinforced levees, and development of transportation infrastructure that has reduced the floodplain area and available riparian habitat compared to historical conditions and caused channel incision.
- A reduction in floodplain area, combined with flashy flood patterns of the river, which has increased the flood hazard to developed areas and infrastructure.
- Historical clearing of riparian vegetation, in combination with lowering of the groundwater table through direct extraction and channel incision, which has decreased riparian vegetation extent and suppressed riparian vegetation recovery.
- Historical aggregate mining that has caused considerable channel incision, which led directly to need for the Freeman Diversion Dam that further disrupts longitudinal connectivity of aquatic habitat.
- Invasive species, particularly arundo (giant reed; *Arundo donax*), that out-compete native plant species and further reduce the quantity and quality of riparian habitat.
- A reduction in riparian habitat area that has negative impacts on native animal and plant species, some of which are listed as threatened or endangered.
- A reduction in the suitability and diversity of aquatic habitats that has negative impacts on native fish and invertebrates, including endangered tidewater goby (*Eucyclogobius newberryi*) and unarmored threespine stickleback (*Gasterosteus aculeatus williamsoni)*.
- Barriers to upstream fish migration that impede the southern California coast steelhead to reach spawning habitats and limit the population of this endangered species.

IMPACTS TO THE RIVER

- Encroachment and development of infrastructure in the riparian corridor
- Construction of levees
- Reduction in floodplain area
- Clearing of riparian vegetation
- Lowering of the groundwater table
- Aggregate mining
- Invasive species
- Reduction in riparian habitat
- Reduction in aquatic habitat suitability and diversity
- Barriers to upstream fish passage

Many of the anthropogenic impacts to the watershed are the results of human interventions that were undertaken to develop local agriculture and the local economy. Strategies for Parkway acquisition and floodplain restoration, therefore, require an understanding and integration of the needs and concerns of local landowners, water users, and industry. In addition, effective restoration actions must be feasible to implement within the constraints of the contemporary and foreseeable physical and political landscape. Among other issues, permanent infrastructure; lasting effects from historical land

uses; and water supply, flood control, and land use policy and management shape the suite of restoration actions that are both technically and politically suitable for the lower Santa Clara River.

The primary actions of the Santa Clara River Parkway project—acquisition of high-quality habitat and flood-prone lands and active and passive process-based floodplain restoration—are intended to partially ameliorate the impacts and constraints from development within the lower Santa Clara River and its floodplain, and to enhance the river's capacity to provide a number of human and ecological benefits within current and foreseeable future land use, water supply, and other policy constraints in the river corridor. The benefits expected from process-based floodplain restoration are depicted in Figure 1-3 and potentially include the following:

- Reduced flood risk outside the Parkway area and reduced levee maintenance and other public works costs associated with damages during flood flows, as flood flows spread out and slow down over the floodplain.
- Improved water quality by stands of wetland and riparian vegetation that filter nutrients and sediment from runoff.
- Improved water supply through groundwater infiltration and recharge during floodplain inundation.
- Streambank stabilization and food web contribution by riparian vegetation.
- Increased length and width of riparian and in-channel habitat, and greater connectivity among habitats along the mainstem, in upland areas, and along major tributaries.
- Expanded and protected open space areas and natural habitats that provide recreational and educational opportunities for the community.

BENEFITS OF RESTORATION

- Reduced flood risk
- Reduced levee maintenance
- Improved water quality
- Groundwater recharge
- Stabilized stream banks
- Increased extent and diversity of riparian and in-channel habitats
- Open space for recreation and education

The Feasibility Study presents a process-based approach to restoration planning in the Santa Clara River Parkway. Process-based restoration focuses on establishing natural rates and magnitudes of geomorphological, hydrological, and biological processes that sustain biodiversity and biological productivity, with the understanding that the habitat-forming processes are dynamic (Pess *et al.* 2006). A process-based approach to restoration is typically the most cost-effective and sustainable approach to large-scale river corridor or watershed restoration. The typical alternative, active reconstruction and restoration of river and floodplain habitats following a "form-based" approach (*i.e.*, construct the desired feature rather than reestablish the feature-supporting process), is generally more costly and more likely to fail unless alterations to natural processes have also been addressed (Downs and Gregory 2004). In addition, the relatively unpredictable physical processes in the channel and floodplain environment of the Santa Clara River (*e.g.*, dynamic channel bed, extreme flood events, and very high sediment yield) limit any

ability to implement a form-based approach, where "designed" quantities and types of habitat would be expected to meet the needs of specific focal species and persist for many decades. A process-based approach to restoration design has, therefore, been adopted that provides the floodway with the needed room for physical processes (such as floodplain inundation, bed scour, bank erosion and sediment deposition) to occur without risking nearby land uses, and that provides a template for the habitat types needed to sustain native plants and animals (Figure 1-3). Active, form-based restoration efforts may then be considered at specific sites, as appropriate, within a larger process-based restoration framework.

This effort represents a proposed shift in the management paradigm on the lower Santa Clara River—from the sole use of levees and other structures to manipulate and control river processes, to a vulnerability modification approach that will eventually reduce flood risk by ensuring adequate space for floods and other river processes and minimizing the extent of vulnerable infrastructure and development in the floodway. This approach includes land acquisition and conservation easements; incorporates the floodplain as a primary element in the reduction of flood damage and recognizes its value as an important biological resource; and incorporates in-channel and riparian

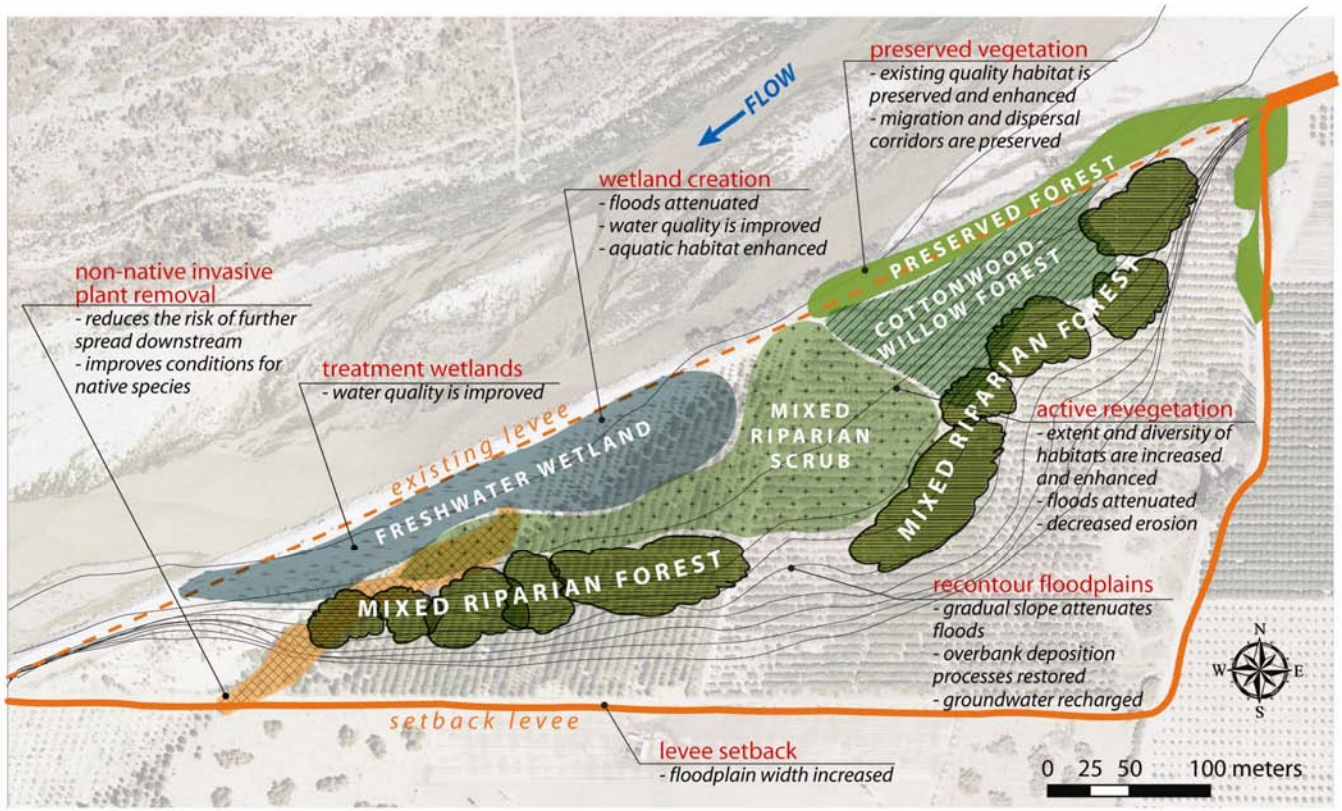

Figure 1-3. Conceptual restoration design illustrating the diverse benefits of process-based floodplain restoration on the lower Santa Clara River. Ideally, restoration actions would be implemented on multiple, contiguous parcels along the river to maximize effectiveness.

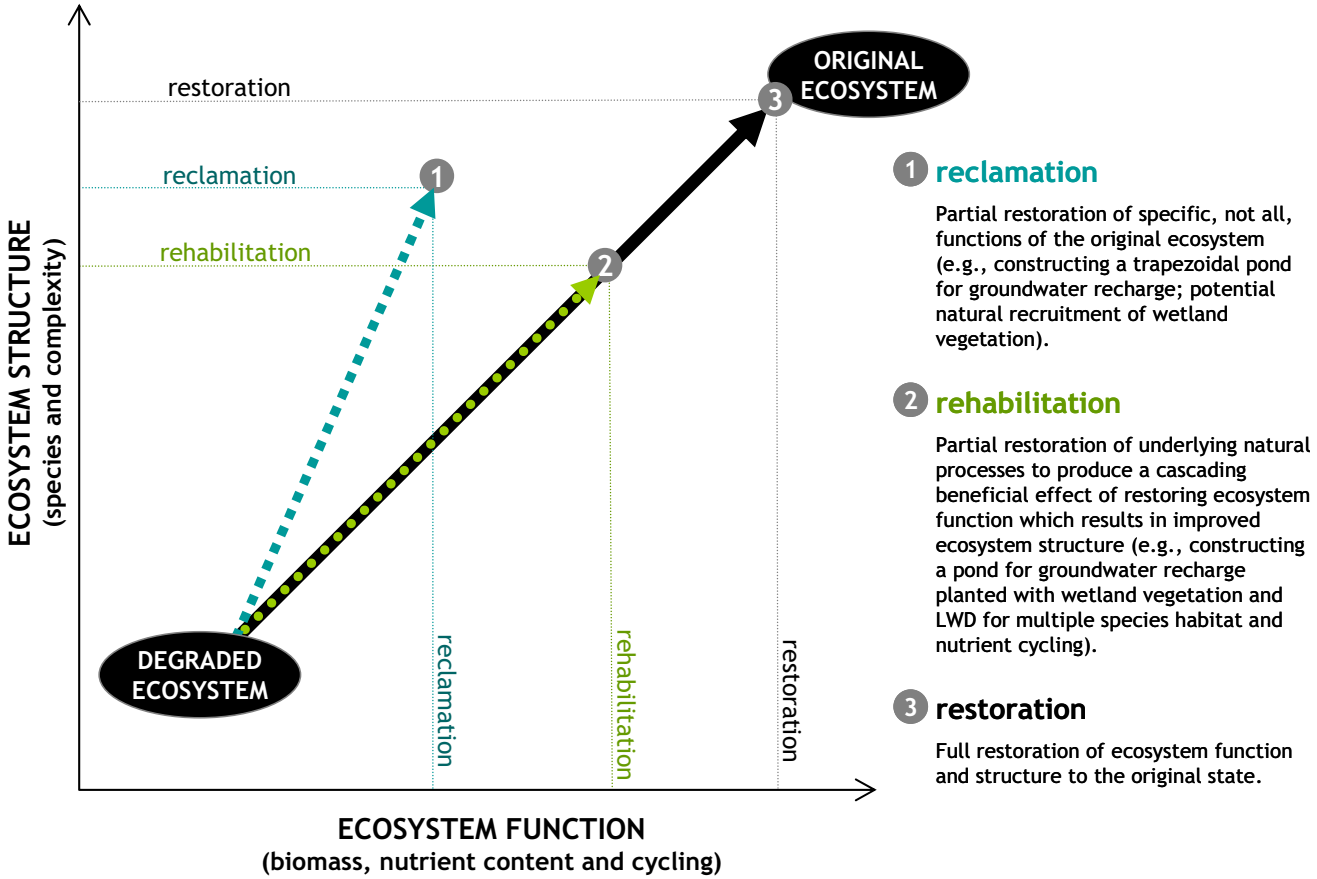

Figure 1-4. Restoration, reclamation and rehabilitation trajectories from degraded toward reference ecosystem conditions (modified from Bradshaw [2002] and Downs and Gregory [2004]).

habitat protection, restoration, and/or creation in land use planning. In addition to providing measurable and immediate reductions in flood risk and benefits to the river ecosystem, the Parkway strategy will afford the Santa Clara River the area and resiliency necessary to respond to unpredictable or uncertain changes in the watershed, such as climate change and sea-level rise, with minimal impacts to adjacent land uses.

Although the term "restoration" is used throughout this document, completely restoring the Santa Clara River to pre-colonial ("historical") conditions is not possible and, for many reasons, may not be desirable. This Feasi bility Study will guide efforts to rehabilitate river function to the fullest extent possible within current and foreseeable land use, water supply, and other constraints in the river corridor. Rehabilitation of the river corridor will include increases in ecosystem function (*e.g.*, nutrient cycling) with increasing ecosystem structure (*e.g.*, number of native species), putting the river on a trajectory towards the original ecosystem state (NRC 1992, Bradshaw 2002, Downs and Gregory 2004) (see Figure 1-4).

1.5 Selected Restoration Efforts & Studies in the Watershed

Several conservation and restoration efforts, and prior studies of river ecosystem conditions, have been undertaken across the Santa Clara River watershed over the past two decades. These efforts have commonly included a variety of stakeholders in the watershed and developed measures to protect natural resources, and restored some of the natural resources that were negatively impacted from previous activities in both the upper portion of the Santa Clara River in Los Angeles County and the lower portion of the Santa Clara River in Ventura County. These efforts have been critical in refining the goals, objectives, and approach of the Parkway project and this Feasibility Study, because they provide a wealth of information to build upon while highlighting areas in which further work is needed.

Santa Clara River Enhancement and Management Plan

The Santa Clara River Enhancement Plan (SCREMP) was designed to provide guidance in the preservation, enhancement, and sustainability of the physical, biological, and economic resources that occur within the 500-yr floodplain limits of the Santa Clara River mainstem (AMEC 2005). The SCREMP arose from efforts by former Ventura County Supervisor Maggie Kildee and the U.S. Fish and Wildlife Service (USFWS) (Ventura office) with funding from the Coastal Conservancy. In 1991, the interested parties decided to work together to develop a coordinated management effort, and the Project Steering Committee (PSC) was convened (AMEC 2005). The PSC, made up of 26 members, including private land owners, local government, industry, special districts, interest groups, and state and federal resource and regulatory agencies, compiled the SCREMP. The SCREMP process emphasized improved coordination and information exchanges among all PSC members and on resolution of conflicting uses of the river. The study sought to give balanced consideration to habitat objectives, natural river processes, private property rights, economic interests, and community objectives in support of preparing a plan that contains mechanisms for implementing the PSC's recommendations (AMEC 2005).

By 1999, the PSC released preliminary, river-wide and reach-specific recommendations on multiple topics. These involved public outreach, private property rights, water quality, water rights, salt water intrusion, water supply, river gradient, public flood protection facilities, maintenance of design flow capacity, private flood protection, cultural resource protection, fish passage, habitat conservation priorities, biological management, control of exotic species, biological mitigation, public access and recreation, recreational property acquisition, and permit streamlining (CRWQCB 2004). Several of these recommendations have begun to be implemented by a collection of local agencies.

Santa Clara River Natural River Management Plan

The Santa Clara River Natural River Management Plan (NRMP) for the Upper Santa Clara River within Los Angeles County was devised by the Newhall Land Company (formerly The Valencia Company). Its purpose was to address cumulative impacts of Newhall Land development projects over the next 20 years on 486 hectares (1,200 acres) of affected drainages, including the South Fork of the Santa Clara River, the mouth of Bouquet Creek, San Francisquito Creek, and the Santa Clara River from Castaic Creek confluence to 2.5 miles upstream of the Bouquet Canyon Development (AMEC 2005, CalTrans 2005). The NRMP was written as a US Army Corp of Engineers (USACOE) General Permit and proposed as the basis for a Regional Development Plan. The NRMP was reviewed and approved by Los Angeles County, USACOE, California Department of Fish and Game (CDFG), and other regulatory agencies (AMEC 2005). The NRMP contains maintenance procedures (to be followed by Los Angeles County Dept. of Public Works) designed to avoid impacts to endangered species and minimize impacts to riparian resources (CalTrans 2005). This includes maintaining natural river hydraulics and sediment transport along a 15-mile mainstem reach in Los Angeles County, providing for a conservation easement of riparian habitat within this reach, providing for groundwater recharge by maintaining sand-bedded channels, establishing vegetated buffers in urban areas, and installing filters and wetlands to protect the water quality of the Santa Clara River (AMEC 2004). Management of riparian corridor and upland properties to be protected through the NRMP has been delegated to regional land trusts and conservancies.

Santa Clara River Trustee Council Restoration Plan

The Santa Clara River Trustee Council Restoration Plan (Restoration Plan) was designed to provide a framework for restoration alternatives to restore, rehabilitate, replace or acquire the equivalent of the damaged natural resources resulting from the 1994 ARCO oil spill along the Santa Clara River (Santa Clara River Trustee Council 2002). In 1997, a settlement of $7.1 million was reached between ARCO and federal, state, and county agencies. From this settlement, the Trustee Council, made up of representatives from CDFG and the U.S. Fish and Wildlife Service (USFWS), was formed and given the responsibility of developing the Restoration Plan for the resources in and along the Santa Clara River. It was also tasked with allocating the settlement funds and ensuring the success of the restoration activities. Restoration activities include land acquisition/conservation easements (60% of funds), invasive, non-native plant species control (20% of funds), restoration project grants program (10% of funds), information and education (5% of funds), and watershed evaluation and monitoring (5% of funds). The first land purchase authorized under the Restoration Plan was 337 acres of riparian habitat in Ventura County (at the confluence of the Santa Clara River and Piru Creek) that will be managed and maintained by The Nature Conservancy

(OSPR News 2006). Through the Restoration Plan process, the Trustee Council also funded studies to assess populations of steelhead trout (Kelley 2004, Stoecker and Kelley 2005) and riparian birds (Labinger and Greaves 2001a, b), map riparian vegetation (Stillwater Sciences and URS Corporation 2007), research biological control of giant reed (Dudley, in progress), and prioritize sites along the river for purchase and/or conservation easement (Court *et al.* 2000). The results of these studies were used, in part, to describe the ecosystem conditions presented in Section 2 of this report and to develop appropriate restoration strategies and priorities (Section 4).

Santa Clara River Watershed Project Management Plan (Reconnaissance and Feasibility)

Following an initial Reconnaissance Phase Study in 2002, the USACOE-Los Angeles District determined that there was a federal interest in a watershed-based study that could provide a holistic approach to evaluating resource problems and opportunities, and that would lead to the development of a watershed protection plan that balances the need for sustainable development with the need for watershed protection (Buxton 2006). When completed, the next phase of the project (the Feasibility Phase) will provide technical data required for identifying and understanding the water resource problems and opportunities in the watershed, with particular attention to the effects of future land developments on the river (Buxton 2006). The Feasibility Phase study is intended as a scientific study that will be a tool for decision makers involved in regional flood control management (AMEC 2005). The first phase of the Feasibility Study, the Project Management Plan, was completed in 2003. The original projected time for the entire Feasibility Study was three years, although funding limitations have delayed many of the original studies.

The Nature Conservancy's Lower Santa Clara River Focus Plan and Upper Santa Clara River Watershed Conservation Plan

The Nature Conservancy (TNC) has been involved in conservation planning and implementation in the Santa Clara River watershed since 1999 and is an important partner to the Coastal Conservancy in implementing the Parkway project. TNC's overall land preservation strategy for the region, termed their "LA-Ventura Project", comprises 3 major features: 1) the Santa Clara River watershed (to assist in the implementation of the Santa Clara River Parkway Project); 2) the coastal areas of McGrath State Beach and Ormond Beach; and 3) and several wildlife linkages between the Los Padres National Forest, Angeles National Forest and the Santa Monica Mountains. To date, the Nature Conservancy has worked with local partners to acquire 2,500 ac (18 properties)—about 11 mi—along the Santa Clara River in Ventura County (~1/3 of river length in Ventura County) (TNC 2007). In conjunction with land acquisition, TNC has also developed plans for conserving natural resources in

both the lower reaches (Ventura County) and upper reaches (Los Angeles County) of the Santa Clara River.

The Lower Santa Clara River Focus Plan (Focus Plan) addresses conservation planning (under both a longer-term vision and shorter-term focused objectives) related to riparian and aquatic resources along the lower 30 miles of the river (Cox *et al.* 2001). The long-term vision includes protection of over 3,500 acres of riparian and alluvial scrub habitat, maintenance of viable populations of native resident and anadromous fish in the lower Santa Clara River, and adoption of permanent county-wide open space protection measures. Key focused objectives and strategies identified to reach the long-term vision include land acquisition, partnerships, marketing/funding, science, and land use planning. To determine where to focus conservation efforts, the Focus Plan ranks the biological resources in the lower Santa Clara River and the stresses to the biological resources. The Focus Plan also details an 'Initial Conservation Design' for the lower Santa Clara River based on riparian 'nodes', which are thought to be viable habitat patches independent of each other, and a continuous riparian corridor. The Focus Plan is currently being updated and expanded as *AConservation Plan for the Lower Santa Clara River and Surrounding Areas* (TNC 2007).

Los Angeles County Upper Watershed General Plan

The Los Angeles County Upper Watershed General Plan (General Plan) serves as the blueprint for future growth and development within unincorporated areas in Los Angeles County as a whole and the upper Santa Clara River in particular (Los Angeles County General Plan Update 2007). One component of the General Plan is the designation of proposed Significant Ecological Areas (SEAs). SEAs, originally developed by Los Angeles County in the 1970s, are land and water areas that are considered valuable to plant and animal communities, some of which may be threatened or endangered. More specifically, SEAs are areas where the County requires development to be designed around existing important biological resources (in contrast to areas where development is prohibited completely).

The SEA proposed for the Santa Clara River encompasses the entire Los Angeles reach of the Santa Clara River and functionally covers 5,410 acres of land considered severely degraded (Los Angeles County General Plan Update 2007). The proposed Santa Clara River SEA supports many regional biological values, including habitat for endangered species, important migration corridors, and essential habitat for life-stages of various species (AMEC 2005). Management recommendations for the SEA include ensuring development is outside the existing floodplain to minimize the need for future bank stabilization, critical reviews of proposals for new or increased groundwater extraction to prevent dewatering of riparian vegetation, and

implementing of best management practices (BMPs) for agricultural activities (AMEC 2005).

Upper Santa Clara River Watershed Arundo/Tamarisk Removal Plan

The Ventura County Resource Conservation District (VCRCD), with funding from the State Water Resources Control Board (SWRCB), is leading this programmatic effort to map, remove, and monitor arundo and tamarisk *(Tamarix* spp.) in the Santa Clara River watershed (impacts associated with arundo and tamarisk infestations are discussed in more detail in Section 2.4.1). Efforts in the upper watershed began with mapping of arundo and tamarisk along the upper Santa Clara River and its tributaries, and the completion of an Environmental Impact Report (EIR) to assess and mitigate the impacts of large-scale, programmatic arundo and tamarisk removal projects (VCRCD 2006a).

In 2006, the Upper Santa Clara Arundo River Watershed Removal Program (SCARP) Long-term Implementation Plan (VCRCD 2006b) was completed. This plan includes a programmatic California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA) document and related environmental documentation and permits for the implementation, maintenance, and monitoring of arundo and tamarisk removal projects within the riparian corridor of the upper Santa Clara River watershed. Any agency or organization that wishes to undertake an arundo and/or tamarisk removal project in the upper watershed may apply to the VCRCD to use the programmatic SCARP environmental documents and permits. To be eligible for the programmatic SCARP documents, removal projects must use methods described in the SCARP, be coordinated through the VCRCD, and include a minimum of one year of post-project monitoring (N. Cabanting, Wildscape Restoration, pers. comm., 2007). It is anticipated that the first removal projects under SCARP will be implemented in 2008. Priority will be given to projects located in the upper reaches of the mainstem and tributaries (N. Cabanting, Wildscape Restoration, pers. comm., 2007).

More recently, the VCRCD has begun efforts to expand the SCARP to the lower watershed. The arundo and tamarisk mapping conducted in the upper watershed will be combined with the mapping conducted for the Parkway project in the lower watershed (Stillwater Sciences and URS Corporation 2007). Eventually, a new EIR will be completed for the lower watershed and a similar suite of environmental documents offered through the current SCARP will be available to agencies and organizations conducting arundo and tamarisk removal projects in the lower watershed. Removal of arundo and tamarisk, in addition to other non-native invasive plant and animal species is one of the Parkway project restoration strategies developed in Section 4.4 of this report. Coordination between the SCARP and Parkway project efforts should greatly enhance the feasibility and effectiveness of arundo and

tamarisk removal projects in the lower watershed. In addition, removal projects coordinated through the SCARP in the lower watershed should be informed by current research on the biological control of arundo funded by the Santa Clara River Trustee Council.

2 THE LOWER SANTA CLARA RIVER SYSTEM

This chapter describes a conceptual model, based on existing literature, data, and recent Feasibility Study investigations, of the processes that shaped historical conditions in the lower Santa Clara River and how watershed impacts have changed those processes and conditions in ways that result in the riparian corridor we now see. A conceptual understanding of historical watershed conditions is critical in determining *how the ecosystem **once** functioned*, while an understanding of present conditions reveals *how the ecosystem functions **now***. The integration of historical information over time helps form the foundation for determining how the changes in ecosystem function occurred. Understanding each of these elements makes it possible to hypothesize the potential future trajectory of watershed conditions and thus can help guide sustainable corridor restoration strategies.

2.1 Historical River System Conditions

In their analysis of historical steelhead populations, Boughten *et al.* (2006), describe the probable baseline conditions of southern California steelhead-bearing rivers prior to 1894–1904 when the first USGS maps were developed for the area. This and other information on the historical conditions of southern California watersheds in general, and the Santa Clara River in particular (*e.g.*, Freeman 1968, Schwartzberg and Moore 1995), provide insight into the physical processes and biological resources of the Santa Clara River prior to widespread European ranching and colonization.

Our current understanding of historical conditions in the Santa Clara River will be greatly enhanced by the results of the Ventura County Historical Ecology Study, which is a collaborative effort being led by the San Francisco Estuary Institute and funded by the Coastal Conservancy. This study is scheduled to be completed in early 2009 and will synthesize historical data resources to create a practical understanding of fluvial, riparian, and wetland resources prior to significant Euro-American modification.

Historical photograph of the lower Santa Clara River watershed (circa 1900).
(Photo courtesy of Ventura County Watershed Protection District)

Before widespread European ranching and colonization (approximately pre-1820, following establishment of the first mission in 1782), the lower Santa Clara River may have had perennial stream flow in all reaches except in the driest years, a higher channel elevation, and a reasonably continuous and broad riparian forest. There are historical reports that describe perennial stream flow for several southern California rivers, including the Santa Ana, Santa Margarita, and San Luis Rey, that are now intermittent as a likely result of water impoundment, diversion, and groundwater pumping (Everman 1886, Cooper 1887, and Hutchinson 1965 as cited in Nautilus Environmental 2005, Schwartzberg and Moore 1995, Boughten *et al.* 2006). In addition, it has been argued that the maintenance of grasslands by Native Americans increased water yield (in contrast to chaparral or sage-scrub habitats) and contributed to historical perennial stream flow (Keeley 2002a and 2002b, as cited in Boughten *et al.* 2006). In the Los Angeles River basin, perennial stream flow resulted in lower water temperatures and supported suites of aquatic species, such as red-legged frog, threespine stickleback, freshwater lamprey, and freshwater shrimp, which are now extinct or are primarily found only in northern California (Mendenhall 1908, McGlashan 1930 and Miller 1961, as cited in Boughten *et al.* 2006).

Prior to removal of riparian vegetation for ranching and other land uses, the Santa Clara River flowed at elevations closer to the floodplain surface (Freeman 1968, Boughten *et al.* 2006). Boughton *et al.* (2006) suggest that prior to the first USGS maps in the late 1800's and early 1900's, many southern California river channels had already experienced significant incision as a result of vegetation clearing, ranching, other human land alteration, and climatic events. Similarly, Faber *et al.* (1989) cites analysis of historical aerial photographs that supports the idea that much of the middle and higher elevation floodplain surfaces along the lower Santa Clara River had already been converted to agriculture by 1927.

These land uses, and possible climatic conditions of the time, resulted in decreased stream bank stability and increased stream power that allowed high flows to entrench the channel. Prior to incision, the Santa Clara River channel would have supported higher groundwater elevations and more frequent floodplain inundation under lower flows (*i.e.*, floodplain inundation would often have occurred at lower discharges and with lower velocity flows compared to current conditions). These channel conditions would have facilitated the recruitment and establishment of large tracts of riparian vegetation. In addition, prior to incision and the increased supply of fine sediment caused by watershed land clearing, rivers like the Santa Clara likely supported a far greater proportion of gravel and cobble substrates in their lower reaches than under present-day conditions (Boughton *et al.* 2006). These substrates would have provided suitable spawning habitat for fish species along

a greater extent of the river, as well as providing habitat for benthic macroinvertebrates on which fish feed.

Perennial stream flow, higher channel and groundwater elevations, and an unconfined floodplain likely supported a diverse mosaic of woodland, scrub, herbaceous and seasonal wetland habitats. Simons, Li & Associates (1983) report that the Santa Clara River floodplain was historically as much as two miles wide in its lowermost reaches. The riparian area likely supported dense, multi-storied stands of broadleaf trees, including cottonwood, sycamore, and various willows, that extended from a few to several miles wide (Faber *et al.* 1989, Schwartzberg and Moore 1995, Boughton *et al.* 2006). Prior to any vegetation removal, the extent and composition of riparian vegetation in the Santa Clara River watershed would have supported a diversity of native animal species (Knopf *et al.* 1988, RHJV 2004). In addition, the greater extent of riparian vegetation would have provided a higher degree of ecosystem services such as filtering run-off, shading the river, and providing energy from leaf litter and woody debris that serves as habitat for instream organisms (Gregory *et al.* 1991, Malanson 1993, Naiman and Decamps 1997) (see Figure 1-3).

2.2 Impacts to & Changes in River System Conditions

Historical land-use change and the evolution of water and river management practices within the Santa Clara River watershed can be grouped into five distinct historical periods (Table 2-1, Figure 2-1) that provide a conceptual understanding of how ecosystem changes in the watershed have occurred.

Beginning in the 1820s, floodplain forests were cleared to prepare the land for grazing and farming and for fuel. In the past several decades, vegetation was removed to increase flood conveyance. The removal of riparian vegetation dramatically decreased habitat availability for native plants and animals. Removal of riparian and adjacent upland vegetation is also likely to have caused significant changes to rainfall–runoff relationships as deep-rooted native perennial grasses in the valleys and hillslopes were replaced by shallow-rooted, non-native annual grass species, which are less able to resist soil erosion. Drought in the 1860's caused a shift from traditional cattle grazing to sheep, probably accelerating the removal of vegetation and subsequent erosion and facilitating the invasion of non-native annual grasses. The expansion of farming in the Santa Clara River valley during the continued drought of the 1870s probably further contributed to erosion and changes in runoff characteristics. The effects of increased grazing and farming in the watershed is suspected of promoting severe channel erosion throughout the watershed following the 1884 flood, which ultimately resulted in tributaries devoid of large, stabilizing vegetation prone to future incision and erosion.

Table 2-1. Historical periods characterizing land use and impacts to the Santa Clara River watershed.

Period	Description
Pre-European Colonization *prior to 1820*	Natural events (including wildfires) are suspected of acting relatively independent of human activities, with the exception of Native American grassland management.
Ranching and Colonization *1820–1890*	Significant European arrival in the watershed, extensive riparian vegetation removal, the introduction of livestock, and resultant changes in vegetation cause loss of riparian habitat, changes in rainfall-runoff relationships and hillslope erosion rates, and associated decreases in the quality of instream aquatic habitat.
Irrigation and Diversions *1890–1955*	Floodplain agriculture necessitates tributary diversions and the construction of small dams, causing changes in surface water and groundwater dynamics, potentially increasing the "flashy" nature of the river and decreasing water quality through agricultural runoff.
Dams and River Modifications *1955–1990*	Completion of major dams, construction of an extensive network of levees and bank protection, and intensive river and floodplain aggregate mining result in a notable decrease in runoff and sediment, an increase in flood flow confinement and channel incision, associated decreases in aquatic habitat connectivity, and continued decreases in water quality.
Urbanization *1990 to present*	Continued rapid population increases in the watershed cause large-scale conversion of floodplain agricultural land to residential developments, further affect rainfall-runoff relationships in the watershed and potentially contribute to greater river erosion, further water quality degradation from urban runoff, and continued decreases in availability of aquatic habitat.

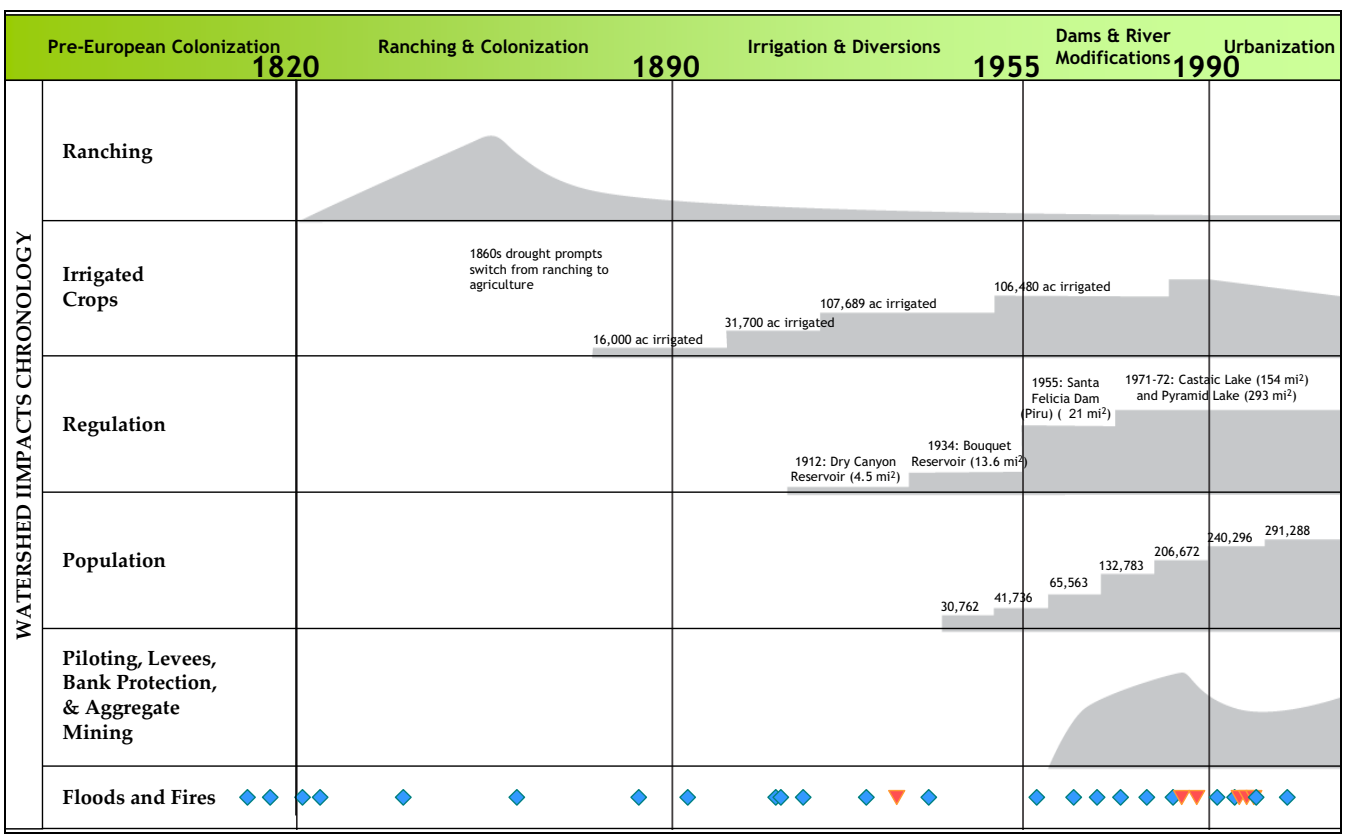

Figure 2-1. Chronology of impacts to the Santa Clara River watershed.

The post-1890 period is characterized primarily by the expansion of water-intensive agriculture: first sugar beet and then citrus crops (particularly following the First World War), which required large-scale irrigation. In this period, irrigation using surface flow from the Santa Clara River was supplemented by pumped groundwater supplies. Following the formation of the Santa Clara River Protective Association (now United Water Conservation District) in 1925, diversions began first from Piru Creek (1930) and then Santa Paula Creek (1931). Irrigated acreage in Ventura County increased from 31,700 ac in 1919 to 107,700 ac in 1949. The impact was an initial reduction in baseflow within the Santa Clara River, and a subsequent lowering of the groundwater table due to pumping (see Freeman 1968). Lowering of groundwater in particular may have led to the degradation of mature riparian vegetation (in areas where riparian vegetation was not replaced by orchards), which is reliant primarily on groundwater during the summer dry season.[2] Large floodplain areas with extensive riparian vegetation may have attenuated floods along the Santa Clara River; the removal and degradation of large riparian stands would have therefore increased the "flashy" response of the river to flood events. The removal of riparian vegetation would have also resulted in decreased complexity of floodplain habitat and increased water temperature.

By 1912, the first dam in the watershed had been constructed in Dry Canyon, located in the eastern portion of the watershed (the dam was subsequently decommissioned due to leakage issues). In 1926, the St. Francis Dam was completed on San Francisquito Creek (also in the eastern watershed); however the dam failed catastrophically in March 1928, resulting in one of the largest and most tragic dam failures in United States history. The long term effects of the St. Francis Dam disaster on the morphology of the Santa Clara River are unknown, but are potentially significant and ongoing. From 1955, with the completion of the 200 ft high Santa Felicia Dam on Piru Creek (regulating 421 mi^2), the watershed was subjected to an increasing amount of direct flow regulation and channel manipulation. At present, approximately 34% of the watershed is regulated by large dams and storage reservoirs, reducing runoff to the lower watershed by approximately 25% (Warrick 2002) and suspended and bedload delivery to the mainstem by approximately 21% (Brownlie and Taylor 1981,Warrick 2005). The effects of reduced sediment yield are generally most severe immediately downstream of dams, where channel incision is often observed due to more effective erosion of the channel bed by sediment-starved water (*e.g.,* Williams and Wolman 1984). Construction of multiple large dams and water diversions, including the Vern Freeman Diversion Dam on the mainstem and various dams and diversions

[2] Historical groundwater levels and the magnitude of groundwater table lowering are not well documented. It is anticipated that the Ventura County Historical Ecology Study will improve understanding of these critical factors.

on major tributaries, also interrupted longitudinal aquatic habitat connectivity, decreasing the ability of the lower Santa Clara River to sustain a spatially distributed, diverse community of aquatic organisms including anadromous southern California coast steelhead, unarmored threespine stickleback (*Gasterosteus aculeatus williamsoni*), and pacific lamprey (*Lampetra tridentata*).

The lower Santa Clara River floodplain and channel were increasingly modified—first in 1959 with the dredging of pilot channels; in 1961 with the construction of the extensive levee system from South Mountain to Highway 101; and, following the flood of 1969, construction of various additional levees, groins, and bank protection projects that continue to the present day in conjunction with urban expansion onto the floodplain. By design, the levees constructed along the Santa Clara River have confined high flows to the active channel width and have significantly reduced the riparian area historically inundated by large floods. The levees have also reduced the effective flow width during floods and stabilized the river's planform, resulting in an alteration of channel morphologic development and sediment transport. Furthermore, the levees have effectively reduced the flood water storage capacity of the river, thus forcing the majority of high flows to be conveyed solely within the active channel rather than being allowed to spread out upon the floodplain (Stillwater Sciences 2007a).

During high flows, the narrowing of the active flow width combined with the increase in flood water volume moving through the river channel due to levee confinement has increased flood stages and velocities. Thus, there has been greater potential for bed and bank scour. Since the levees were first constructed in 1961, a pattern of channel bed lowering, or incision, has developed particularly in the downstream-most reaches, which are confined by the majority of the river's levees (see Section 2.3.7). The presence of multiple flood-control structures and reinforced levees also interrupted lateral habitat connectivity, decreasing the degree of linkage between instream aquatic habitat and riparian vegetation and/or freshwater wetlands in the floodplain. During this period, alterations to natural geomorphic processes would have impacted the variety of substrate, water velocity, water temperature, chemical (*e.g.*, salinity, dissolved oxygen), and cover conditions, which vary seasonally and spatially from the headwaters to the ocean, and which are necessary to provide diverse aquatic habitat.

Of great importance to the channel morphology is the instream aggregate extraction that began with small-scale operations in the early twentieth century and accelerated during the 1970's and 1980's, coinciding with increased rates of channel incision upstream of aggregate mining pits in this period. In 1986, the creation of the Ventura County 'red line', restricting the depth of instream aggregate extraction, marked the beginning of the decline of in-

Looking upstream to Vern Freeman Diversion Dam (2003).
(photograph by Stillwater Sciences)

stream mining in the lower river. The construction of the permanent Vern Freeman Diversion Dam in 1992, at the approximate historical bed level, allowed mainstem bed elevations to recover upstream of the dam, although local scour has continued to occur downstream. Aggregate mining was identified as the greatest anthropogenic factor in the morphodynamics of the lower Santa Clara River (Simons, Li & Associates 1983), affecting channel incision dynamics that can undermine in-channel structures and potentially interrupt sediment supply for beach replenishment (Noble Consultants 1989).

The primary new human influence in the watershed is the continuation of rapid population increases in the watershed, causing large-scale conversion of floodplain agricultural land to residential, transportation, and municipal infrastructure. The human population in the watershed has increased approximately ten-fold since the 1940's, with much of the growth occurring adjacent to the mainstem corridor. Increases in population and urbanization will undoubtedly continue into the foreseeable future, and they are likely to have an increasingly noticeable effect on geomorphic and biological processes in the lower river corridor. Typical impacts of urbanization include further construction of levees and bank protection that can alter bed and bank erosion dynamics (as mentioned above), increased impervious area that can lead to 'flashy' flood events (*i.e.*, higher peak discharges and shorter time-to-peak discharge) and increased channel erosion. Additionally, decreases in water quality and flow restrictions create conditions that can fail to meet aquatic species' preferences for flow velocities, flow depths, and water temperature, and within which organisms can experience chronic (or periodically acute) toxicity.

In the future, the Santa Clara River is likely to be affected by changes in temperature, precipitation, and sea-level resulting from global warming. In addition to predicted changes in temperature and precipitation (see Section 2.3.2), climate change may alter the frequency and/or intensity of severe storms and droughts, as well as wildfires and flooding. The effects of these altered processes, driven by shifts in climate patterns, are difficult to predict

particularly when considered in conjunction with human impacts to the watershed.

2.3 Key Physical Attributes

Geomorphic processes in the Santa Clara River are dominated by extreme events associated with the river's highest flows, and they are strongly influenced by the geologic, meteorologic, and fire regime context of the watershed. These events transfer water and sediment from the hillslopes to the estuary and nearshore waters, and they are integral to changes in form of the mainstem Santa Clara River and its floodplain over time. The exchange of sediment between the river channel and floodplain during flood events (*i.e.*, episodes of erosion and deposition) determines the hazards and assets possessed by the river corridor: the hydrologic and geomorphic processes that create "hazards," such as flooding, unwanted bed and bank erosion, and deposition, are the same processes that help sustain river ecosystems by creating such "assets" as aquatic and riparian habitat diversity. Understanding physical attributes and processes in the Santa Clara River watershed is, therefore, a necessary precursor for understanding the hazards and assets of the lower river corridor that are critical in determining the feasibility of proposed restoration strategies and the development and maintenance of habitats that support native plant and animal species.

2.3.1 Tectonics

The Santa Clara River watershed is located within the San Andreas Fault system, a geologically active area that forms the dynamic boundary between the Pacific and North America tectonic plates. The position of unchanneled valleys, creeks, and the Santa Clara River itself are strongly influenced by geologic structure and the location of active faults (Figure 2-2). Below the confluence with Sespe Creek, the Santa Clara River roughly follows the axis of a west-trending synclinal valley, which is bounded by active strands of the San Cayetano Fault (Rockwell 1988) to the north and the Oak Ridge Fault (Azor *et al.* 2002) to the south. Convergence along this axis has led to rapid uplift in coastal and interior mountain ranges throughout the region (Orme 1998, Blythe *et al.* 2000, Duvall *et al.* 2004) and persistent regional geologic instability since about 28 million years ago has exposed a wide variety of highly deformed, fractured, and faulted rock types in the Santa Clara River watershed (Yeats 1981, Rockwell *et al.* 1984, Rockwell 1988), contributing to high bedrock erodiblity throughout the watershed. For example, the sedimentary bedrock along the mainstem valley flanks is often poorly consolidated, intensely folded, and has steeply tilted beds, making it very susceptible to landsliding (*e.g.*, Harp and Jibson 1996) and erosion by dry raveling (Scott and Williams 1978). Even areas underlain by granite, gneiss, and schist (which are normally thought to be relatively resistant to erosion) have also

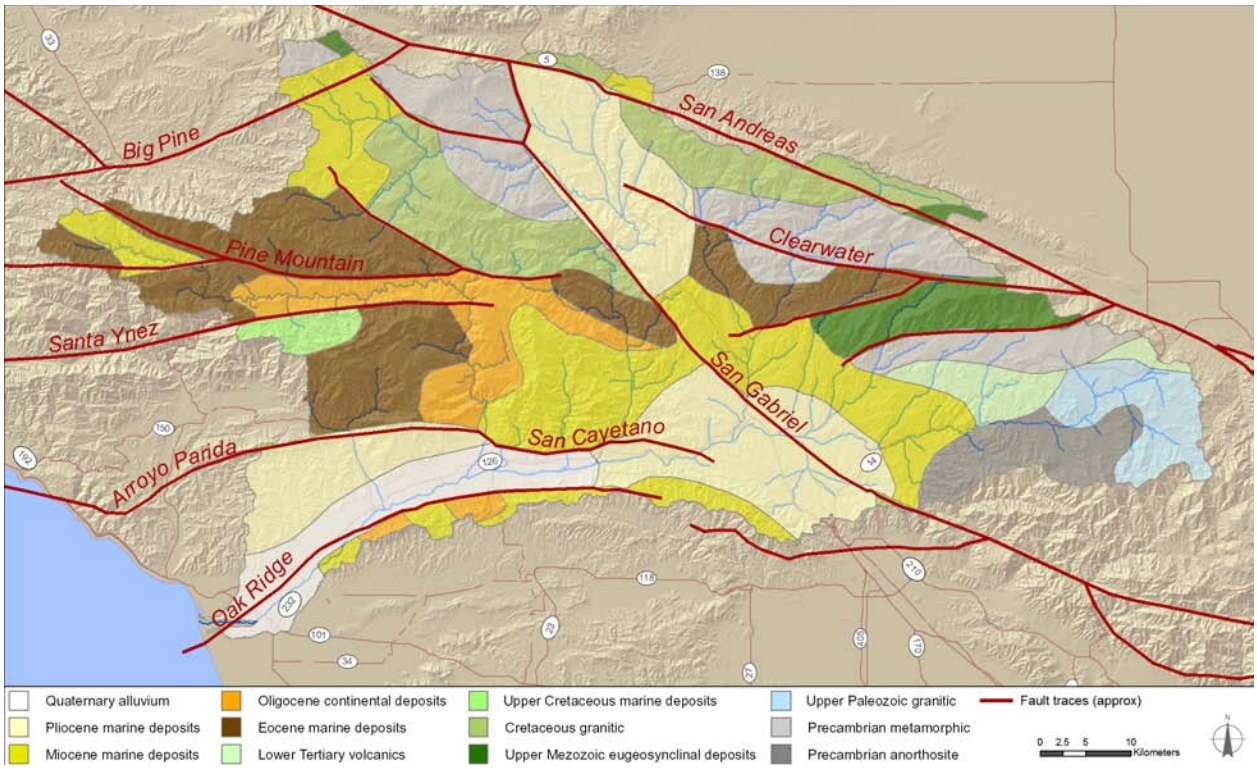

Figure 2-2. Rock units and faults within the Santa Clara River watershed.

been described as being highly erodible (*e.g.*, Scott and Williams 1978, Wells *et al.* 1987) due to extensive deformation and fracturing.

2.3.2 Climate

The Santa Clara River watershed experiences a semi-arid Mediterranean-type climate, with cool wet winters and warm dry summers. Proximity to the Pacific Ocean moderates both seasonal and diurnal temperatures, air moisture, and precipitation (Figure 2-3). Air moisture is greatest at the coast and decreases to near-desert conditions towards the eastern watershed boundary. Most precipitation occurs between November and March and varies significantly throughout the watershed due to topographic features (Figure 2-3). For example, average annual rainfall is more than 34 inches in the mountainous headwaters of Sespe Creek, while only about 8 inches in the drier eastern portions of the watershed near the Mojave Desert (PWA 2003).

The climate of the Santa Clara River watershed is also affected by the El Niño-Southern Oscillation (ENSO), a climatic phenomenon which is characterized by warming and cooling cycles (oscillations) in the waters of the eastern equatorial Pacific Ocean. ENSO events typically have 1–1.5 year durations, a 3–8 year recurrence interval, and are related to changes in atmospheric circulation, rainfall, and upper ocean heat content (see Deser *et al.* 2004 and references contained therein). In southern California, El Niño years are

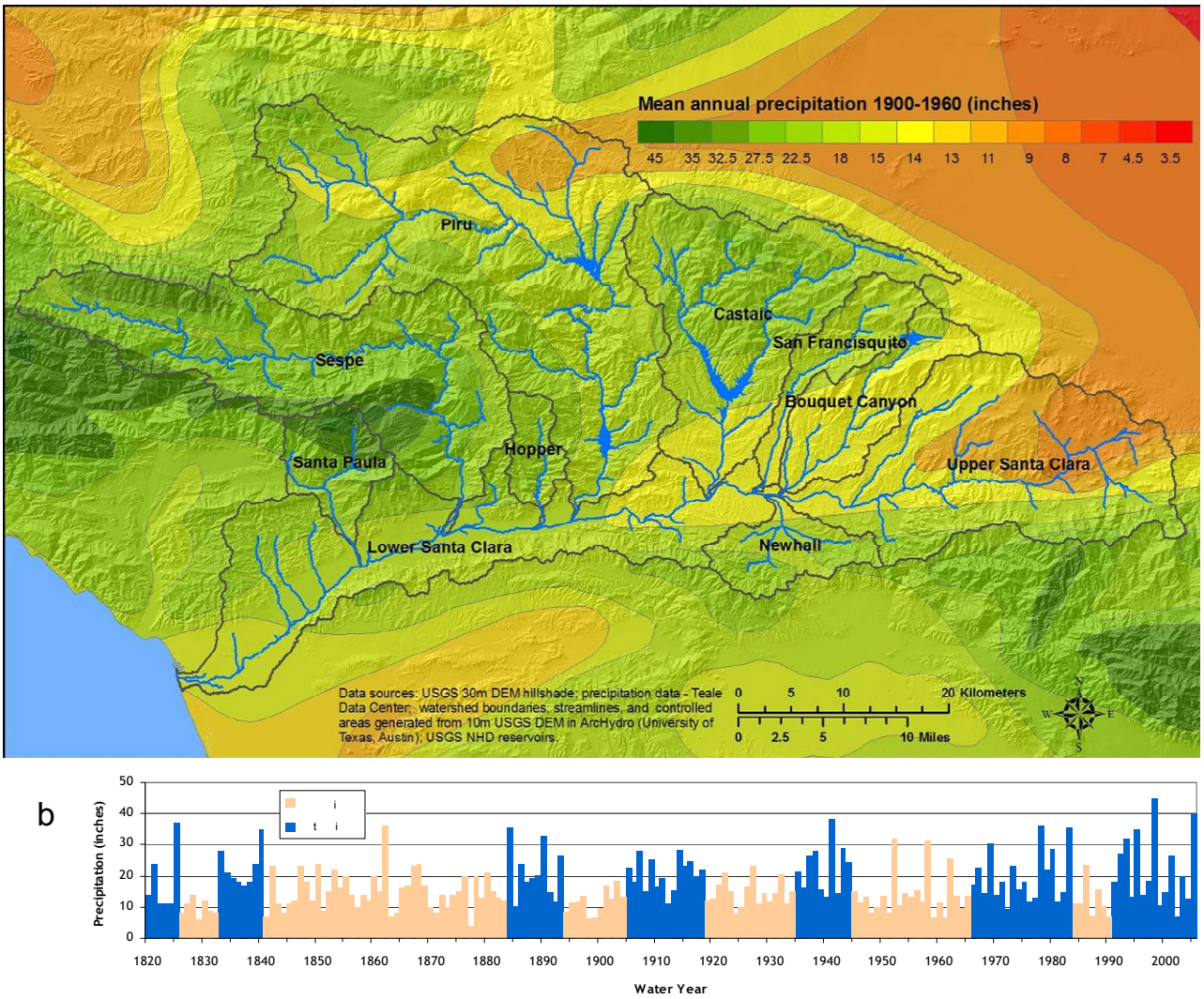

Figure 2-3. a) Distribution of mean annual precipitation (1900 to 1960); b) Annual precipitation at the Santa Paula Creek gage (VCWPD no. 245) and the multi-year cycle of wet and dry periods based on data and narrative accounts from Lynch (1931) and Freeman (1968).

characterized by relatively high rainfall intensities, with rivers and streams exhibiting higher annual peak flow magnitudes than they do in non-El Niño years (Cayan *et al.* 1999, Andrews *et al.* 2004). For El Niño years there is a greater than 70% probability of peak flow exceeding 40,000 cfs near the mouth of the Santa Clara; for a non-El Niño year the probability of such a flow is less than 10%. A recent wet-period ENSO cycle (from 1969 to the present) has been marked by strong El Niño years every 3–7 years, a relative increase in the number of large storms, and mean sediment fluxes for Southern California rivers (from the Pajaro River south to the Tijuana River) that have been approximately five times greater than during the preceding dry period (1944–1968) (Inman and Jenkins 1999).

Predictions of climate change in California in the next century include warmer winters (by 5–6° F), slightly warmer summers (by 1–2° F), and increased winter precipitation (primarily as rain rather than snow), particularly in the mountains (Field *et al.* 1999). ENSO events may increase in intensity and/or frequency (Field *et al.* 1999). In southern California the change in precipitation timing is expected to lead to increased winter runoff and decreased summer stream flow. Climate change is also expected to have indirect effects on ecosystems, including changes in the frequency and/or intensity of extreme weather events such as severe storms and droughts, and ecological processes, such as wildfires, flooding, and disease and pest outbreaks.

2.3.3 Fire Regime

Historical records indicate that much of the Santa Clara River watershed has burned at least once since the late 19th century, with many areas of the lower watershed, including South Mountain and the lower Sespe, Hopper, and Piru creek watersheds, burning up to nine times since 1878 (CDF 2007) (Figure 2-4). Fires in 2003 burned 119,105 ac or 11.4% of the watershed slopes, and the Day Fire in 2006 burned 162,842 ac, mostly in the Santa Clara River watershed. Sediment production within the Santa Clara River watershed is significantly affected by the 'flood–fire' sequence, in which post-fire winter

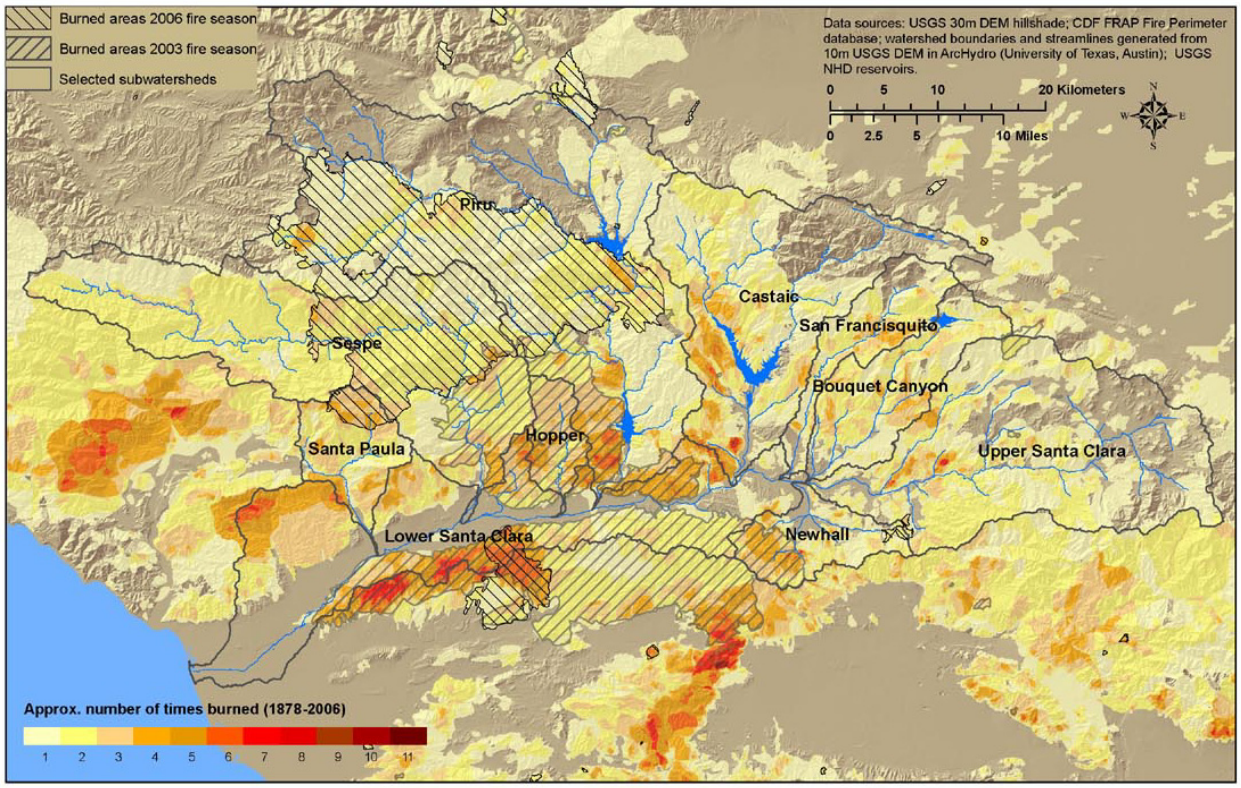

Figure 2-4. Fire reoccurrence within the Santa Clara River watershed since 1878 and extent of the 2003 and 2006 fire seasons.

rains lead to increased runoff and accelerated erosion, which in turn results in debris flows, landslides, and floods.

Although riparian ecosystems generally function as barriers to wildfire, the fires in 2003 burned large expanses of riparian habitat along the Santa Clara River in what appears to be an arundo-fire regime cycle (Bell 1997, Dudley 2000, Coffman 2007). Arundo accumulates large quantities of biomass (dense thickets of dead and live stalks) that increases both the susceptibility of the riparian corridor along the Santa Clara River to fire, and the risk of fire spreading to surrounding shrublands, towns, and agriculture (Coffman 2007). Immediately following fires, elevated soil ammonium-nitrate and phosphorus levels and lack of competition from native species stimulates arundo growth rates (Coffman 2007). Within one year following the burning of the riparian corridor in 2003, arundo had reached 99% cover in some burn areas and had densities nearly 20 times higher and productivity 14–24 times higher than native plants (Coffman 2007). The resulting extensive and dense stands of arundo further increase the susceptibility of the riparian corridor to subsequent fire.

2.3.4 Hydrology

Consistent with other rivers in the region, the Santa Clara River watershed experiences highly variable annual rainfall and peak flows. Generally, flows in the river are relatively small: 75% of the time flows are less than 150 cfs at the Montalvo gage (approximately 4.5 mi upstream of the mouth) and 50% of the time flows are less than 10 cfs (URS 2005). However, large peak flows associated with winter storm events exceed 100,000 cfs once every 10 years on average (URS 2005) (Figure 2-5). The two largest peak flows on record occurred during the 1969 flood event (165,000 cfs) and the more recent 2005 flood event (136,000 cfs). During the rainy season, flows can increase, peak, and subside rapidly in response to high intensity rainfall, with the potential for severe flooding under saturated or near-saturated watershed conditions (Figure 2-5). Between winter rainfall events in wet years, the river may exhibit continuous baseflow to the ocean from residual watershed discharge; in dry years, flow may be intermittent.

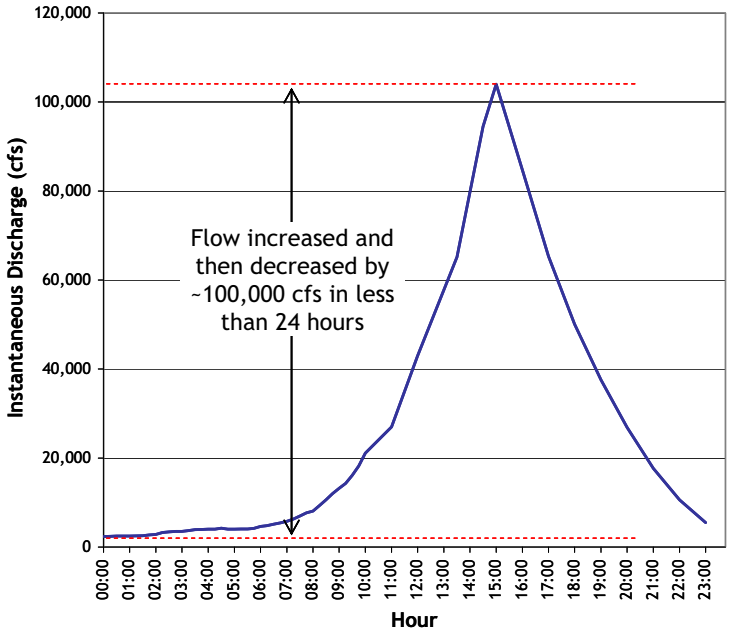

Figure 2-5. Daily flow hydrograph at the Montalvo gage (USGS 11114000) from February 12, 1992.

During the dry summer season, flows in the mainstem and tributaries are intermittent or non-existent, depending primarily

on areas of rising groundwater or inflows from dam releases or other anthropogenic sources, such as irrigation runoff and treated wastewater effluent. Groundwater discharges to the mainstem Santa Clara River occur when groundwater levels are high. In the lower Santa Clara River, two geologic features are important to surface water-groundwater interactions on the mainstem—the Piru and Fillmore narrows (located in the County Line Reach [11] and Above Santa Paula Reach [5], respectively; see Figure 1-2). In these locations, constrictions in the width of unconsolidated deposits, combined with subsurface bedrock controls, cause groundwater to rise and discharge to the Santa Clara River, depending on groundwater levels and surface flow conditions (AMEC 2005, URS 2005). In areas away from the bedrock controls, surface flow is lost through the highly permeable bed materials to groundwater.

Tributaries of the Santa Clara River include Santa Paula, Sespe, Hopper, Piru, Castaic, San Francisquito, and Bouquet Canyon creeks. These tributaries, in addition to the upper Santa Clara River (upstream of the Los Angeles County line) provide approximately 85% of the flow that exits the mouth of the Santa Clara River (URS 2005). The remaining flow is delivered from numerous barrancas (small, generally incised tributary streams) and unnamed ephemeral creeks. As in the mainstem, flows in the tributaries are relatively small except during high-intensity, short-duration storm events. On average, storm-induced flow exceeds 41,000 cfs in Sepse Creek, 18,000 cfs at the Los Angeles County line, 8,500 cfs in Santa Paula Creek, and 500 cfs in Piru Creek approximately once every 10 years (URS 2005) (Figure 2-6). Due to Santa Felicia Dam, flow in Piru Creek is highly regulated and varies much less than the other main tributaries (*e.g.*, daily peak discharge within Piru Creek below Santa Felicia Dam has ranged from 20 to 900 cfs between 1955 and 2003).

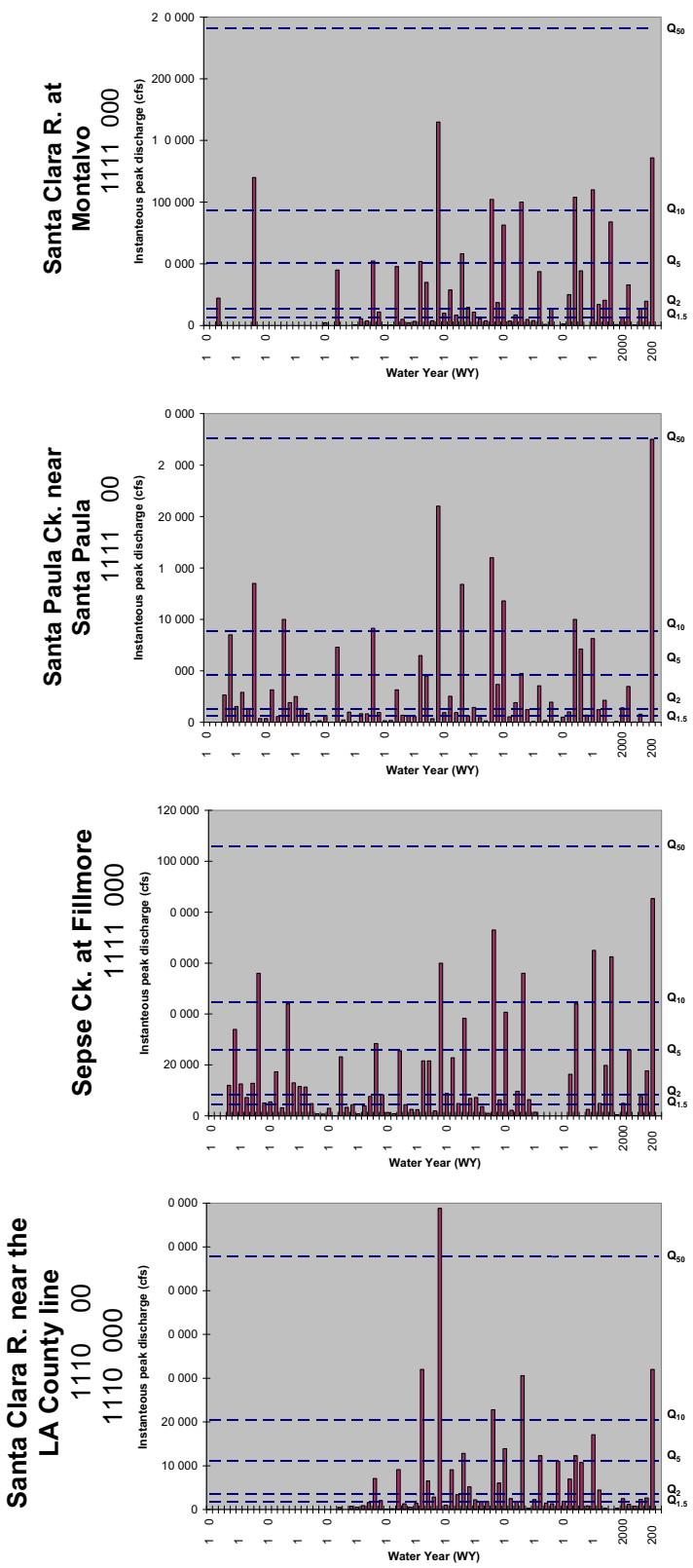

Figure 2-6. Annual maximum discharge for the four main USGS gages in the lower Santa Clara River watershed. Years with no available data are plotted as a zero value.

More than one-third of the watershed area lies upstream of dams and debris basins that regulate water and/or sediment discharge to the lower river corridor. Major dams include Santa Felicia Dam on Piru Creek and Castaic Dam on Castaic Creek (see Figure 1-1). Throughout the year, controlled releases of water from Piru Reservoir supplement surface flows in the river between the confluence with Piru Creek and Vern Freeman Diversion Dam. Additional flow is supplied from water reclamation plant discharges and imported water runoff from the upper watershed in the middle reach from the vicinity of Santa Clarita in Los Angeles County down to the Ventura County line.

Water in the estuary is supplied predominantly by upstream flow from the Santa Clara River and effluent from the Ventura Water Reclamation Facility (waste water treatment plant), with local agricultural runoff and wave overwash also contributing to the overall supply (Swanson *et al.* 1990, as cited in ESA 2003). The Ventura Water Reclamation Facility discharges an average of 7.2 million gallons per day of treated wastewater into the estuary (Nautilus Environmental 2005), which is equivalent to an average year-round stream flow of approximately 11 cfs. During the winter months when river flows dominate and generally maintain an open mouth, effluent discharge is a relatively small portion of total discharge volume. However, the average daily effluent discharge is far more than the average summer and fall streamflow that would be expected from an unregulated southern California river with a closed mouth (ESA 2003). Discharge of treated effluent from the wastewater treatment plant while the mouth is closed can cause the water level of the estuary to rise above the sand barrier, causing the barrier at the mouth to breach at a time of year when this would not naturally occur (Swanson *et al.* 1990, as cited in ESA 2003).

2.3.5 Sediment Production

Rapid tectonic uplift rates, frequent high-intensity storm events, and erodible bedrock lead to extremely high rates of sediment production from hillslopes in the Santa Clara River watershed. The Santa Clara River's location within the San Andreas Fault zone also makes its slopes especially prone to earthquake-induced landsliding. In 1994, the magnitude 6.7 Northridge earthquake triggered nearly 7,400 landslides in the Santa Clara River watershed (Figure 2-7). Over the long term, the supply of sediment to channels is thought to be fairly continuous (Scott and Williams 1978), with wet-season contributions from overland flow, landslides, and soil slumps, and dry-season contributions from dry ravel. Over the short-term, sediment is delivered from tributaries to the mainstem more episodically, in flows associated with big storms, and also in moderate storms that follow fires (Florsheim *et al.* 1991, Wells 1981). Naturally high rates of sediment production are exacerbated by post-fire soil rilling and human land uses in the watershed.

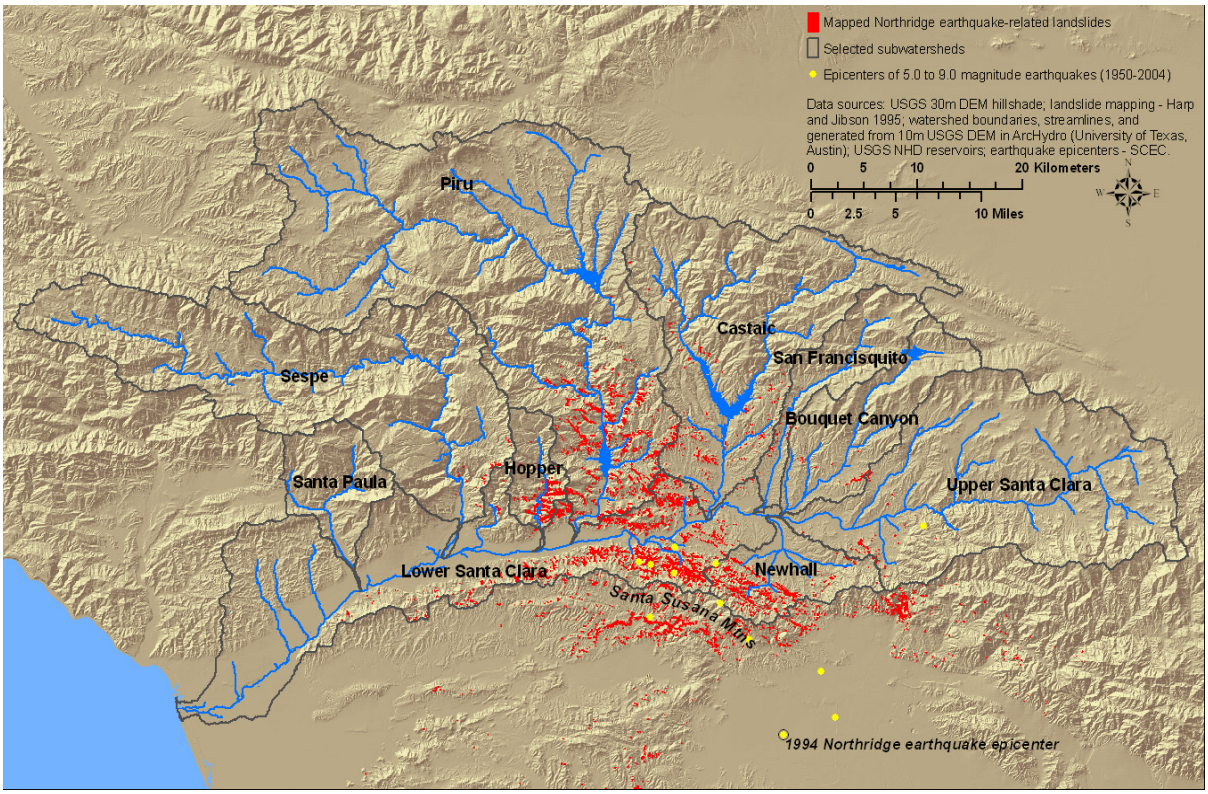

Figure 2-7. Landslides triggered by the 1994 Northridge earthquake (magnitude = 6.7).

2.3.6 Sediment Transport

Sediment transport processes in the Santa Clara River are dominated by extreme events associated with the river's highest flows. For instance, an estimated 55% of the roughly 63.5 million tons of sediment that passed the USGS gage at Montalvo near Highway 101 between 1968 and 1975 was transported during high flows in just two days during two separate floods of record in January and February 1969 (Williams 1979). Analysis of the Montalvo gage data for the period 1968–1985 indicates that about 94% of the suspended load was transported by storm runoff in just 57 days, or 1% of the nearly 5,700 days covered by the flow record. A more recent study concludes that for the period 1928–2000, 25% of the total sediment discharge occurred in just four days (Warrick 2002).

Bedload particle sizes at the Montalvo and Los Angeles County line gages, measured during low to moderate flow, consist mainly of fine and coarse sand, with fine gravel-sized particles also present at higher flows. Bedload particle sizes in Sespe Creek at Fillmore are generally coarser than the sediment in the mainstem Santa Clara River, and range from coarse sand to medium gravel.

The Santa Clara River discharges a considerable amount of sediment through the mouth/estuary complex, primarily during high-intensity low-recurrence storm events. In general, the coarser sediment (coarse sand and larger) that is delivered from the Santa Clara River during storm events contributes to the building of near-shore and offshore deltas, which in turn provides sediment for littoral transport (and down-coast beach deposition) and supplies sediment that builds the barrier beach and causes mouth closure during periods of low river discharge. The magnitude of sediment transport out of the watershed depends on whether the storm causes net bed aggradation or incision throughout the mainstem Santa Clara (which is a function of the relative flow and sediment contribution from Sespe Creek (Figure 2-8).

Overall, the yield of sand and gravel from the Santa Clara River has been suggested to have decreased by approximately 25% from pre-development rates (Brownlie and Taylor 1981). The high discharge events in the Santa Clara River that deposit sediment to the offshore delta are dominated by 'hyperpycnal flows' in which the river discharge is denser than ocean water due to high suspended sediment concentration (Warrick 2002, Warrick and Milliman 2003). The density and velocity associated with hyperpycnal flows from the Santa Clara River cause the suspended sediment to pass through the estuary and nearshore zone, and be either temporarily deposited on the offshore delta or lost to the Santa Barbara Channel.

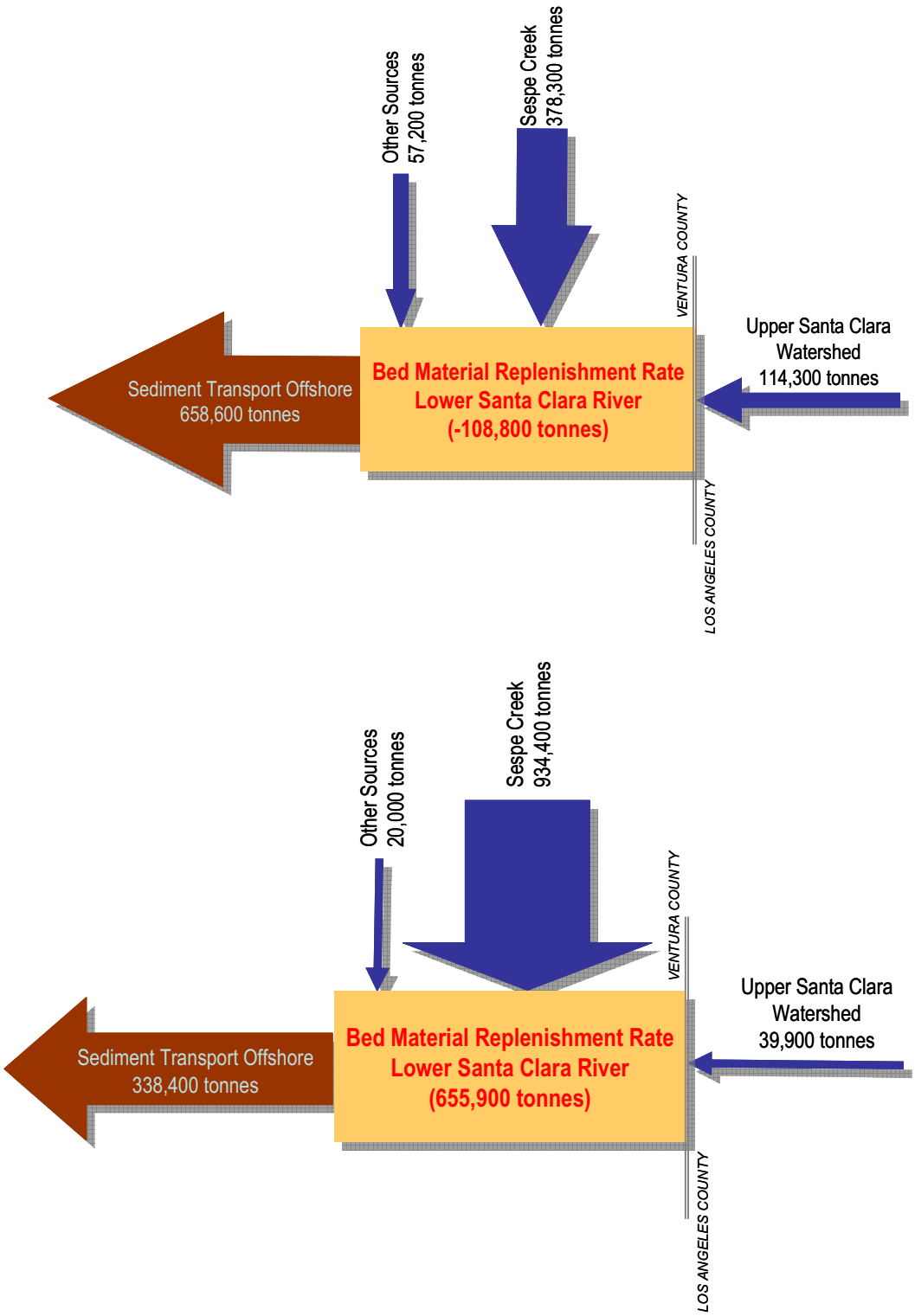

Figure 2-8. Illustration of the conceptual model of sediment transport dynamics within the lower Santa Clara River presented in Simons, Li & Associates (1983). Case A (top) demonstrates a degradational (incision) event, based on the Simons, Li & Associates (1983) analysis of data from the January 25, 1969 flood. Case B (bottom) shows an aggradational event based on their analysis of data from the February 10, 1978 flood.

2.3.7 Channel Morphology

Conditions in the Santa Clara River contrast sharply with those observed in alluvial rivers in humid environments, which have provided the basis for many of the classic generalizations of fluvial geomorphology. These include the concept of "dominant discharge" or "bankfull", the flow that, over the long-term average, performs the most work in terms of sediment transport and is most directly responsible for shaping and maintaining the channel in a characteristic equilibrium morphology (Wolman and Miller 1960). In humid environments, the most common flow occurs at an intermediate discharge, the sediment transport rate increases steadily with increasing flow, and total sediment load exhibits a maximum at an intermediate discharge (Figure 2-9).

However, within the Santa Clara River watershed, there is such a wide range of flows, and such a rapid increase in sediment load with increasing discharge, that the total coarse sediment load instead increases monotonically across the entire range of flow data, with a maximum at the highest flow (Figure 2-10). Hence the "dominant discharge" for the Santa Clara River is not an intermediate flood, it is the largest discharge on record.

The fact that the dominant, channel-forming flow is the largest flow on record implies that the Santa Clara River will not generally behave like a classic alluvial river. For example, the channel will probably not typically overflow its banks every one to three years, or maintain a well-defined, regularly-spaced riffle-pool sequence. In general, morphology will not exhibit equilibrium tendencies, showing small, year-to-year fluctuations around a long-term average condition. Instead, the channel and its floodplain will experience significant shifts in planform and channel cross-section in episodic high flows, thus increasing the chance of a rapid onset of hazardous conditions during a large flood event.

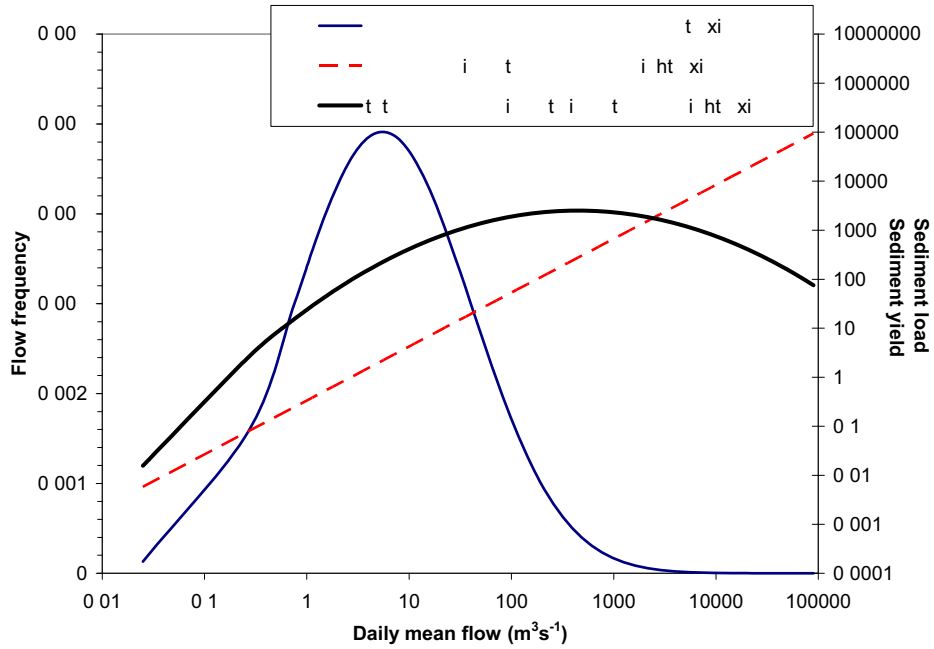

Figure 2-9. Flow frequency (left axis, scaled to 1) and sediment load (right axis) plotted against flow, showing conceptual, dominant discharge model of Wolman and Miller (1960). Blue line tracks flow frequency (for mean daily flow), red line tracks sediment transport rate (in tons/day) and black line tracks total sediment load (in tons). Sediment load increases to a maximum at an intermediate flow.

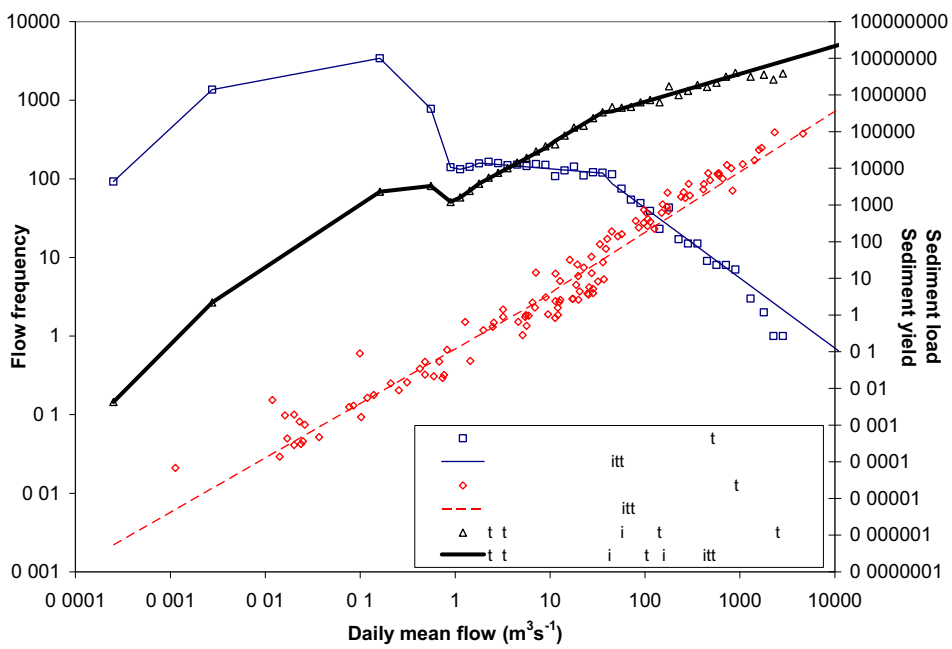

Figure 2-10. Flow frequency (left axis) and coarse sediment load (right axis) as a function of daily mean flow for the Santa Clara River at Montalvo (USGS11114000). Blue line tracks flow frequency, red line tracks sediment transport rate (in tons/day) and black line tracks total sediment load (in tons). The dominant discharge (*i.e.*, the one that carries most of the total sediment load) is the largest discharge of record. Details of this analysis are presented in Appendix C.

Estuary Bed Characteristics

The surface sediments of the estuary are characterized by highly stratified layers of coarse sand with relatively small amounts of silt and clay (ESA 2003), although cobble and boulder-sized sediment have also been observed being transported from the estuary during storm events (O'Hirok 1985; J. Warrick, USGS, pers. comm., 2005). Deposition of silt and clay-sized material has been observed due to fluvial delivery following storm events (USFWS 1999a) and flocculation (aggregation of fine sediment) induced by mixing of river and ocean water (O'Hirok 1985).

Channel/Estuary Planform Dynamics

In planform, the lower Santa Clara River is characterized by a wide, relatively straight floodway with one or more low-flow channels that are reconfigured after each flood event (Figure 2-11). The full mainstem channel bed is occupied only during high-magnitude floods (Stillwater Sciences 2007a). Erosion of alternate outer banks of the active floodway in some

A) Pre-high flow:

- Flow is conveyed in one primary low-flow channel with one or more secondary braids
- Vegetation has heavily encroached into the active channel since the last flood

B) High flow:

- Channel widens and forms a low sinuosity single-thread channel with a meandering thawleg
- Vegetation scoured away during flood event

C) Summer baseflow following flood event:

- High flows recede to leave a braided channel during summer baseflows
- Vegetation begins to re-establish in the active channel

Figure 2-11. Channel planform dynamics in the lower Santa Clara River.

reaches following large floods in January-February 2005 suggests that the entire floodway of the contemporary lower river behaves in a manner similar to a broad, single-thread meandering channel at very high flows. As floods recede, the river becomes more braided in character, with multiple flow courses. There is insufficient perennial flow to retain multiple flowing channels in a majority of the lower Santa Clara River and, in general, a single dominant channel defines the channel thalweg (Figure 2-11). In some reaches, however, residual flow continues to be carried by secondary channels. The low-flow channel boundary changes rapidly and comprehensively during flood events according to the magnitude of the event and other factors. Changes in the boundary of the mainstem channel, in contrast, will be more limited but of greater importance in determining the relationship between the river's geomorphology and human activities on the floodplain, because boundary changes imply flood inundation and possible erosion and/or deposition processes that can impact nearby land uses.

Evidence digitized from aerial photographs taken after large flood events since 1930 indicates that overall, the active width of channel bed of the 37-mi-long lower Santa Clara River has become narrower by almost 50% from 1938–2005 (from 1,585 to 827 ft) (Stillwater Sciences 2007a). Further, over large stretches, the relationship between active width and flood magnitude that might be expected in a semi-arid river has diminished over time. As such, few reaches of the lower Santa Clara River vary their active width commensurately with flood discharges, demonstrating the influence of human activities on channel morphology.

Similar to the mainstem Santa Clara, the estuary has undergone considerable changes over the past 150 years (Figure 2-12). Agricultural encroachment and development within the historical estuary footprint have contributed to an approximate 75% decrease in estuary extent (Swanson *et al.* 1990). Comparison of the 1969, 1993, and 2002 aerial photographs indicated that the shoreline and river mouth migrated to the south following the 1993 flood (compared to conditions in 1969) and that the estuary "channel" had begun to erode towards the north, while the mouth advanced to the south by 2002. Significant changes to both the river mouth and channel location also occurred as a result of the 2005 flood events.

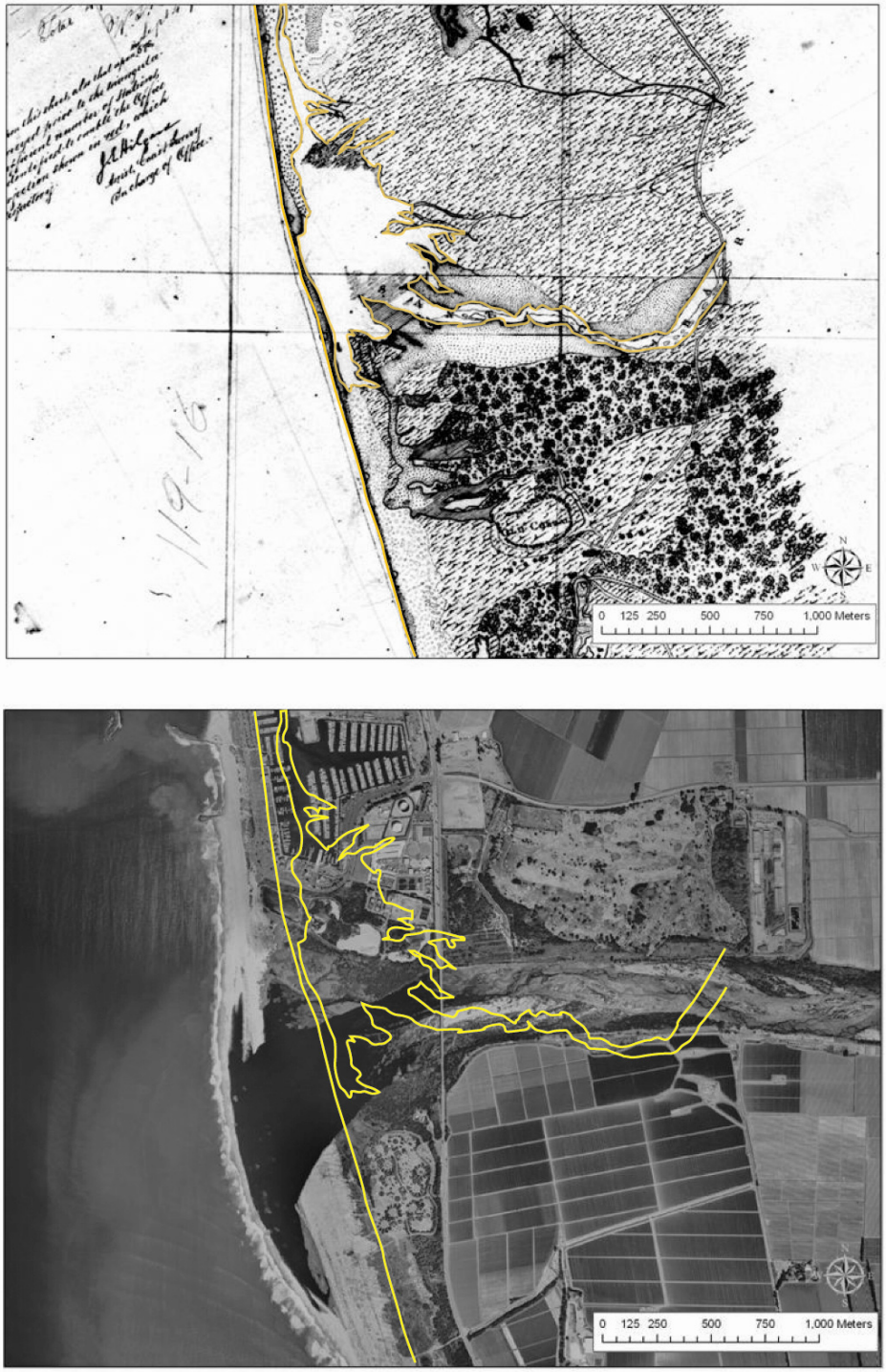

Figure 2-12. 1855 and 2005 maps of the Santa Clara River estuary. (top) The 1855 U.S. Coast and Geodetic Survey (USC&GS) map shows a meandering river channel with a broad floodplain and an extensive estuary/lagoon complex with a distributary channel network at the southern extent of the mouth complex. (bottom) The 1855 shoreline and the river mouth (and associated estuary) (yellow trace) are inland and the mouth/estuary complex is further north compared with the 2005 location.

Channel Profile

Examination of channel thalweg surveys indicate that, overall, the lower Santa Clara River has incised by 2.3 ft from 1949–2005 (Figure 2-13). Incision is focused in the lower parts of the river, where the maximum single-station incision over the 56-year period is 25.1 ft just downstream of Freeman Diversion. Using a base date of 1949 for consistency, the lower Santa Clara River shows:

- a trend of incision from 1949 to 2005 downstream of the Santa Paula Creek confluence;
- a variable trend of minor incision and aggradation from Santa Paula Creek to Sespe Creek, and
- moderate aggradation upstream towards the Los Angeles County line.

Incision gives way to aggradation towards the upper end of the lower Santa Clara River (maximum single-station aggradation of 10.2 ft) such that over the period of record, the gradient of the lower Santa Clara River has in-

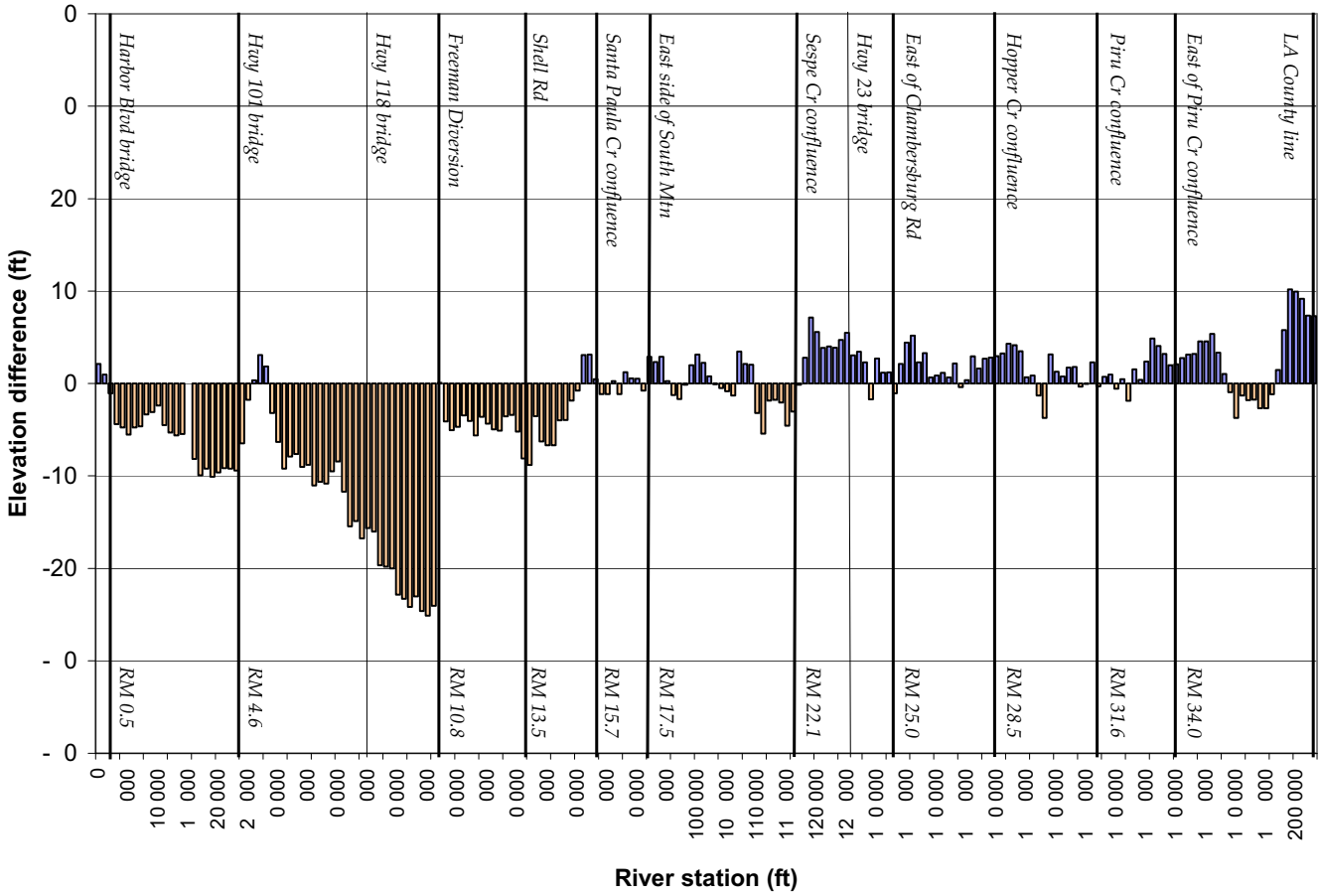

Figure 2-13. Net thalweg elevation change in the Santa Clara River from 1949 to 2005. River miles provided for reach boundaries.

creased slightly from 0.0040 to 0.0041. Narrower and deeper rivers are more effective at transporting sediment and it is notable that the downstream end of the lower Santa Clara River now has a greater stream power (a measure of the potential to transport sediment) than farther upstream, and this is contrary to upstream-to-downstream trends in stream power found in many natural rivers. Such changes in the lower Santa Clara River over the period of record help to explain why flood events now result in the net export of sediment from the watershed (*i.e.*, net incision); but a full explanation of the changes requires some additional context in terms of recent human activities in the watershed.

2.3.8 Groundwater

The lower Santa Clara River is underlain from east to west by the Piru, Fillmore, Santa Paula, Montalvo, and Oxnard Plain groundwater basins. The general vertical structure of the basins is recent and relatively thin alluvial deposits overlying older alluvial deposits that are much thicker. The recent alluvial deposits are generally younger than 10,000 years and are locally derived from the mountains bounding the Santa Clara River (UWCD and CLWA 1996). Because the overlying deposits are young by geologic standards, they are also relatively thin compared to the much thicker and older deposits which they overlie. The underlying sedimentary deposits are as old as 1.8 million years and up to 10,000 ft thick (UWCD and CLWA 1996). Since the alluvial deposits are relatively porous, nearly all of the groundwater basins along the lower Santa Clara River are unconfined aquifers: they are able to receive water from the surface and their water table surface fluctuates freely in response to recharge and discharge rates. Only the Oxnard Plain is a confined aquifer.

Broadly speaking groundwater flow follows the east to west trend of the Santa Clara River. The upstream and downstream bounds of the groundwater basins are typically defined by an aquaclude, or barrier to subsurface flow. At these locations, groundwater return flow to the surface is common (and results in the gaining reaches of the river – see Table 1-1). The unconfined aquifers in the lower watershed range from approximately 6,400 to 15,000 ac, while the Oxnard Plain is approximately 83,000 ac (Table 2-2) (UWCD and CLWA 1996).

Mechanisms for groundwater recharge are varied, but in the upstream-most, unconfined basins – Piru, Fillmore, and Santa Paula – percolation of surface flows from the Santa Clara River and its tributaries is the primary recharge mechanism, particularly in the winter when surface flows are highest (UWCD and CLWA 1996). In the fall, these basins are recharged by the Piru spreading grounds which are fed by flow releases from Lake Piru (UWCD and CLWA 1996). The Montalvo groundwater basin is primarily recharged from the Saticoy and El Rio spreading grounds, which receive water diverted

from the lower Santa Clara River at Freeman Diversion Dam, although it also receives water directly from Santa Clara River surface flows in the winter (UWCD and CLWA 1996). Rainfall, irrigation return flows, water treatment facility effluent, and water from the adjoining upstream basin also contribute to recharge in the unconfined aquifers (Table 2-2). The Oxnard Plain basin is also primarily recharged by the Saticoy and El Rio spreading grounds, but via the Montalvo basin. Historically, groundwater discharged into the ocean through the Oxnard Plain basin, but intensive groundwater pumping caused groundwater levels to decline below sea level in parts of the basin, allowing sea water to enter the freshwater aquifer (i.e., saltwater intrusion) (UWCD and CLWA 1996).

Table 2-2. Characteristics of the groundwater basins underlying the lower Santa Clara River.*

Groundwater basin	Approx. area (acres)	Estimated max. depth (ft)	Average annual extraction (ac-ft)	Primary replenishment mechanisms
Piru	12,000	8,000	11, 106	Santa Clara River surface flow (winter), Piru spreading grounds (fall), precipitation, irrigation returns
Fillmore	15,000	8,000	48,447	Santa Clara River surface flow (winter), Piru spreading grounds (fall), Piru groundwater basin, precipitation, irrigation returns, treated sewage effluent
Santa Paula	13,700	>10,000	23,339	Santa Clara River surface flow (winter), Piru spreading grounds (fall), Fillmore groundwater basin, precipitation, irrigation returns
Montalvo	6,400	*no data*	25,586	Santa Clara River surface flow (winter), Saticoy and El Rio spreading grounds (fall), Santa Paula groundwater basin, precipitation, irrigation returns
Oxnard Plain	83,200	2,000	67,195	Montalvo groundwater basin, , marine infiltration

*Information in this table was extracted from UWCD and CLWA (1996).

Groundwater and the surface flow of the lower Santa Clara River are clearly intimately linked. Generally, in wetter years, the water table surface is shallow and return flow from the groundwater basins to the surface is an important component of river discharge (see Section 2.3.4). In contrast, during drought years return flow is either minimal or absent and many reaches of the river lose water (see Table 1-1). Groundwater extraction, one of the primary methods of supplying irrigation water to the region, also removes a portion of the groundwater available for surface return flow (see Table 2-2), and has a variable impact depending on the water year type and the total volume of water extracted. Because riverine flora and fauna depend on the availability of surface flow and high water tables, the annual and seasonal condition of the groundwater basins and return flow to the river can have

important consequences for aquatic species and must be considered when developing restoration strategies for the lower Santa Clara River. For example, the establishment and survival of native riparian plant species is dependant on relatively shallow water tables and, thus, groundwater levels influence where active revegetation is appropriate (see Section 4.4). Similarly, the exchange between groundwater and surface flow affects instream habitat availability and quality and will be important in evaluating restoration potential for aquatic focal species (see Sections 2.4.3 and 4.7).

2.4 Key Biological Attributes

The Santa Clara River watershed is a regionally important area for native plant and animal species for several reasons. First, the distinct climate gradients and dynamic hydrology and geomorphology of the Santa Clara River watershed help support a variety of natural vegetation types The eastern, drier part of the watershed is characterized by desert scrub, with juniper, pinyon pine and Joshua tree woodlands. The western, semi-arid portion of the watershed supports coastal sage scrub, chaparral, oak woodland, grassland, and riparian communities, several of which are considered sensitive or rare (CDFG 2005). Second, the Santa Clara River is one of the least regulated and altered rivers in southern California. In terms of hydrology, there are no large dams or storage reservoirs on the mainstem, and relatively intact patches of riparian vegetation remain along the lower reaches, particularly in

Figure 2-14. Protected lands in the Santa Clara River watershed.

comparison to its dammed and channelized neighbors. Third, the watershed's position between the Santa Monica Mountains and Sierra Madre Range provides a regionally important connection between these two large, protected wildlife areas in the southern California coastal ecoregion (Penrod *et al.* 2006) (Figure 2-14). Fourth, the watershed has the potential to support recovery of southern California coast steelhead (Stoecker and Kelley 2005, NMFS 2007). Together, these watershed attributes provide critical habitat for several rare and endangered species, and a movement corridor for a number of native species that require extensive areas to survive (Davis 1994, CDFG 2005, Penrod *et al.* 2006).

This section describes the native plants and animals that occur in the lower river corridor, and the non-native species that currently threaten native habitats and species. Understanding the distribution and population dynamics of these species is critical to identifying high-use, preferred habitats as well as rare habitat types. This knowledge can then be used to prioritize preservation efforts and develop and prioritize process-based restoration strategies that target the creation, enhancement, and/or maintenance of these habitats.

2.4.1 Riparian Vegetation and Habitats

Riparian vegetation performs many functions in natural river systems such as filtering runoff and nutrients, providing habitat for terrestrial wildlife, shading the river, and providing energy from leaf litter and woody debris that serves as habitat for instream organisms (Gregory *et al.* 1991, Malanson 1993, Naiman and Descamps 1997, Mitsch and Gosselink 2000) (Figure 2-15). In addition, large tracts of diverse natural vegetation provide open space and recreational opportunities for the local human community. Understanding the distribution and composition of riparian vegetation allows us to develop restoration strategies that maximize these benefits by preserving intact, high-quality stands of vegetation and restoring degraded areas.

Riparian Vegetation Extent

Several factors currently affect riparian forest extent, structure, and species composition on the lower Santa Clara River. Historical accounts of central

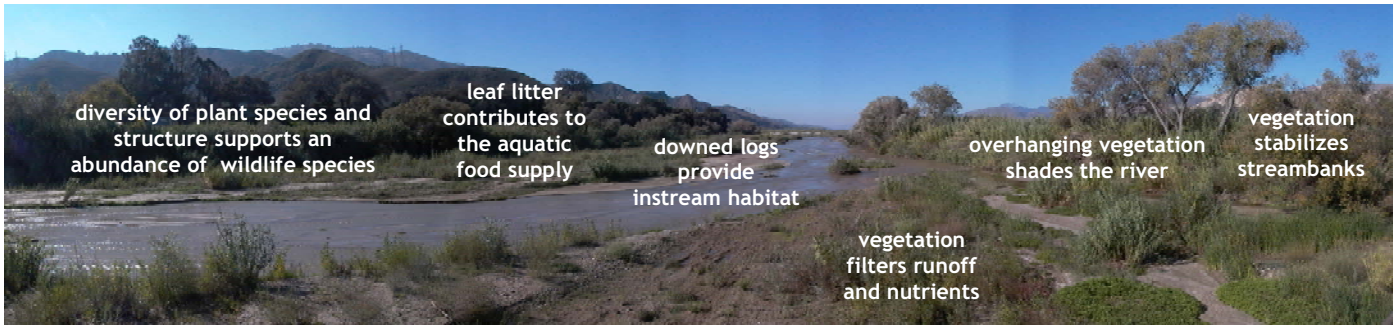

Figure 2-15. The Santa Clara River downstream of Newhall Bridge, at river kilometer 56.2 (river mile 34.9), illustrating some of the ecosystem functions provided by riparian vegetation.

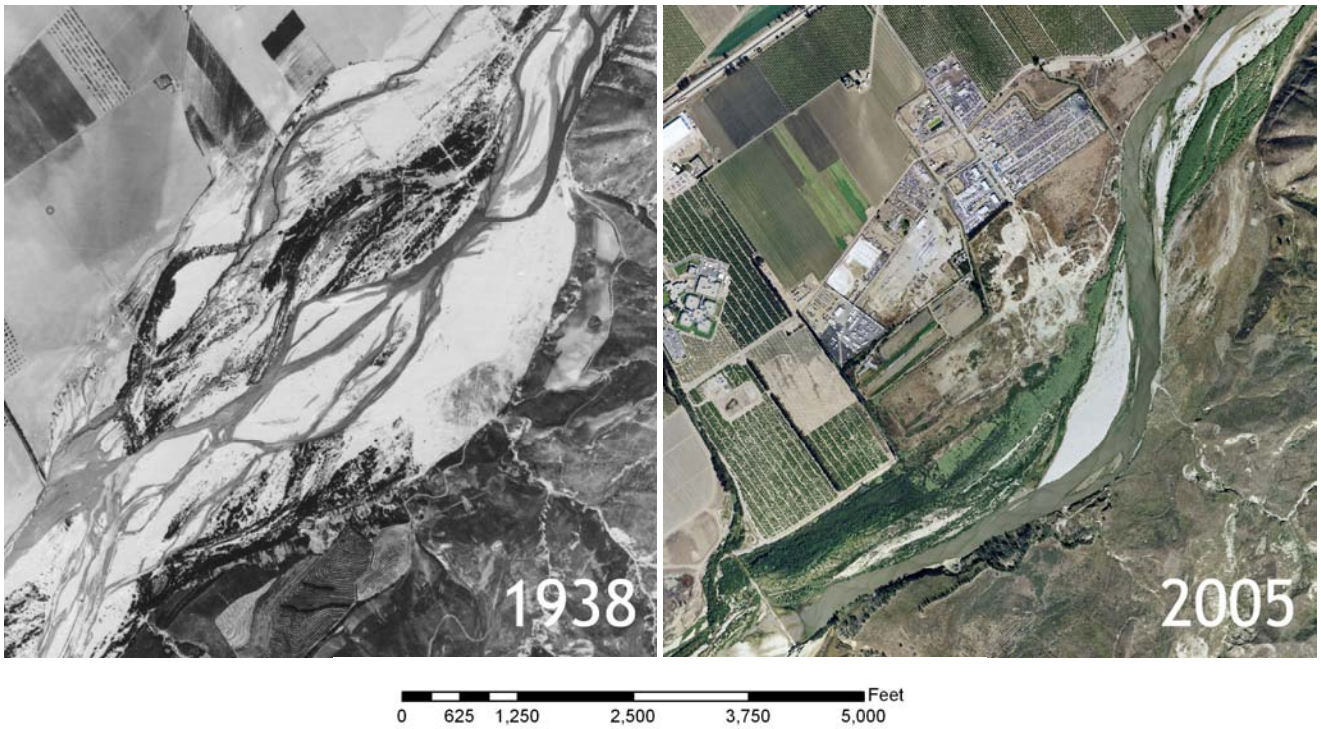

Figure 2-16. Comparison of riparian vegetation distribution in 1938 and 2005 near river mile 11.

and southern California coastal rivers describe extensive efforts to clear the "monte" —the cottonwood and willow forests that covered the lower reaches of the large rivers (Boughton *et al.* 2006). Vegetation clearing occurred primarily to prepare the land for ranching and farming and for fuel. More recently, urban development has begun replacing the farm land that replaced riparian forests. In addition to direct removal, alterations to the river's hydrology and groundwater levels have also likely reduced the extent of riparian vegetation in the lower Santa Clara River. Pumping has likely lowered the groundwater table beyond the reach of tree roots in some areas. Without groundwater to sustain seedlings, saplings and mature trees through the dry summer, the historical distribution of riparian forest cannot be sustained (Boughton *et al.* 2006). The construction of levees in the lower reaches of the river, together with development on the floodplain, dramatically reduced the area available for floods to inundate and, thus, for riparian forests to recruit and grow (Figure 2-16). In addition, numerous non-native invasive plant species have been introduced to the riparian corridor. These factors and the current condition of the lower Santa Clara River riparian corridor are described in the following sections.

Simons, Li & Associates (1983) report that the Santa Clara River floodplain was, historically, as much as 2-mi wide in its lowermost reaches. Regular flood inundation over a wide floodplain supported the recruitment of riparian trees over a vast area, while groundwater sustained plants through the

summer, allowing mature forests to develop. The riparian area likely supported dense, multi-stored stands of broadleaf trees, including cottonwood, sycamore, and various willows, that extended from a few to several miles wide (Schwartzberg and Moore 1995, Briggs 1996, Boughton *et al.* 2006).

Currently, the riparian corridor of the lower Santa Clara River is much narrower compared to historical accounts (Figure 2-16 and Figure 2-17). The 2005 flood (136,000 cfs, 16-year recurrence interval) inundated just over 7,000 ac along 34 mi of the lower river (Figure 2-17). For comparison, the 1938 flood (120,000 cfs, 14-year recurrence interval) inundated over 12,000 ac in this same longitudinal area (Figure 2-17). This difference represents a nearly 40% loss in the extent of the riparian corridor. This loss is most acute in the lowest reaches of the river (river mile 0 to 7) where nearly 70% of the riparian corridor has been lost. Working to reverse this loss and restore the historical extent of the lower Santa Clara River riparian corridor (approximately 12,000 ac) is a goal of the Parkway project. Estimates of the historical extent and loss of the riparian corridor will be greatly enhanced by the Ventura County Historical Ecology Study, which is currently being conducted by the San Francisco Estuary Institute through Coastal Conservancy funding.

Riparian Vegetation Composition

A wide range of vegetation conditions currently exists in the lower Santa Clara River corridor, from coastal, tidal marsh, through bands of riparian scrub and forest, to more xeric and upland vegetation types. Major vegetation cover types in the lower Santa Clara River are mapped in Figure 2-17 and listed in Table 2-3. These major types represent aggregations of many more detailed vegetation types, including 58 alliances and approximately 130 potential associations, which were recently described and mapped (Stillwater Sciences and URS Corporation 2007).

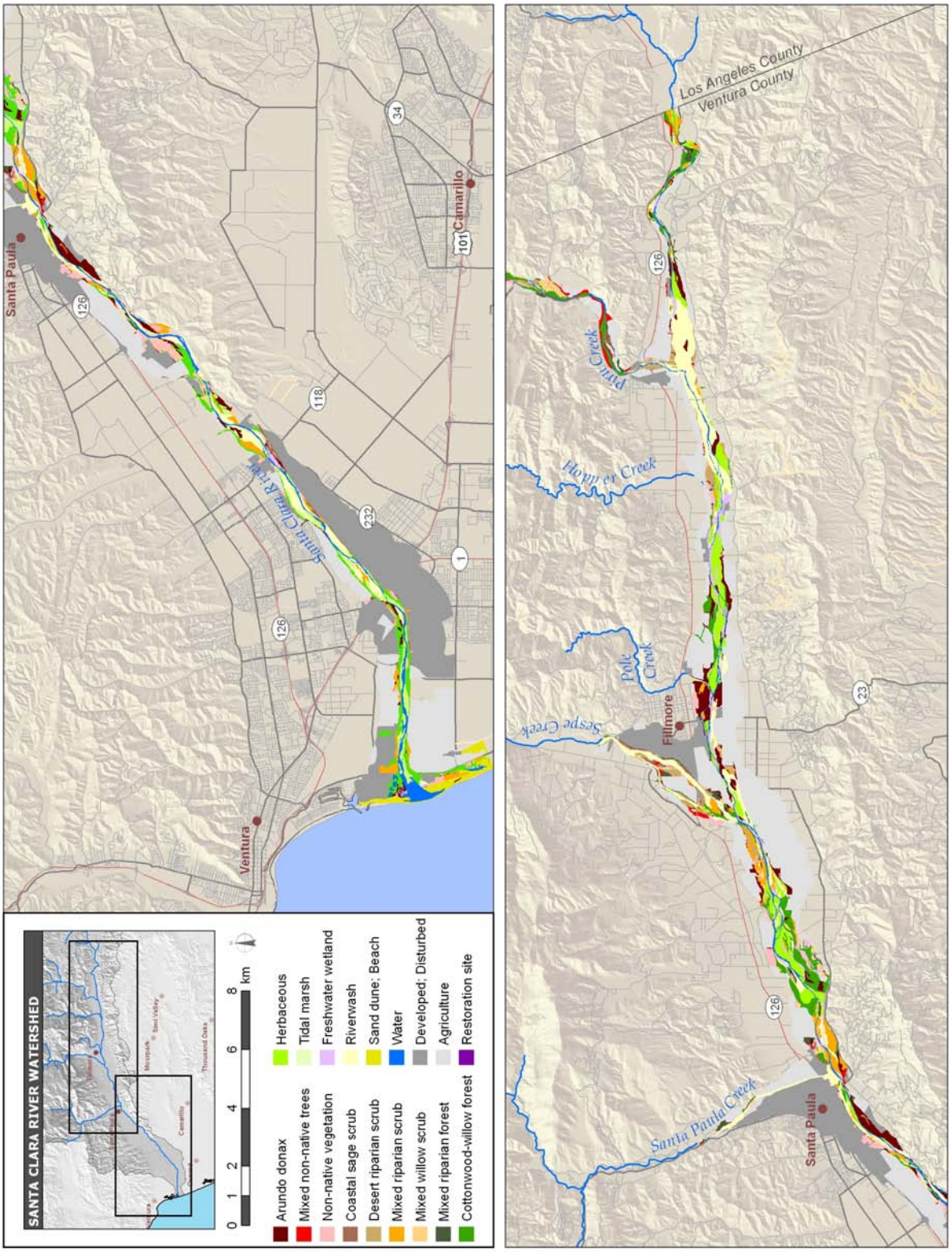

Figure 2-17. Vegetation communities within the 500-year floodplain of the lower Santa Clara River.

Table 2-3. Major vegetation types found within the 500-year floodplain of the lower Santa Clara River.

Vegetation Type	Associated Species	Acres	Hectares	Percent of total
Herbaceous	• western ragweed (*Ambrosia psilostachya*) • California aster (*Lessingia filaginifolia* ssp. *filaginifolia*) • giant rye (*Leymus condensatus*) • shortpod mustard (*Hirschfeldia incana*) • non-native bromes (*Bromus* spp.) • white sweetclover (*Melilotus alba*) • tocolote (*Centaurea melitensis*)	1,936	783	27
Mixed riparian forest	• black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) • Fremont cottonwood (*Populus fremontii* ssp. *fremontii*) • red willow (*Salix laevigata*) • arroyo willow (*Salix lasiolepis*) • shining willow (*Salix lucida* ssp. *lasiandra*) • red willow (*Salix laevigata*) • California walnut (*Juglans californica*) • western sycamore (*Platanus racemosa)* • coast live oak (*Quercus agrifolia*) • narrowleaf willow (*Salix exigua*) • mulefat (*Baccharis salicifolia*) • arundo (*Arundo donax*)	1,670	676	23
Mixed riparian scrub	• arundo (*Arundo donax*) • mulefat (*Baccharis salicifolia*) • arroyo willow (*Salix lasiolepis*) • red willow (*Salix laevigata*) • shining willow (*Salix lucida* ssp. *lasiandra*) • narrowleaf willow (*Salix exigua*)	1,080	437	15
Arundo donax	• arundo (*Arundo donax*) • mulefat (*Baccharis salicifolia*) • narrowleaf willow (*Salix exigua*) • red willow (*Salix laevigata*) • arroyo willow (*Salix lasiolepis*)	893	361	12
Freshwater wetland	• bulrush species (*Scirpus* spp.) • cattail (*Typha* spp.) • yerba mansa (*Anemopsis californica*) • salt grass (*Distichlis spicata*) • sprangletop (*Leptochloa uninervia*) • creeping wildrye (*Leymus triticoides*) • common reed (*Phragmites australis*) • knotweed (*Polygonum* spp.) • watercress (*Rorippa nasturtium-aquaticum*) • water speedwell (*Veronica anagallis-aquatica*)	536	217	7

Vegetation Type	Associated Species	Acres	Hectares	Percent of total
Desert riparian scrub	• big sagebrush (*Artemisia tridentata* ssp. *parishii*) • fourwing saltbush (*Atriplex canescens*) • scalebroom (*Lepidospartum saquamatum*) • California buckwheat (*Eriogonum fasciculatum*) • black sage (*Salvia mellifera*) • coyote brush (*Baccharis pilularis*) • chaparral yucca (*Yucca whipplei*)	338	137	5
Sand Dune/Beach	• beach bursage (*Ambrosia chamissonis*) • red sand-verbena (*Abronia maritima*) • pink sand-verbena (*Abronia umbellata*) • iceplant (*Carpobrotus edulis*, *C. chilensis*, and *Mesembryanthemum crystallinum*)	289	117	4
Coastal sage scrub	• California sagebrush (*Artemisia californica*) • California buckwheat (*Eriogonum fasciculatum*) • California encelia or brittlebush (*Encelia californica*) • deerweed (*Lotus scoparius*) • coyote brush (*Baccharis pilularis*) • quail bush (*Atriplex lentiformis*)	224	91	3
Mixed non-native trees	• eucalyptus (*Eucalyptus* spp.) • Peruvian peppertree (*Schinus molle*) • castor bean (*Ricinus communis*) • myoporum (*Myoporum laetum)* • arundo (*Arundo donax*) • tamarisk (*Tamarix ramosissima*)	175	71	2
Disturbed	• Primarily bare soil with sparse herbaceous vegetation	60	24	1
Tidal marsh	• salt grass (*Distichlis spicata*) • alkali heath (*Frankenia salina*) • marsh jaumea (*Jaumea carnosa*) • pacific silverweed (*Potentilla anserina* ssp. *pacifica*) • pickleweed (*Salicornia virginica*),	9	3	<1
Restoration site	Mixture of native riparian species	4	2	<1
	Grand Total	**7,214**	**2,919**	**100**

Riparian Habitat Types

Native vegetation types that occur in the lower Santa Clara River corridor are of special concern due to their ecological importance in the riparian zone, their declining distribution in California, or their role as key habitat for selected wildlife species (Stillwater Sciences and URS Corporation 2007, Stillwater Sciences 2007c).

Mixed riparian forest and scrub are abundant vegetation types throughout the 500-year floodplain of the lower Santa Clara River, including tributaries, and provide nesting, foraging, and movement habitat for a variety of native animal species (see Sections 2.4.2 and 2.4.4). Mixed riparian forest is generally found on the banks of mainstem and tributary channels where there is shallow groundwater (Figure 2-17). In these areas the community is characterized by an open to dense tree canopy and variable shrub and understory layers (Stillwater Sciences and URS Corporation 2007). In more geomorphically dynamic areas of the floodway, where mature forests cannot typically establish and earlier successional stages of vegetation generally dominate, mixed riparian forest transitions to mixed riparian scrub. In addition to whatever native riparian tree species that typically dominate stands of the vegetation community, arundo is nearly always present in either the shrub or understory layers (or both) at low to moderate densities (1–50% cover) (Stillwater Sciences and URS Corporation 2007). The structural diversity of mixed riparian forest and scrub vegetation types provide nesting habitat for numerous breeding birds such as western yellow-billed cuckoo (*Coccyzus americanus occidentalis*) which nests in dense riparian woodland, and least Bell's vireo (*Vireo bellii pusillus*), an endangered songbird which nests in dense willow thickets. Riparian forests also provide roosting and foraging habitat for several bat species including pallid bat (*Antrozous pallidus*), and cover for other mammal such as ringtails (*Bassariscus astutus*), bobcats (*Lynx rufus*), gray foxes (*Urocyon cinereoargenteus*), and mountain lions (*Puma concolor*).

(top) A stand of mixed riparian forest along the lower Santa Clara River; (bottom) Invasion of arundo on the lower Santa Clara River floodplain following a fire.
(photographs by Stillwater Sciences)

Arundo, an invasive non-native species related to bamboo, is by far the most abundant species in the lower river and is out-competing and quickly replacing native vegetation types such as mixed riparian forest. The arundo vegetation community is abundant and well distributed throughout the 500-year floodplain of the lower river. The community has a dense, continuous shrub layer

completely dominated by arundo or it may have mulefat (*Baccharis salicifolia*), or various willow species (*Salix* spp.) as co-dominant species. While the extent of the mapped arundo vegetation type is 893 acres, it is important to note that arundo is nearly always present in the shrub or understory layers of mixed riparian forest and scrub communities at low to moderate densities. Arundo-specific vegetation mapping indicates that the species occurs at varying levels of percent cover in 5,242 ac of the lower river corridor (Stillwater Sciences and URS Corporation 2007).

Desert riparian scrub is a rare vegetation community that is generally found in alkaline or saline washes, scrub habitat, sandy and gravelly washes, stream terraces, and chaparral habitats. It is distributed primarily in the upper reaches and tributaries of the lower Santa Clara River (Figure 2-17). This vegetation community is characterized by a continuous, intermittent or open shrub layer, a sparse to intermittent or grassy herbaceous understory, and little to no tree layer (Stillwater Sciences and URS Corporation 2007). This vegetation type provides habitat for silvery legless lizard *(Anniella pulchra pulchra)*, foraging habitat for coastal California gnatcatcher *(Polioptila californica californica)*, and appropriate growing conditions for Nevin's barberry (*Berberis nevinii*) and Slender-horned spineflower *(Dodecahema leptoceras).*

The lowest reaches of the Santa Clara River (the Estuary Reach [0] and part of Hwy 101 Reach [1]) consist primarily of the estuary (see Table 1-1) and are dominated by open water and **sand dune and tidal marsh** vegetation types (Figure 2-17). The sand dune and beach communities are sparsely vegetated with low-growing perennial forbs. The tidal marsh areas are characterized by dense, low-growing, perennial species that are tolerant of daily tidal inundation and higher soil salinities (Stillwater Sciences and URS Corporation 2007). The coastal areas at the mouth of the Santa Clara River provide sandy burrowing habitat for silvery legless lizard, and foraging and nesting habitat for a variety of shorebirds, including long-billed curlew (*Numenius americanus*) and western snowy plover (*Charadrius alexandrinus nivosus*).

Coastal sage scrub, another rare vegetation community, is found throughout the lower Santa Clara River and along its tributaries, although it is most abundant in Below Freeman Reach (2) and along Sespe Creek, where it occurs on dry terraces and other upland portions of the 500-year floodplain Figure 2-17). This vegetation community tends to have a dominant shrub layer with open to dense cover with a sparse to dense herbaceous layer typically dominated by non-native grasses and forbs (Stillwater Sciences and URS Corporation 2007). Upland areas adjacent to the river are host to several species including including western fence lizards (*Sceloporus occidentalis*), San Diego horned lizards (*Phrynosoma coronatum blainvillii*), coast patch-nosed snakes (*Salvadora hexalepis virgultea*), northern harriers (*Circus cyaneus*), white-

tailed kites (*Elanus leucurus*), coopers hawks (*Accipter cooperii*), mule deer (*Odocoileus hemiunus*) and coyote (*Canis latrans*).

Riparian Vegetation Dynamics

A variety of landscape position and physical habitat conditions shape the types and distribution of vegetation types along the river. In the lower Santa Clara River, periodic short-duration, high-intensity flood events through the meandering and braided river channel result in dynamic patterns of scour, sediment deposition, and floodplain inundation (Stillwater Sciences 2007a). These dynamic hydrologic and geomorphic processes have been documented in other semi-arid stream systems, where they have been shown to influence groundwater patterns and riparian vegetation distribution, structure and composition, and result in patches of varying successional stages and species assemblages (*e.g.*, Baker and Walford 1995, Hupp and Osterkamp 1996, Bendix 1997, Shafroth *et al.* 1998, Bagstad *et al.* 2006).

Studies of riparian vegetation dynamics have shown that water availability is the strongest driver of vegetation patterns in semi-arid systems, but results have varied on the particular source (stream flow or groundwater) and mechanism (*e.g.*, scour, inundation, or water supply) of water, and other influential physical and biological variables. Studies to identify the strongest influences on vegetation patterns in semi-arid streams have revealed the importance of the frequency and magnitude of flood disturbance (Bendix 1994, Bendix 1997, Harris 1999, Bendix and Hupp 2000), distance to groundwater (Stromberg *et al.* 1996, Shafroth *et al.* 1998), and a combination of the two (Hupp and Osterkamp 1996, Lite 2003, Bagstad *et al.* 2006, Leenhouts *et al.* 2006). Other physical variables, such as sedimentation (Baker and Walford 1995), fire regime (Bendix 1994), and flood timing (Shafroth *et al.* 1998) have also been found to affect vegetation patterns, as have post-establishment successional and competitive processes (Baker and Walford 1995, Shafroth *et al.* 1998, Bagstad *et al.* 2006).

Upland (background), willow scrub (midground), and floodplain wetland and herbaceous (foreground) vegetation along the lower Santa Clara River.
(photograph by Stillwater Sciences)

On the lower Santa Clara River, the strongest drivers for vegetation patterns align well with those found in previous studies. Relative elevation and time since last flood were two of the

strongest correlates to the distribution of vegetation alliances in the lower river (Stillwater Sciences 2007b). These results, like those of other studies, indicate that flood frequency and vegetation age are largely responsible for determining vegetation distribution, composition, and structural complexity. Riparian vegetation along the lower Santa Clara River is subject to infrequent but dramatic resets during large flood events, particularly during wet years associated with ENSO (Stillwater Sciences 2007a). In addition, distance from the river mouth was also a correlate to distribution of vegetation alliances, indicating that longitudinal position in the river corridor is also important in determining vegetation patterns (Stillwater Sciences 2007b). While the precise mechanism for this correlation is difficult to ascertain, differences in local climatic conditions between the coastal fog belt, where humidity is relatively high and evapotranspiration demand relatively low, and the more arid inland portions of the watershed are probably at least partly responsible for these species distribution trends. Since the distribution of gaining vs. losing reaches was determined in part by vegetation cover, analysis of the independent effects of groundwater reach type in comparison with other physical site variables on plant species and vegetation alliance distribution was not possible. However, the distribution of many key riparian plant species and alliances reveals significant bias for gaining vs. losing reaches (Stillwater Sciences 2007b).

This information helps inform restoration strategy development in several ways. Based on physical information from a potential restoration site, vegetation types that most frequently occur under those conditions can be identified and used to improve predictions of what species can be expected to recruit naturally or what planted species are likely to be successful in the long-term. Conversely, if a particular vegetation community is targeted for revegetation because it is rare or provides critical habitat, the physical variables most often associated with that vegetation community can be used to identify optimal revegetation sites (along with other non-ecological constraints, such as land ownership and adjacent land uses) (Stillwater Sciences 2007b).

2.4.2 Aquatic Habitats

Riverine

The following discussion is largely based on recent aquatic habitat assessments of the lower Santa Clara River that have focused primarily on southern California coast steelhead habitat preferences and availability (Puckett and Villa 1985, Comstock 1992, Kelley 2004, Stoecker and Kelley 2005). The lower 33 miles of the mainstem Santa Clara River are currently dominated by glide habitat, with small areas of dammed pool, low-gradient riffle, and step-run habitats (Stoecker and Kelley 2005). While mainstem aquatic habitat is considered relatively low quality in terms of southern California coast steelhead habitat parameters, with high substrate embeddedness and low canopy

Glide habitat on the lower Santa Clara River.
(photo by Stillwater Sciences)

cover (Stoecker and Kelley 2005), this can be at least partially attributed to the naturally broad, alluvial nature of the lower mainstem river (Stoecker and Kelley 2005). Even under historical conditions, the lowest reaches of the river would be expected to have a fairly fine channel bed with high percent embeddedness, and the broad and dynamic mainstem channel would not necessarily have supported a high percent cover of overhanging vegetation. The mainstem is more likely to have served primarily as critical migratory habitat for southern California coast steelhead accessing spawning habitats in the upper river and tributaries, and rearing and foraging habitat for species such as arroyo chub and unarmored three-spine stickleback that utilize glide or slower channel-margin habitats.

Two of the primary impacts to instream aquatic habitat in the lower Santa Clara River are: 1) barriers to fish passage resulting from low-flow conditions and diversion structures, and 2) reduced extent and quality of estuarine habitat. Other important impacts include altered river flows resulting from surface water diversion, groundwater pumping, upstream dam releases, treated wastewater effluent, and agricultural return flows; presence of non-native fish species that compete with and prey upon native species (see Section 2.4.4); and poor water quality (see Section 3.5). These impacts combine to limit habitat availability and connectivity for native aquatic species.

Barriers to passage occur when any structure in the stream channel impedes, to varying degrees of difficulty, or completely blocks upstream migration of

an organism. The most significant barrier to upstream fish migration is argued to be the Vern Freeman Diversion Dam (Stoecker and Kelley 2005), located approximately 10 mi upstream from the mouth of the mainstem Santa Clara River. While a fish ladder exists at the diversion dam, National Marine Fisheries Service contends that its operation does not sufficiently accommodate the timing, duration, and magnitude of flow events that anadromous fish require for upstream migration (Stoecker and Kelley 2005). In addition, the Harvey Diversion Dam on lower Santa Paula Creek greatly reduces or eliminates instream flows on that creek during most of the year and does not have an operable fish ladder (Stoecker and Kelley 2005, Titus *et al*., *in prep*.). These two barriers prevent southern California coast steelhead from accessing critical, relatively high-quality spawning habitats in Sespe, Santa Paula, and other tributary creeks (Stoecker and Kelley 2005).

Estuarine

Estuaries are recognized as critical habitat for a variety of aquatic organisms in coastal California watersheds (Shapovalov and Taft 1954, Smith 1990, Bond 2006, Boughten *et al.* 2006). In addition to providing rearing and foraging habitat for birds and estuarine fish such as arroyo chub and tidewater goby, estuaries also provide important rearing habitat for southern California coast steelhead. Steelhead smolts may spend a considerable amount of time in the estuary habitat to acclimate to saltwater and wait for adequate flow conditions to open the mouth of the stream, allowing migration to the ocean (Stoecker and Kelley 2005). Furthermore, steelhead that rear in estuaries rather than in mainstem habitats have been found to reach greater sizes before outmigrating to the ocean, which is important in determining ocean survival (Bond 2006).

The Santa Clara River estuary (looking upstream toward Harbor Blvd. Bridge).
(photo by Stillwater Sciences)

The extent of the Santa Clara River estuary is estimated to have decreased by 75% (Swanson *et al.* 1990). In addition, upstream levees are hypothesized to increase the occurrence of hyperpycnal flow and promote estuary scouring (see Section 2.3.6). Even in an estuary with muted tidal influence, such as the Santa Clara River estuary, intertidal zones are important for providing exposed mudflats at low tide for shorebird foraging and shallow, flooded areas at increased tide heights for filter-feeding invertebrates and foraging small fish. However, the lack of sediment deposition in the Santa Clara River estuary may decrease the availability of transitional zones such as mudflats and shallow, sandy vegetated areas for estuarine biota.

Additionally, summer and fall discharges of treated effluent from the Ventura Water Reclamation Facility can cause the estuary mouth to breach prematurely (Swanson *et al.* 1990, as cited in ESA 2003) and may decrease natural salinity levels during these seasons. However, it is also believed that the Reclamation Facility provides a portion of the historical freshwater inflow that historically entered the estuary but that is now diverted or pumped off the river farther upstream (Nautilus Environmental 2005). Although the reclamation facility may provide some benefits to estuarine environment, identification of other potential impacts of the treated discharge on water quality and aquatic habitat availability requires additional investigation. The estuary is on the 303(d) list as impaired for Chem A, coliform, and toxaphene, but the source of these pollutants is currently considered to be either non-point or unknown (see Section 3.5).

The Santa Clara River and the estuary in particular, may be affected by sea level rise resulting from global warming. Globally, sea level has risen between 4 and 10 inches over the past century, primarily because of a net input of water from icecap melt and water warming (Rahmstorf *et al*. 2007). This rate of rise is an order of magnitude greater than that of the past several millennia (Douglas *et al*. 2001, as cited in Hopkins *et al.* 2008). In southern California, sea level rise is predicted to be in the range of 0.04 to 0.1 inch per year (Hopkins *et al.* 2008). Sea level sets the minimum elevation for an estuary, but land use and climate in the watershed affect processes that deliver sediment to the estuary and allow material to accumulate. The implications of sea level rise and changes in sediment deposition are difficult to predict, particularly in a system such as the Santa Clara River, where levees and floodplain development restrict the estuary's ability to migrate. These types of developed coastal regions are expected to experience a decrease in estuarine and wetland areal extent as sea-level rises (Hopkins *et al.* 2008). This loss in area will reduce the storm buffering and other ecosystem services provided by coastal wetlands and thereby increase the vulnerability of human systems.

2.4.3 Fish and Wildlife

Despite the dramatic reduction, degradation, and fragmentation of riparian vegetation, the aquatic, riparian, and upland habitats of the Santa Clara River watershed support a diverse composition of fish and wildlife species, including over 40 threatened, endangered, and sensitive plant and animal species (CDFG 2007). In addition, the lower Santa Clara River watershed has been identified as a regionally important migration corridor for mountain lion, American badger, and mule deer due to its position between two of the largest protected wildlife areas in the southern California coastal ecoregion, the Santa Monica Mountains and Sierra Madre Range, and the large extent of protected national forest lands (Penrod *et al.* 2006). The habitat value and health of wildlife populations in the lower Santa Clara River can only stand to be improved by the Parkway acquisition and restoration efforts.

Special-status Species

Table 2-4 summarizes the threatened, endangered, and sensitive species that have been documented in the vicinity of the lower Santa Clara River (*i.e.*, the seven USGS quadrangles that include the lower river corridor; CDFG 2007). Additional occurrences of these species, or other species, occur in other areas of the watershed, but are not generally included in Table 2-4. In addition to those special-status species found in the riparian corridor of the lower Santa Clara River, a number of species in Table 2-4 are found in upland habitats that likely use the riparian corridor for occasional foraging or for movement between habitats.

Table 2-4. Threatened, endangered, and sensitive species in the vicinity of the lower Santa Clara River.

Species	Status[1]			Habitat Associations and Occurrence in the Lower Santa Clara River Watershed[2]
	Federal	State	Other	
FISH				
Arroyo chub *(Gila orcutti)*	--	--	CSC	Found in coastal streams with a preference for slow-moving water with mud or sand substrate. Documented to occur in the lower Santa Clara River, but considered to be introduced (Faber *et al.* 1989, Moyle 2002).
Santa Ana sucker *(Catostomus santaanae)*	FT	--	CSC	Found in coastal streams; considered habitat generalists, but prefer sand-rubble-boulder substrates with cool, clear water, and algae. Documented to occur in the lower and upper Santa Clara River, as well as Sespe Creek, but may be introduced (Faber *et al.* 1989, Moyle 2002).
Steelhead (southern CA coast DPS) *(Oncorhynchus mykiss irideus)*	FE	--	CSC	Spawning adults and rearing juveniles found in coastal streams and rivers (feeding adults are found in the ocean). Adults require holding pools during migration, and spawn in shallow, low-gradient riffles; juveniles rear in shallow-water, low-velocity habitats, moving towards deeper and higher velocity water as adults. Adult steelhead last documented in the lower Santa Clara River below Vern Freeman Diversion Dam in 2001; resident rainbow-trout populations occur in the headwaters of Santa Paula, Sespe, Hopper, and Piru creeks (Stoecker and Kelley 2005).
Tidewater goby *(Eucyclogobius newberryi)*	FE	--	CSC	Found in shallow lagoons and lower stream reaches with brackish, low velocity water and high oxygen levels. Documented to occur in the estuary of the Santa Clara River (Entrix 2004)
Unarmored threespine stickleback *(Gasterosteus aculeatus williamsoni)*	FE	SE	FP	Found in coastal streams with a preference for cool (<75°F), clear pools and backwater areas with abundant vegetation. Documented to occur in the Santa Clara River upstream of Piru Creek (Faber *et al.* 1989, Moyle 2002, CDFG 2007).
AMPHIBIANS				
Arroyo toad (*Bufo californicus*)	FE	--	CSC	During breeding, found in open sites open sites such as overflow pools, old flood channels, and pools with shallow margins on streams; otherwise found on sand or fine gravel bars adjacent to stable sandy terraces. Was historically found in the lower Santa Clara River watershed, but currently persists only along Sespe Creek, Piru Creek, and the upper watershed (Sweet 1992, USFWS 1999).
Mountain yellow-legged frog *(Rana muscosa)*	FE	--	CSC	Found in shallow waters of rocky and open foothill streams and lake edges with cool waters and a gentle slope. Documented in Sespe Canyon near the town of Fillmore.

Species	Status[1]			Habitat Associations and Occurrence in the Lower Santa Clara River Watershed[2]
	Federal	State	Other	
REPTILES				
Coast (San Diego) horned lizard *(Phrynosoma coronatum (=blainvillii))*	--	--	CSC	Found in coastal sage scrub and chaparral habitats, with a preference for friable, rocky, or shallow sandy soils. Documented along the Santa Clara River southwest of Fillmore and in the vicinity of El Rio.
Western pond turtle *(Clemmys (=Emys; =Actinemys) marmorata)*	--	--	CSC	Found in ponds, lakes, ditches, perennially filled pools of intermittent streams, and backwater and low-flow areas of perennial streams and rivers. Nest are built in dry, fine soils, on gentle slopes, typically in open, grassy meadows less than 1,500 ft from water. Documented in both the lower and upper Santa Clara River watershed.
Two-striped garter snake *(Thamnophis hammondii)*	--	--	CSC	Found in or near permanent fresh water, often along streams with rocky beds and riparian vegetation. Documented along the mainstem lower Santa Clara River and along tributaries to Sespe Creek.
BIRDS				
Bank swallow *(Riparia riparia)*	--	ST	--	Found in riparian and other lowland habitats; require vertical banks/cliffs with fine-textured soils near streams, rivers, lakes, ocean for nesting. Documented along the coast at the Santa Clara River estuary.
Belding's savannah sparrow *(Passerculus sandwichensis beldingi)*	--	SE	--	Found in coastal salt marshes; nests in pickleweed (*Salicornia virginica)* along margins of tidal flats. Documented in marsh areas along the coastal just south of the Santa Clara River estuary near Ormond and McGrath beaches.
California least tern *(Sterna antillarum browni)*	FE	SE	FP	Found along the coast on bare or sparsely vegetated, flat substrates (sand beaches, alkali flats, land fills, or paved areas). Documented along the coastal strand area of the Santa Clara River.
Coastal California gnatcatcher *(Polioptila californica californica)*	FT	--	CSC	Found in coastal scrub habitats with a preference for sage scrub in arid washes, on mesas and slopes. Documented in the river corridor at Santa Paula.
Cooper's hawk *(Accipiter cooperii)*	--	--	CSC	Found nesting in riparian woodlands, primarily in open, interrupted or marginal sites. Documented along the lower Santa Clara River east of Piru.
Least Bell's vireo *(Vireo bellii pusillus)*	FE	SE	--	Found nesting in riparian scrub in the vicinity of water or in dry river bottoms. Documented to be relatively abundant throughout the lower Santa Clara River riparian corridor (Labinger and Greaves 2001).
Southwestern willow flycatcher (*Empidonax trailii extimus*)	FE	SE	--	Found in flood-prone riparian areas, where water is present and dense vegetation is present or expected to become established. Small numbers of nesting pairs and/or territorial individuals documented throughout the lower Santa Clara River riparian corridor (Labinger and Greaves 2001).

Species	Status[1]			Habitat Associations and Occurrence in the Lower Santa Clara River Watershed[2]
	Federal	State	Other	
Western snowy plover *(Charadrius alexandrinus nivosus)*	FT	--	CSC	Found nesting on sandy beaches, salt pond levees and shores of alkali lakes in sandy, gravelly or friable soils. Documented at the mouth of the Santa Clara River.
Western yellow-billed cuckoo *(Coccyzus americanus occidentalis)*	FC	SE	--	Found in densely foliated riparian trees and shrubs, adjacent to slow-moving watercourses, backwaters, or seeps. Last documented in the lower Santa Clara River watershed in 1971; more recent sightings of migrants documented in the upper watershed (Labinger and Greaves 2001).
White-tailed kite *(Elanus leucurus)*	--	--	FP	Found in rolling foothills/valley margins with scattered oaks and river bottomlands or marshes next to deciduous woodlands; nest in isolated, dense-topped trees and forage in open grasslands, meadows, or marshes. Documented in the lower Santa Clara River watershed east of Santa Paula.
Yellow warbler *(Dendroica petechia brewsteri)*	--	--	CSC	Found nesting in riparian woodlands as well as montane shrub-scrub in open conifer forests. Documented along the lower Santa Clara River east of Piru.
Yellow-breasted chat *(Icteria virens)*	--	--	CSC	Found in riparian thickets of willow and other brushy tangles near watercourses; nest in low, dense riparian scrub. Documented along the lower Santa Clara River east of Piru.
MAMMALS				
Pallid bat (*Antrozous pallidus*)	--	--	CSC	Found in deserts, grasslands, shrublands, and woodlands; most common in open, dry habitats with rocky areas for roosting. Documented in the lower Santa Clara River watershed near Fillmore and Santa Paula.
PLANTS				
Coulter's goldfields *(Lasthenia glabrata* ssp. *coulteri)*	--	--	1B	Grows in coastal salt marshes, playas, valley and foothill grasslands, and vernal pools, typically on alkaline soils. Documented in salt marsh near Ormand Beach south of the Santa Clara River estuary.
Greata's aster *(Aster greatae)*	--	--	1B	Grows in mesic canyon in chaparral, cismontane woodland habitats. Documented in Hopper Canyon in the lower Santa Clara River watershed.
Nevin's barberry (*Berberis nevinii*)	FE	SE	1B	Grows in sandy/gravelly soils on steep, north facing slopes in coastal scrub and chaparral habitat or in low gradient sandy washes in alluvial and riparian scrub habitats. There is one extant occurrence in the upper Santa Clara River watershed.
Plummer's mariposa lily *(Calochortus plummerae)*	--	--	1B	Grows in rocky and sandy sites, usually of granitic or alluvial material in coastal scrub, chaparral, valley and foothill grassland, cismontane woodland, lower montane coniferous forest habitats. Can be very common after fire. Documented south of Fillmore in the lower Santa Clara River watershed.

Species	Status[1]			Habitat Associations and Occurrence in the Lower Santa Clara River Watershed[2]
	Federal	State	Other	
Salt marsh bird's-beak (*Cordylanthus maritimus* ssp. *maritimus)*	FE	SE	1B	Grows in higher elevation zones of coastal salt marshes and in dunes. Documented along the coast at the mouth of the Santa Clara River near Oxnard.
Slender-horned spineflower (*Dodecahema leptoceras)*	FE	SE	1B	Grows in flood deposited terraces and washes in chaparral, coastal scrub, and alluvial fan sage scrub habitats. Three populations documented in the upper Santa Clara River watershed.
Ventura Marsh milk-vetch (*Astragalus pycnostachyus* var. *lanosissimus)*	FE	SE	1B	Typically grows in tidally inundated coastal salt marsh, and more rarely near seeps on sandy bluffs. Documented near the Santa Clara River estuary and McGrath State Beach.

1 FE = Federally listed as endangered
FT = Federally listed as threatened
FC = Candidate for federal listing
1B = listed by CNPS as rare, threatened, or endangered in California and elsewhere
SE = State listed as endangered (California)
ST = State listed as threatened (California)
CSC = listed by CDFG as a California species of special concern
FP = listed by CDFG as fully protected

2 Occurrence information from CDFG (2007), unless otherwise indicated.

Focal Species

A focal-species approach to developing a restoration strategy facilitates the exploration of linkages among ecosystem processes, resultant habitats, and biotic needs. It is based on the premise that maintaining and restoring physical and ecological processes will provide properly functioning habitat for well-distributed populations of native species, many of which have declined and may require habitat restoration to persist in the area. On the Santa Clara River, focal species and their habitat preferences and current potential habitat can be used to: 1) identify factors that are likely limiting the species population or distribution; 2) prioritize areas for conservation or restoration to maintain or improve populations; 3) design and select restoration actions that will create or maintain preferred habitat parameters or ameliorate a factor believed to be limiting a species population; and 4) evaluate the success of implemented management and restoration actions to increase or improve habitat conditions. For the restoration strategies recommended in Section 4, the focal species approach was used to identify high-priority areas for acquisition, active and passive revegetation, and non-native invasive species removal to conserve and restore focal species habitat. Once these restoration strategies begin to be implemented, monitoring of focal species' populations and habitat area can be compared to pre-project conditions and used to evaluate the success of implemented restoration actions. Additional site-specific population and/or habitat data would need to be collected for most focal species and restoration areas prior to project implementation.

Focal species for the Parkway project were selected from a list of candidate species that currently occur or historically occurred along the lower Santa Clara River. The focal species selection process is described in detail in Stillwater Sciences (2007c). They were selected based on their status under state and federal Endangered Species Acts, the occurrence of suitable habitat within the vicinity of the project area, and the ecological niche they represent. They cover a range of aquatic, riparian, and upland habitat requirements and represent various taxonomic groups and guilds within the river corridor ecosystem, ensuring that the focal species will function as indicators for the wide range of species and habitats that occur in the lower Santa Clara River. A few of the selected species no longer occur in the project area but were included because they might re-colonize or be re-introduced if habitat is restored. Arundo and tamarisk, both non-native invasive plant species that degrade riparian habitats, were also chosen as focal species because control of these species is a primary concern of restoration strategy development on the lower Santa Clara River, and the understanding their distribution will help prioritize and evaluate the success of control projects. These species are described in detail in Appendix A.

PARKWAY FLOODPLAIN RESTORATION FOCAL SPECIES

arroyo toad
Bufo californicus

western pond turtle
Clemmys marmarota

least Bell's vireo
Vireo bellii pusillus

southwestern willow flycatcher
Empidonax trailli extimus

western yellow-billed cuckoo
Coccyzus americanus occidentalis

steelhead trout
Oncorhynchus mykiss

tidewater goby
Eucyclogobius newberryi

Nevin's barberry
Berberis nevinii

slender-horned spineflower
Dodecahema leptoceras

arundo
Arundo donax

tamarisk
Tamarix spp.

Potential habitat for focal species was mapped using information on current and historical distribution and life history requirements, and recently collected vegetation and geomorphic data (Stillwater Sciences 2007a, Stillwater Sciences 2007c, Stillwater Sciences and URS Corporation 2007) (Figure 2-18). Potential focal species habitat is based on existing riparian vegetation and geomorphic conditions; it is referred to as "potential" habitat because it is not certain whether focal species currently utilize this habitat. Potential habitat represents areas where, according to known habitat preferences and current vegetative cover, focal species are most likely to be found or establish themselves. This information is critical to identifying areas that are priorities for conservation, because they currently contain high-quality habitat or support focal species, as well as areas and habitat types that are priorities for restoration, because they are currently limited in distribution or degraded for some reason. The extent of focal species habitat could be much greater under restored conditions than illustrated in Figure 2-18, potentially increasing by 3,000 to 5,000 acres after completion of the Parkway project.

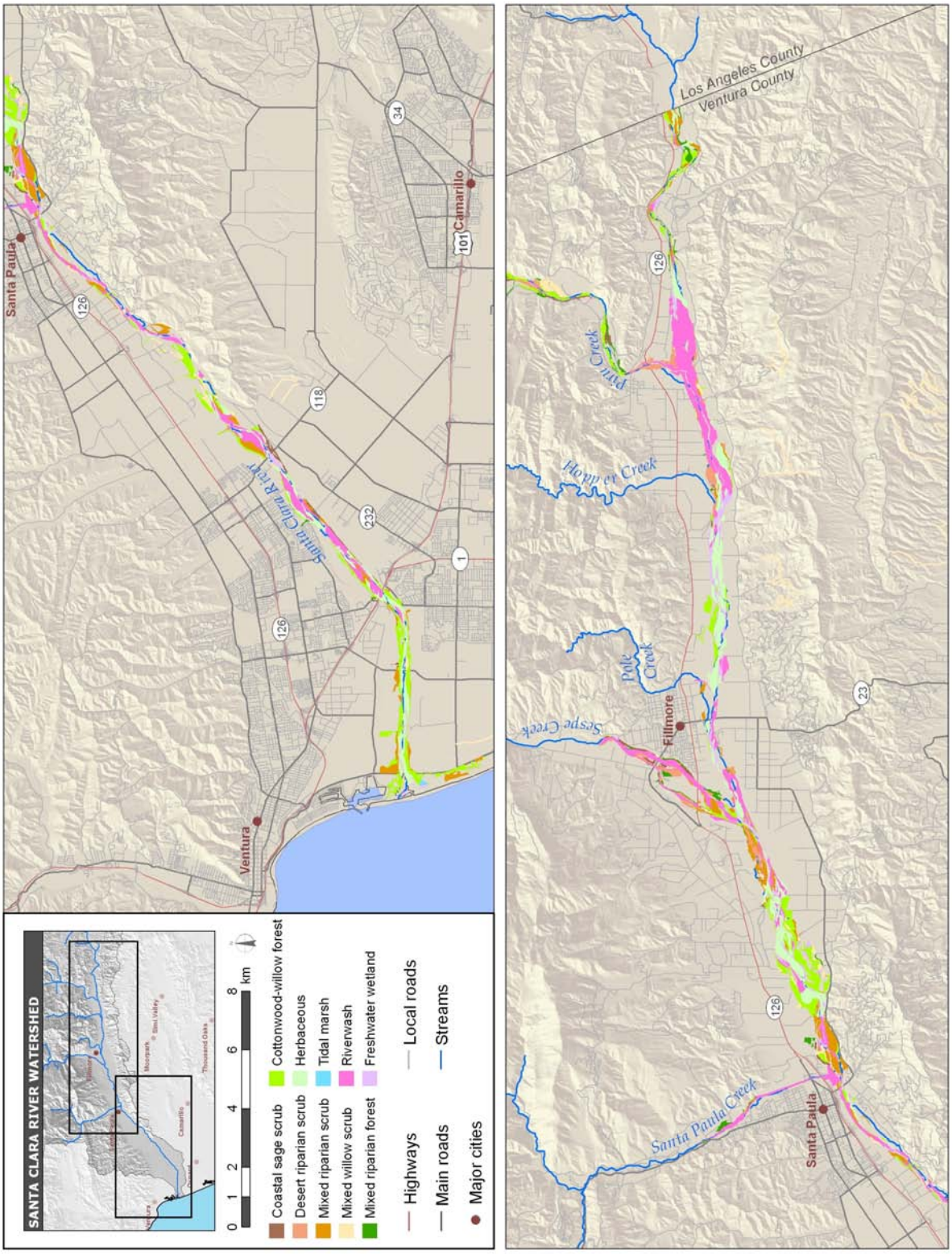

Figure 2-18. Extent of focal species potential habitat in the lower Santa Clara River (Stillwater Sciences 2007c).

Arroyo toad, a federal endangered species and a California species of special concern, was historically found in the upper and lower Santa Clara River basin and currently persists in large numbers along Sespe Creekfrom Hot Springs Canyon upstream to the mouth of Tule Creek (Sweet 1992, as cited in USFWS 1999b, USFWS 1994). They are habitat specialists that are primarily found on riverine floodplains shaped by dynamic fluvial processes, which scour vegetation and provide open riparian habitats (Sandburg 2004, as cited in USFWS 1999b). Arroyo toads require habitat near water. Their breeding habitat consists of open sites, such as pools and old flood channels that provide still water and have little emergent vegetation (Sweet 1992, as cited in USFWS 1999b). Juveniles and adults prefer to forage and burrow on terraces enclosed by dense riparian forest with little herbaceous cover. Many populations have been reduced or extirpated by extensive habitat loss from anthropogenic activities (*e.g.*, flood control, road building, agriculture, and recreation) (USFWS 1999b).

Western pond turtle, a California species of concern, has been observed throughout the lower Santa Clara River basin (CDFG 2007). Several known western pond turtle populations occur in the upper Santa Clara River watershed near Santa Clarita and in the vicinity of Piru Creek. The western pond turtle prefers nesting in grasslands and meadows away from trees and shrubs, and overwintering in upland areas in early- and late-stage riparian scrub and forest (Holland 1994, Reese 1996, Reese and Welsh 1997, Reese and Welsh 1998, Buskirk 2002). Juveniles and adults are generally found within lentic habitats (oxbows, side channels) near terrestrial areas used for basking and nesting (Holland 1994, Jennings and Hayes 1994, Ashton *et al.* 1997). Western pond turtle populations have experienced declines due to extensive conversion of wetland and riparian habitat for urban and agricultural use (Jennings and Hayes 1994, Germano and Bury 2001).

Least Bell's vireo, a state and federal endangered species, was reported as the most abundant and widely distributed endangered bird species within the lower Santa Clara River area (Labinger and Greaves 2001a). Least Bell's vireo prefers dense vegetative cover for nesting and a dense, stratified canopy for foraging (Goldwasser 1981, USFWS 1998a, Labinger and Greaves 2001a). Labinger and Greaves (2001a) observed least Bell's vireo within early successional cottonwood-willow forest, willow woodland, and mulefat scrub along the lower Santa Clara River. Least Bell's vireo was once abundant, but underwent sharp declines in abundance and range during the first half of the 20th century (USFWS 1998a, Labin-

Nesting least Bell's vireo
(photograph by Steve Maslowski, U.S. Fish and Wildlife Service)

ger and Greaves 2001a, Kus 2002). Habitat fragmentation from development within riparian areas and the establishment and spread of non-native plant species are primary factors in population decline. Habitat fragmentation can result in small populations that are spread out among remaining suitable patches. These smaller, more isolated populations are more vulnerable to habitat destruction, disease, low production years, and parasitism (USFWS 1998a, Labinger and Greaves 2001a).

Between 1990 and 2002, **southwestern willow flycatcher**, a federally and state endangered species, was recorded in locations along the Santa Clara River (CDFG 2007). They are generally found in riparian areas, preferring trees and shrubs with dense canopy for nesting and breeding, typically cottonwood, willow, mulefat, and saltcedar (USFWS 2002). Historical accounts suggest that willow flycatchers were once abundant in the inland valleys and coastal regions of central and northern California (Bombay *et al.* 2000). In the last five to six decades, however, southwestern willow flycatchers have been eliminated from most of the lower elevation habitat in California (Unitt 1987, Marshall 2000, Sogge *et al.* 2003). Water diversion and groundwater pumping, changes in flood and fire frequency, grazing, and establishment of invasive non-native plants have caused extensive loss of breeding habitat and reduced populations (USFWS 2002).

Western yellow-billed cuckoo, a state endangered species and a federal endangered species candidate, has been documented in the Santa Clara River watershed (where suitable habitat exists), although it is rare and some sightings may have been migrants (Labinger and Greaves 2001a, CDFG 2007). The bird has narrow habitat requirements, with field studies and habitat suitability modeling concluding that vegetation type (*i.e.*, cottonwood-willow forest), patch size, distance to water, and ratio of high to medium and low tree canopy height are critical factors determining the suitability of habitat for yellow-billed cuckoo breeding pairs (Laymon and Halterman 1989, Greco 1999). Western yellow-billed cuckoos typically inhabit densely foliated stands of deciduous trees and shrubs, particularly willows, with a dense understory, adjacent to slow-moving watercourses, backwaters, or seeps (CDFG 1983).

Adequate patch size and loss of habitat are the primary threats to western yellow-billed cuckoo populations. Loss of habitat is attributed to riparian and floodplain land conversion for agricultural and urban development, and to water management (*e.g.*, dams, channelization, ground water pumping and diversion) that alters the hydrologic regime and precludes the renewal and establishment of riparian trees and shrubs.

Steelhead, a federally threatened species, historically spawned and reared in tributaries of the lower Santa Clara River basin, downstream of the Santa Clara River and Piru Creek confluence (Kelley 2004, Harrison *et al.* 2006). Steelhead have specific habitat requirements for each life history stage (egg, fry, juvenile, smolt, and adult). The fish use the river as a migration corridor from the ocean to spawning and rearing habitats upstream in Santa Paula, Sespe, and Piru creeks (Stoecker and Kelley 2005). Currently, the mainstem supports low-quality steelhead habitat but historically may have provided important over-summering habitat for adult fish (Stoeker and Kelley 2005). The current distribution of anadromous steelhead in the Santa Clara River basin is influenced by several complete and partial migration barriers. The Vern Freeman Diversion Dam, approximately 10 mi upstream from the mouth of the mainstem, is likely a partial migration barrier (Stoecker and Kelley 2005). Since 1991, only 14 adult steelhead are known to have successfully passed through the diversion's fish ladder. Upstream of the Vern Freeman Diversion Dam, passage within Santa Paula Creek is limited by a fish ladder damaged during the 2005 floods[3], and Santa Felicia Dam has eliminated access to Piru Creek since 1955, leaving Sespe Creek as the only unregulated and potentially accessible spawning tributary available to upstream migrants.

Juvenile steelhead
(Photograph by Stillwater Sciences)

Tidewater goby, the Central California Coast Evolutionary Significant Unit (ESU) of which is a federal threatened species, has been observed in the Santa Clara River estuary as far as three miles upstream (AMEC 2005). Tidewater goby is an estuarine species that are an important part of estuarine food webs, as they provide prey for larger fish and piscivorous birds (Swenson and McCray 1996). The fish require shallow water (<3 ft) at the upper end of tidal lagoons and estuaries, sandy substrate for breeding, and velocity refuge during floods to prevent dispersal to the ocean or areas that are too saline (Moyle 2002, USFWS 2005). It is estimated that tidewater goby has disappeared from 74 percent of the coastal lagoons south of Morro Bay (USFWS 2005). The main threats to tidewater goby populations are changes in water

[3] Restoration and enhancement of fish passage at the Vern Freeman Diversion Dam and in Santa Paula Creek is currently being considered. The Vern Freeman Diversion Dam is undergoing formal Section 7 consultations under the federal Endangered Species Act, lead by the National Marine Fisheries Service. Barriers within the Santa Paula Creek sub-basin are being addressed through studies funded by the California Department of Fish and Game and the California Department of Transportation.

quality, degradation and loss of habitat due to urbanization (for example, the Santa Clara River estuary was approximately 300 ac, but is now closer to 30 ac [Stoeker and Kelley 2005]), and predation from invasive species such as piscivorous fish and African clawed frog (*Xenopus laevis*) (Lafferty *et al.* 1999, Lafferty and Page 1997). Conservation of tidewater goby habitat likely requires conserving the hydrologic regime and morphodynamics of the entire estuary system.

Nevin's barberry, a shrub in the barberry family, is a federal and state endangered species and listed by the California Native Plant Society as seriously endangered in California, with one extant occurrence in the Santa Clara River basin (CDFG 2007). Nevin's barberry generally grows within sandy, gravelly soil, on north facing slopes or low-gradient washes (Boyd 1987, Hickman 1993, CDFG 2006). On north facing slopes, it is associated with coastal scrub and chaparral habitat, while in low-gradient washes it is found in alluvial and riparian scrub (Boyd 1987, CDFG 2006). Population decline is likely related to low fecundity and habitat loss (Boyd1987, Mistretta 1989). Populations that occur in alluvial washes are threatened by urban and agricultural development, competition by non-native plant species, off-road vehicle activity, road maintenance, and vegetation clearing and channelization for flood control (Mistretta 1989, USFWS 1998b, CNPS 2006, NatureServe 2006).

Slender-horned spineflower
(photograph by U.S. Fish and Wildlife Service)

Slender-horned spineflower, a small annual in the buckwheat family, is federally and state endangered and a California Native Plant Society list 1B.1 species (seriously endangered in California), with three extant occurrences within the Santa Clara River basin (CDFG 2007). The flower is found on stabilized alluvial fans, floodplains, and terraces that are greater than 100 years in age (Wood and Wells 1996) and are inundated every 50 to 100 years (Prigge *et al.* 1993, as cited in Dudek and Associates 2000). In general, urbanization and stream channelization are the main causes of population decline (CNPS 2006). Preservation of older, stable alluvial surfaces in the historical range of slender-horned spineflower should be the primary focus for the protection of the species (Wood and Wells 1996).

2.4.4 Non-native Invasive Plant and Animal Species

The lower Santa Clara River riparian corridor, like most California landscapes, is host to many non-native invasive plant and animal species. These species can displace native plants and associated animals and disrupt food web dynamics and ecological processes. The most highly invasive species documented in the lower river and the locations where they were observed are shown in Table 2-5. More detailed accounts of these species are provided in Appendix A. The plant species listed in Table 2-5 have been documented

as aggressive invaders that displace native plants and disrupt natural habitats (Cal-IPC 2007, DiTomoso and Healy 2007). Other non-native plants have been documented in the lower river (see Appendix C of Stillwater Sciences and URS Corporation [2007]), but these are primarily agricultural or landscape plants and are not considered to be serious threats to native ecosystems. The animal species listed in Table 2-5 have been documented to impact focal species populations (see Stillwater Sciences 2007c) or are known to significantly impact ecological processes in other river systems.

Table 2-5. Distribution of non-native invasive plant and animal species in the lower Santa Clara River.

Species Name	General Distribution in California and Lower Santa Clara River
Woody or Persistent Perennial Plant Species	
giant reed *(Arundo donax)*	Widespread, high-impact invader of riparian areas; found throughout the Santa Clara River watershed.
pampas grass *(Cortaderia jubata)*	Widespread, high-impact invader of coastal forests, grasslands, dunes and scrub, riparian areas, wetlands, and serpentine soils; limited distribution in the lower Santa Clara River.
cape ivy / German ivy *(Delairea odorata)*	Widespread, high-impact invader of coastal riparian areas; limited distribution in the lower Santa Clara River.
Spanish broom *(Spartium junceum)*	Widespread, high-impact invader of coastal scrub, grassland, wetland, oak woodland, and forest habitats; limited distribution in the lower Santa Clara River.
salt cedar/tamarisk *(Tamarix* spp.*)*	Widespread, high-impact invader of desert washes, riparian areas, seeps and springs; found primarily in the upper reaches of the lower Santa Clara River.
Herbaceous Plant Species	
yellow star thistle & tocalote *(Centaurea solstitialis & C. melitensis)*	Widespread, high-impact invaders of woodlands, grasslands, and some riparian areas; found in many disturbed herbaceous/grassland habitats along the lower Santa Clara River.
sweet fennel *(Foeniculum vulgare)*	High-impact invader of grasslands and scrub habitats; found primarily in disturbed, scrub vegetation along the lower Santa Clara River.
perennial pepperweed *(Lepidium latifolium)*	High-impact invader of coastal and inland marshes, riparian areas, wetlands, and grasslands; limited to the estuary area of the lower Santa Clara River.
Animal Species	
brown-headed cowbird (*Molothrus ater*)	Widespread brood-parasite of many native bird species, including least Bell's vireo, in riparian areas throughout California, especially those near agricultural lands; found throughout the lower Santa Clara River, particularly in upper- and lower-most reaches where cowbird trapping was not implemented.

Species Name	General Distribution in California and Lower Santa Clara River
African clawed frog (*Xenopus laevis*)	Likely widespread in California and elsewhere around the world, they are drought and saline tolerant and feed on a wide range of aquatic invertebrates and vertebrates, (*e.g.*, tad-pole and juvenile amphibians, arroyo chub, mosquito fish, unarmored three-spined stickleback, and tidewater gobies); currently found in muddy, slow-water areas throughout the upper and lower Santa Clara River, including the estuary and tributaries.
black bullhead (*Ameiurus melas)*	Widespread in California rivers and reservoirs, they compete with native fishes for space and food, are voracious predators of smaller fish, and have been found to be at least partially responsible for the decline of the native amphibian species in other states; observed in Sespe Creek in 2005 and believed to be widespread in the lower reaches of the Santa Clara River.
green sunfish (*Lepomis cyanellus)*	Likely found in all drainages in California, out-compete and prey on other native fishes and appear to be at least partially responsible for local extinctions of California roach (*Hespero-leucus symmetricus)*; observed in Sespe Creek in 2005, but be-lieved to be widespread in the lower reaches of the Santa Clara River.

Distribution sources: Labinger and Greaves (2001), Stoecker and Kelley (2005), Stillwater Sciences and URS Corporation (2007)

3 OPPORTUNITIES & CONSTRAINTS

To be successful, restoration efforts must work within the ecological as well as the social, institutional and infrastructural context of the river. This context includes the legacy of historical impacts, land use and zoning, water resource development and management, flood control requirements, physical structures (such as bridges), environmental regulations, and local policy and management. In addition, geomorphic functioning, water quality, and the presence of existing habitat are two important attributes of the river that influence the priority and long-term success of implemented restoration strategies. Each of these topics is discussed in the following sections to provide insight into potential opportunities and constraints for floodplain restoration. Recognizing these opportunities and constraints, acquisition and floodplain restoration strategies on the lower Santa Clara River can be designed to be implementable and functional within the current and foreseeable social, institutional, and infrastructural framework of the river.

3.1 Morphologic Legacy Effects

Restoration efforts have their best chance of succeeding if measures are set properly within their watershed historical context, as well as other social, institutional and infrastructural constraints. Central to the watershed historical context is the recognition that human impact on river systems means that they have changed from their pre-disturbance state, and that restoration measures that strive solely to "turn back the clock" are unlikely to be successful. Mindful of this fact, an extensive study of geomorphic processes in the Santa Clara River watershed (Stillwater Sciences 2007a) underpins these restoration plans.

It is apparent that, in general, the lower 38 miles of the Santa Clara River have undergone significant morphological transformation over the last approximately 70 years (*i.e.*, the length of time for which there is quantifiable historical data)(Stillwater Sciences 2007a). Based on analysis of repeat aerial photographs, the average width of the active channel bed became almost 50% narrower in the period 1938–2005 (from approximately 1,580 feet to 830 ft). Furthermore, the width of the active channel is, over large stretches of the river, no longer related to the magnitude of the last flood as is typical in a semi-arid river, suggesting the influence of human activities instead. Narrowing is most pronounced in the reaches below the Santa Paula Creek confluence (Reaches 1-4) whereas the channel retains its responsiveness in the reach upstream of the Santa Paula Creek confluence to the Sespe Creek confluence.

Repeat thalweg surveys of channel bed elevation, supplemented with 2005 LiDAR imagery, indicate that the entire lower Santa Clara River has also incised an average of 2.3 ft in recent history (1949–2005, see Figure 2-9). This change is also most pronounced in the reaches between Santa Paula Creek and the estuary (Reaches 1–4) where the average incision is nearly eight feet, with a single station maximum exceeding 25 ft of incision just downstream of the Vern Freeman Diversion Dam. Since the diversion dam was constructed in 1991, the Above Freeman and Below Santa Paula Reaches (3 and 4) have recovered their bed level significantly, as would be expected, and have shown an increase in sinuosity. The Below Freeman Reach (2) continues to incise just below the dam, as does the Hwy 101 Reach (1) near the mouth of the river. Conversely, in the reaches upstream of the Sespe Creek confluence, the channel bed has aggraded an average of just over two feet in recent history, with a single station maximum increase of just over 10 ft. Between the Santa Paula and Sespe Creek confluences, the bed level has remained fairly static.

The overall picture is one of significant functional change in parts of the lower Santa Clara River. Naturally, the river is transitional between braided and meandering river forms, but over the last 70 years it has incised to such an extent that it now operates increasingly like a low-sinuosity meandering channel with a compound cross-section. Sediment budget studies indicate that the large floods that drive the Santa Clara fluvial system will generally result in a net sediment loss, unless there is sustained high-magnitude flooding from Sespe Creek at the same time. This means that incision (especially in the lower reaches) is likely to continue in the foreseeable future without corrective measures.

Sediment budget studies also indicate that the primary force for change was instream aggregate mining for sand and gravel. As in many other rivers in California, aggregate mining was responsible for extracting from the bed of the river far more sediment than was supplied by flood events over the long-term average. Floods alone are only capable of explaining 0.4 ft of the average 2.3 ft incision of the lower Santa Clara River; the remaining 1.9 ft can be explained by material extracted for aggregate (Stillwater Sciences 2007a). However, instream aggregate mining is no longer permitted in the Ventura County portion of the Santa Clara River and, as the river has naturally very high rates of sediment supply from hillslopes in its headwater tributaries, there remains a question about why the river bed elevation, especially in the below Freeman Reach (2) which saw the majority of the mining effort, has not recovered in two decades after the cessation of instream mining. The answer appears to lie in the existence of levees that constrain the width of the river during flood at far less than natural extent. This width constraint imparts a very high capacity for sediment transport (with relatively high stream

power) that enables the river to transport out more sediment than is transported in during almost all floods. Incision is thus inevitable.

Restoration efforts should recognize and understand the implications of these changes. In this regard, the lower Santa Clara River can be conveniently sub-divided into three sections. The legacy effects are greatest from the mouth to Santa Paula Creek, where the river is far narrower and deeper than it was 70 years ago, and where the river bed has been effectively disconnected from its floodplain by a combination of aggregate mining and the construction of reinforced levees. Partial bed level recovery in the Above Freeman and Below Santa Paula Reaches (3 and 4) was forced by the construction of the Vern Freeman Diversion Dam, which acts as a major grade control. The river is apparently becoming more sinuous in these reaches ,which suggests a priority on floodplain acquisition here to relive the potential future problems of bank erosion at the outside of meander bends. Downstream of this grade control, the river continues to incise; in numerous locations there are constraints on floodplain re-connection due to floodplain development and floodplain aggregate mining.

Between the confluence of Santa Paula and Sespe creeks, the river is functionally similar to 70 years ago. This is not necessarily equivalent to pre-disturbance conditions, as many changes may have occurred between Euro-American settlement of the watershed and the availability of quantitative historical data. However, the reaches are the most "natural" of those currently in existence in the lower Santa Clara River and, critically, the river bed still appears to respond naturally to flood events. The reasons for this condition seems to be three-fold: these reaches (*i.e.*, 5 and 6) were not subject to instream aggregate mining, are largely unconstrained by levees, and are the first to receive flood flows and sediment from the unregulated Sespe Creek (which frequently exceed flows from the upper watershed of the Santa Clara River). As such, restoration efforts should focus on preserving the current river-floodplain as much as possible, and releasing constraints where they exist. This includes, for example, setting back bank-edge levees where feasible.

Upstream of Sespe Creek, in reaches 7–10, the active river bed has both narrowed and aggraded slightly, suggesting that there has been a change in the balance between flood flows and sediment supply in the reach. Narrowing of the active river bed width during floods may be related to the extreme regulation of flood flows from Piru Creek since 1955, which has reduced the overall magnitude of flow flows in this portion of the Santa Clara River. In concert, there are three possible episodic causes for increased sediment load to the reach including (1) the increased frequency of ENSO-generated large flood flows since 1969, potentially delivering more than "normal" amounts of sediment to the reach; (2) incidents of landsliding associated with the 1994

Northridge earthquake and/or fire-related sediment production that has increased sediment supply to the lower Santa Clara River in flood events: or (3) a pulse of construction-related sediment resulting from the rapid upstream growth of the city of Santa Clarita. Whatever the true cause, there appears to be now relatively more sediment supplied than can be carried by the flood flows. Restoration efforts in these reaches should focus on floodplain and river bed acquisition as a basis for enhancing conservation values. Restoration activities should be planned cognizant of the fact that urban expansion generally results in a decrease in sediment supply per unit discharge in the long term, and so these reaches may begin to incise in future years if they are indeed responding to the expansion of Santa Clarita.

3.2 Land Use

The lower 33 miles of the river within the 500-year floodplain are currently dominated by agricultural and developed land uses (Table 3-1; Figure 3-1), although 7,214 ac of riparian vegetation is still supported (Stillwater Sciences and URS Corporation 2007).

Table 3-1. Land use-land cover types within in the 500-year floodplain of the lower Santa Clara River.

Land Use - Cover Type	Acres	Hectares	Percent of Mapped Area
Agriculture	8,141	3,295	33%
Developed	6,484	2,624	26%
Riparian Vegetation	7,214	2,919	29%
Riverwash	2,096	848	8%
Open Water	857	347	3%
Total Mapped Area	**24,791**	**10,033**	**100%**

Agriculture (orchards, vineyards, croplands, and pasture) is the primary developed land use in the lower river corridor, accounting for 33% of the land use in the 500-year floodplain (Table 3-1). Golf courses, mining, urban development, and municipal infrastructure are other important land uses in the lower Santa Clara River watershed, and continued population growth in both Ventura (*e.g.*, Oxnard, Ventura, Santa Paula, Fillmore, and El Rio) and Los Angeles counties (*e.g.*, Santa Clarita and the Newhall Ranch Development) is resulting in the continued and rapid expansion of these land uses.

The 10,167 ac of open water, riverwash, and riparian vegetation (Table 3-1) present an obvious minimum goal for Parkway project acquisition. In addition, vacant, undeveloped lands and flood-prone agricultural lands present clear opportunities for acquisition and restoration implementation. Property owners are more likely to sell or place conservation easements on relatively unproductive lands; these types of land uses are generally free of infrastruc-

ture that might complicate the implementation or compromise the effectiveness of restoration actions; and they can provide immediate benefits, even if funding for restoration or maintenance are not available. In fact, 3,250 ac of these land types have already been acquired within the 500-year floodplain of the lower Santa Clara River for public access and/or conservation and res toration purposes (see Section 3.5). While parcels of vacant, undeveloped lands occur throughout the lower river, the upper reaches (approximately Reaches 8 through 11) present particular opportunities for conservation and passive restoration strategies.

The large extent of developed land in the lower Santa Clara River watershed is a constraint to restoration. Large-scale restoration actions would not be appropriate on lands zoned for urban or residential uses. This is a particular issue near the towns of Santa Paula and Fillmore, where Ventura County growth boundaries currently allow for urban development within the 500-year floodplain (but see further discussion below). These areas have or could potentially have intensive development and concentrated populations, factors that limit the ecological effectiveness of restoration activities. Furthermore, developed property constrains the types of restoration actions that are appropriate on adjacent property: implemented restoration actions cannot compromise nearby land uses and must be done with concern for increased public access, vandalism, and trespassing on adjacent private property. Where appropriate, however, small-scale urban-oriented restoration projects, such as parks and interpretive areas, could be implemented in urban and residential areas.

Ventura County's current urban development restrictions provide an opportunity for restoration that should be capitalized upon as soon as possible to protect ecologically sensitive areas in perpetuity before land-use laws potentially change. Ventura County's Save Open space and Agricultural Resources (SOAR) boundaries limit urban growth to existing urban centers, such as the cities of Ventura, Santa Paula, and Fillmore, unless approved by a County vote (Fulton *et al.* 2003). While some agricultural and open space lands are within the growth boundaries, the vast majority of these land uses are located outside of the boundaries. Acquisition of these lands should be a priority while the SOAR boundaries are in place (current SOAR boundaries will expire between 2013 and 2018). Conversely, acquisition of agricultural or open space areas *within* SOAR boundaries, particularly those areas within the 500-year floodplain near the towns of Santa Paula and Fillmore (Reaches 3, 4 and 5 and Reach 7, respectively), should be top priorities to protect the floodway from urban development.

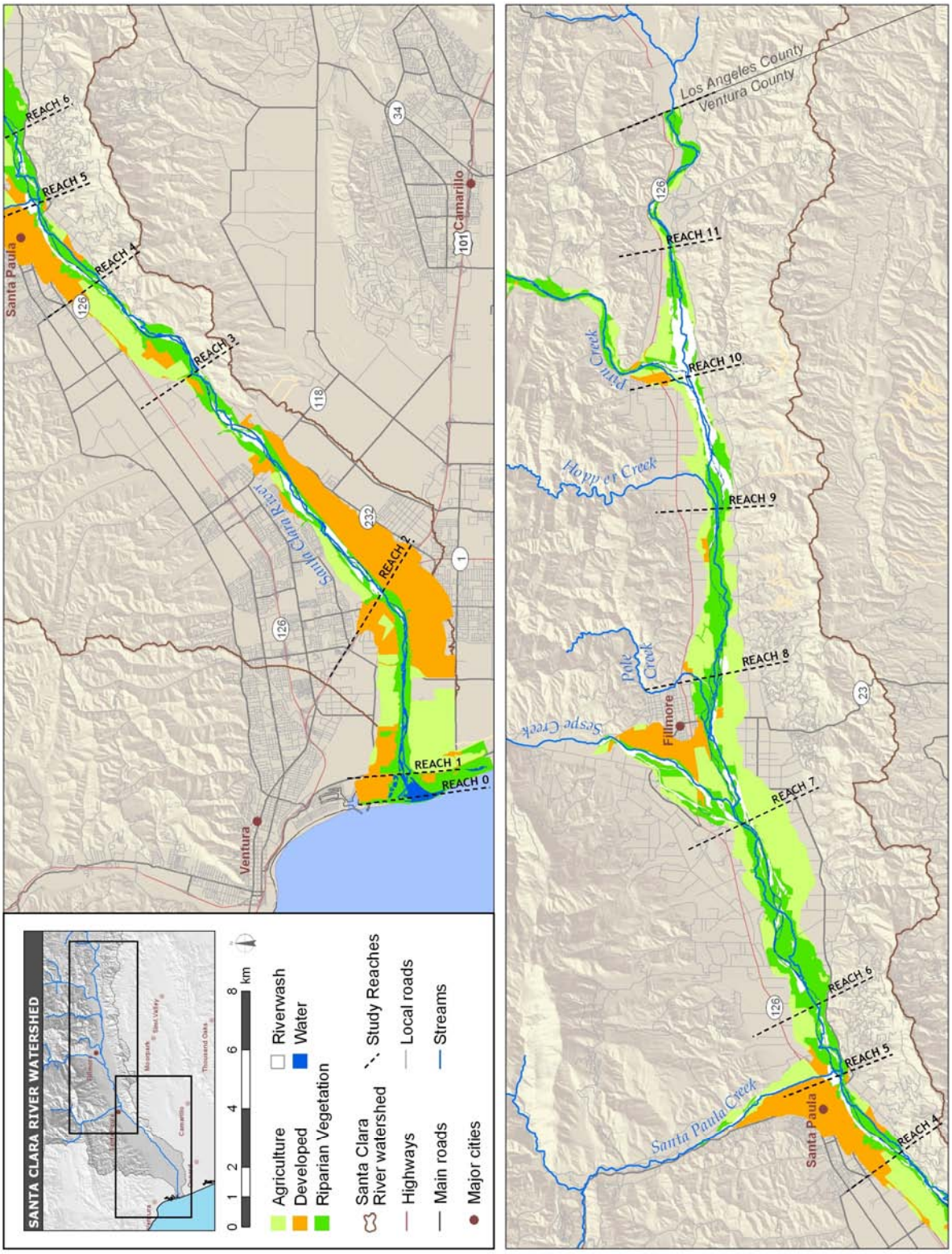

Figure 3-1. Land use-land cover types within the 500-year floodplain of the lower Santa Clara River.

As the population of Ventura County grows, however, there will be increasing pressure to convert agricultural and other open space to urban and suburban land uses. Fulton *et al.* (2003) indicates that urban areas in Ventura County have increased 20%, with a corresponding decline in farmland by 14% between 1986 and 2000. Because only 20,800 ac of unconstrained land occurs within the SOAR growth boundaries, any additional growth in the area would necessitate urbanization of either agricultural lands or important natural habitats (Fulton *et al.* 2003). This pressure to urbanize agricultural and natural areas, as seen in the town of Fillmore, presents a clear constraint to future restoration: urban land uses are far less compatible with natural river functioning and Parkway objectives than agriculture, and conversion of natural areas may result in there being no riparian corridor or river processes worth conserving or restoring.

3.3 Water Management & Flood Control

Water resource management (*i.e.*, flow diversion and flow regulation) has been affecting in-channel and floodplain geomorphic and ecological condition within the lower Santa Clara River since the early 1800's (Stillwater Sciences 2007a). Major water diversions for irrigation and groundwater recharge have occurred in the lower Santa Clara River since the early 1930's. The most significant diversion of water occurs at the Vern Freeman Diversion Dam (river mile 10.8), where 69,000 ac-ft (approximately 28% of the total annual runoff from the Santa Clara River) of water is diverted annually from the Santa Clara River to groundwater recharge spreading grounds in El Rio and Saticoy (URS 2005) (Figure 3-2). A portion of this diverted water can return to the mainstem below the diversion through groundwater discharge and agricultural return flow. Dams regulate flow in over one-third of the Santa Clara River watershed and have reduced flow to the mainstem by over 25% (Warrick 2002). Major attempts at flow regulation in the watershed began with the construction of ill-fated St. Francis Dam in San Francisquito Canyon in 1924 and in the lower Santa Clara River in 1955 with the completion of Santa Felicia Dam on Piru Creek (Figure 3-2). Reservoir releases in Piru Creek are currently the main source of flow in the lower Santa Clara River during the dry season, providing potentially unnaturally high summer season flows (URS 2005, Stillwater Sciences 2007a).

In addition to water resource management, flood control has also had a profound effect on geomorphic and ecological conditions within the lower Santa Clara River (Stillwater Sciences 2007a). Historically, flow spread out on the Oxnard Plain before reaching the Pacific Ocean. Settlement in the lower watershed resulted in the establishment of an extensive levee system to protect floodplain agriculture and commercial and residential developments. Over 33% of the lower Santa Clara River has levees on the adjacent banks (URS 2005), totaling 31.2 mi in length. The levee system includes those maintained

by the U.S. Army Corp of Engineers and the Ventura County Watershed Protection District (total length of 14.1 mi [22.6 km]) as well as private property owners (total length of 17.1 mi [27.5 km]) (Figure 3-2). Privately maintained levees are generally designed to protect agricultural fields and many need to be rebuilt after flood events.

Levees represent the most dramatic loss of floodplain habitat restoration opportunities, but development in the floodplain will continue to reduce the amount of natural floodplain area. It will also continue to raise the risk to existing floodplain infrastructure and flood-protection structures, because current rules allow structures or filling in the floodplain that result in as much as a one-foot rise in water-surface elevation. Alternative, zero-rise floodplain regulations that would significantly reduce not only the amount of floodplain disturbance but also the risk of future damage to existing structures and property have been applied in several other U.S. jurisdictions, although not to date in any Southern California communities. Zero-rise floodplain regulations require developers to show that proposed developments do not increase flood elevations at the site and/or downstream. Developments within the floodplain that increase floodplain water surface elevations are prohibited.

Recently, a comprehensive regional water resource management plan (or Integrated Regional Watershed Management Plan [IRWMP]) that includes the lower Santa Clara River was developed by the Watershed Coalition of Ventura County (WCVC 2006). The purpose of the IRWMP is to integrate watershed restoration planning and implementation efforts with the goal of improving water supply reliability, water recycling, water conservation, flood control, wetlands enhancement and creation, and environmental habitat and protection. Watershed-specific plans will eventually be developed, with opportunities for local stakeholder review. A similar plan is currently being developed for the upper Santa Clara River in Los Angeles County.

Existing water resource management and flood control practices, as well as the recent IRWMP, represent constraints on the restoration scenarios devised for lower Santa Clara River as part of this project. Restoration strategies will have to be carefully designed to avoid impacts to water management infrastructure (*e.g.*, diversions, levees adjacent to the Ventura Water Reclamation Facility and other developed land uses) and prevent any increase in flood risk to nearby development. In addition, restoration activities implemented as a part of the Parkway project will need to be coordinated with the recently developed IRWMP, which could potentially represent a constraint on the options available for restoration implementation.

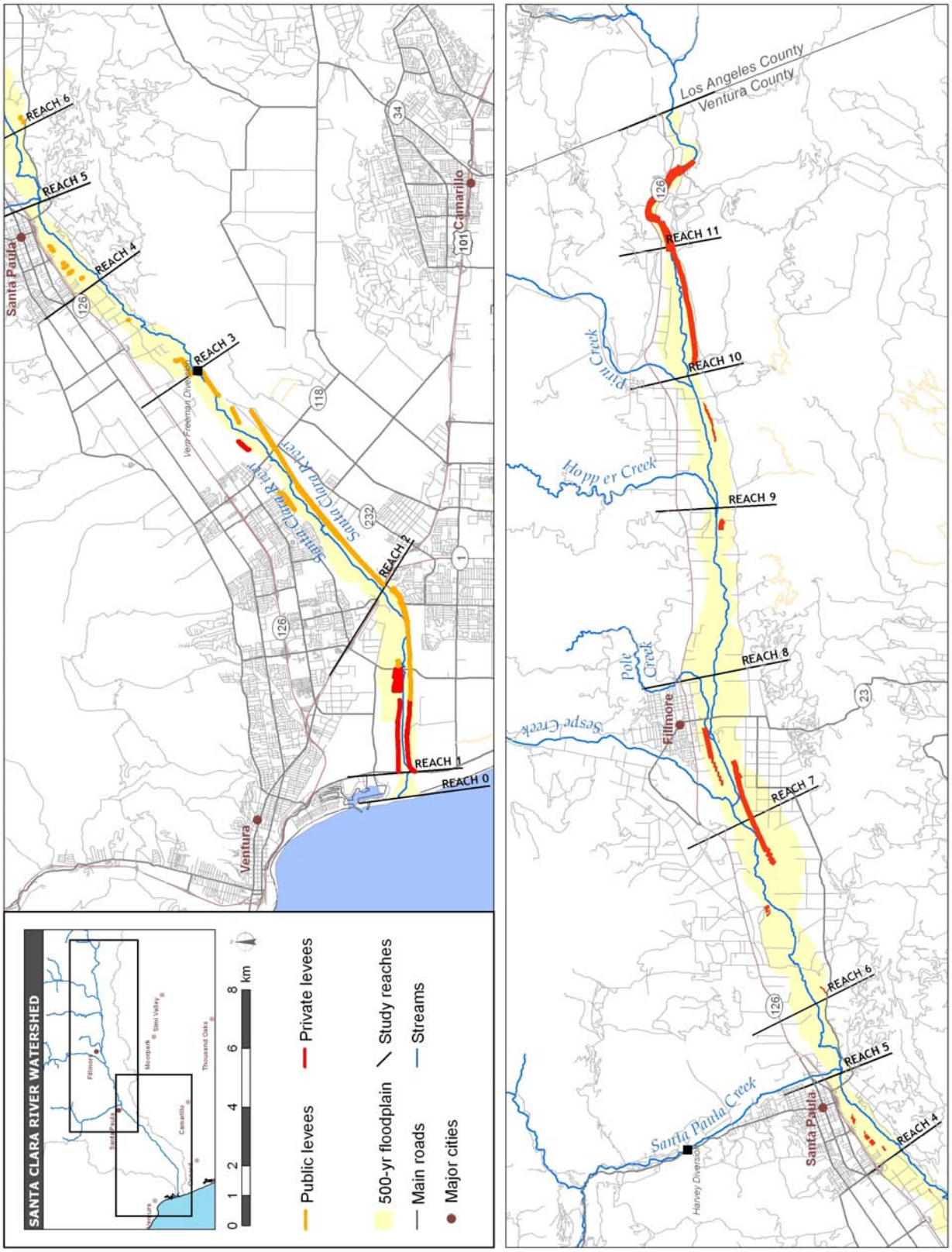

Figure 3-2. Public dams, diversions, groins and levees in the lower Santa Clara River.

Despite the considerable design constraints that water resource management and flood control practices will present to restoration implementation, there are several restoration opportunities related to these structures. First, there is considerable momentum in replacing or redesigning fish ladders at both Vern Freeman Diversion Dam and Harvey Diversion Dam on Santa Paula Creek to improve aquatic habitat connectivity, particularly for southern California coast steelhead which spawn in several sub-basins in the upper watershed. As discussed in more detail in Section 4.7, increasing fish passage is a necessary first step to improving aquatic habitat conditions in the lower Santa Clara River and, quite possibly, to sustaining southern California coast steelhead populations in the watershed.

The extensive network of privately maintained levees also presents an opportunity for restoration. These agricultural levees are far less engineered than those constructed and maintained by the U.S. Army Corp of Engineers and the Ventura County Watershed Protection District and, as a result, are frequently damaged by high flows (URS 2005). Purchasing flood-prone agricultural lands with these types of levees, such as in Reaches 6 and 8 through 11, from willing sellers reduces maintenance costs on less productive farmland and presents a technically feasible and cost effective opportunity to passively or actively remove and/or set back these levees.

3.4 Infrastructure

Infrastructure in the channel and floodplain of the Santa Clara River has impacted physical and biological process in the lower Santa Clara River since European settlement and has contributed to several contemporary challenges for river management and restoration. Infrastructure building began in the watershed in the 1800's with the establishment of permanent settlements and introduction of agriculture, and has increased rapidly since the 1960's with a five-fold increase in population within the watershed. Major in-channel infrastructure within the lower Santa Clara River includes eight bridges (Harbor Blvd., Victoria Ave., Southern Pacific Rail Road, Highway 101, Highway 118, 12th Street, Highway 123, and Newhall), levees protecting gravel mining operations (approximately one mile in length downstream of Freeman Diversion Dam), flood protection levees (discussed in Section 3.3), and rock groins installed for levee protection (approximately eight miles in length) (URS 2005). Major infrastructure within the 500-year floodplain is concentrated in urban areas (Oxnard, Ventura, Santa Paula, Fillmore, and El Rio) and includes the Ventura marina, Ventura Water Reclamation Facility, McGrath State Beach, and Santa Paula Airport (URS 2005).

The existing in-channel and floodplain infrastructure represent significant constraints on the restoration scenarios devised for lower Santa Clara River

as part of this project. Given the permanence and importance of the infrastructure discussed above, restoration activities will have to be carefully designed to avoid negative impacts, such as increased risk of flooding, sediment deposition, or woody debris accumulation, to existing or planned infrastructure that will remain intact following restoration. As opportunities arise, restoration strategies that incorporate the relocation, removal, or modification of flood-prone, high-risk and/or highly constraining infrastructure should be pursued. These opportunities are discussed in more detail in Section 4.2. For example, while any modification to the recently and expensively widened Highway 101 bridge is unlikely in the next several decades, there may be opportunities to widen or modify smaller, high-maintenance bridges farther upstream during or in addition to normal maintenance to improve flood conveyance and minimize the risk of damage from flooding and channel changes is minimized.

3.5 Water Quality

Segments of the lower Santa Clara River are impaired by several point and non-point source pollutants, including TDS (total dissolved solids), chloride, coliform, sulfate, ammonia, pH, toxaphene, and ChemA[1] (CRWQCB 2006, 2007). Section 303(d) of the Clean Water Act requires states to report to the Environmental Protection Agency (EPA) a list of waters that do not meet water quality standards and therefore require implementation of Total Maximum Daily Load (TMDL) requirements. Several reaches of the lower Santa Clara River (including the estuary) were listed on the 2006 303(d) list of impaired waters (Table 3-2, Figure 3-3) by the California Regional Water Quality Control Board – Los Angeles Region[2] (CRWQCB 2007). In addition, several pollutants of concern have been identified in stormwater discharge to the river, including total and fecal coliform, mercury, polyaromatic hydrocarbons (PAHs), DDT and their by-products, diazinon, sediment/total suspended solids (TSS), chlorpyrifos, copper, lead, thallium, bis(2-ethylhexyl) phthalate, and phosphorous (VCSQMP 2000).

[1] Chem A (Group A Pesticides) includes: aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan, and toxaphene

[2] The Los Angeles Region of the California Regional Quarter Quality Control Board has jurisdiction over all coastal drainages flowing to the Pacific Ocean between Rincon Point (on the coast in western Ventura County) and the eastern Los Angeles County line.

Table 3-2. CWA 303(d) water quality limited segments of the lower Santa Clara River (including tributaries).

Location[1]	Pollutant /stressor[2]
Santa Clara River – Reach 0 (Estuary)	Chem A[3]
	Coliform bacteria
	Toxaphene
Santa Clara River - Reach 1 (Estuary to Hwy 101 Bridge)	Toxicity
Santa Clara River – Reach 3 (Freeman Diversion to A Street)	TDS
	Ammonia[4]
	Chloride[5]
Santa Clara River – Reach 5 (Blue Cut gaging station to West Pier Hwy 99 Bridge)	Chloride[4]
	Coliform bacteria
Santa Clara River – Reach 6 (W Pier Hwy 99 to Bouquet Cyn Rd)	Chlorpyrifos
	Coliform bacteria
	Diazinon
	Toxicity
	Chloride[3]
Santa Clara River - Reach 7 (Bouquet Canyon Rd to above Lang Gaging Station)	Coliform bacteria
Hopper Creek	Sulfates
	TDS
Wheeler Canyon/ Todd Barranca	Sulfates
	TDS
	Nitrate and Nitrite[6]
Pole Creek	Sulfates
	TDS
Santa Clara River – Reach 11 (Piru Creek, from confluence with Santa Clara River Reach 4 to gaging station below Santa Felicia Dam)	Boron
	Sulfates

Source: CRWQCB (2007)

1 Reaches delineated as per CRWQCB 2007

2 All pollutants are from nonpoint or unknown sources

3 Chem A (Group A Pesticides) includes: aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan, and toxaphene

4 TMDL approved by USEPA in 2005

5 TMDL approved by USEPA in 2002

6 TMDL approved by USEPA in 2004

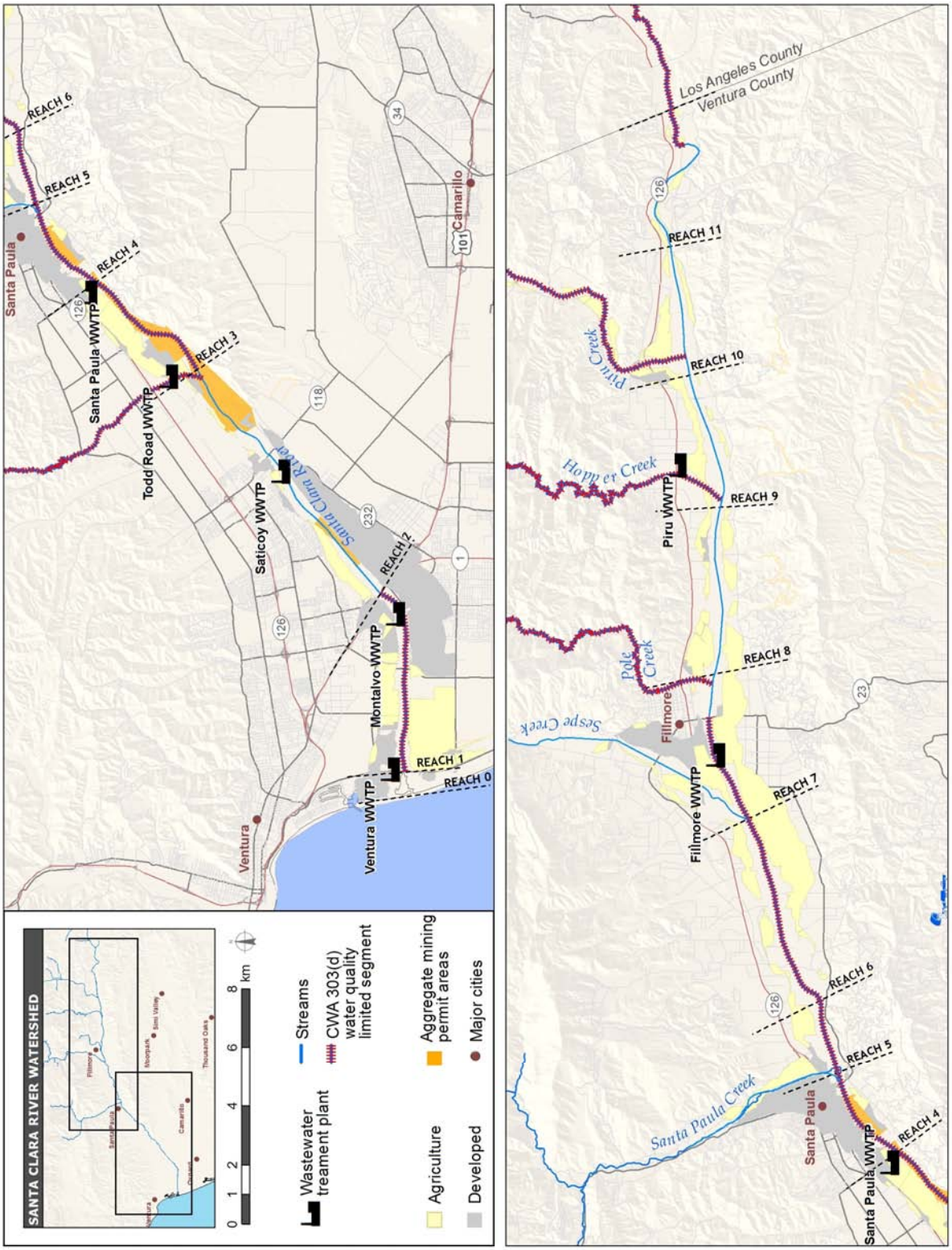

Figure 3-3. CWA 303(d) water quality limited segments relative to point and non-point sources for pollutants (Source: USEPA 2006).

Depending on the level of the pollutant and its effect on aquatic organisms, water quality impairment can constrain restoration on the lower Santa Clara River by potentially compromising the ecological benefits and effectiveness of implemented restoration strategies, particularly in the reaches and downstream of the tributaries listed in Table 3-2. Excess nutrients can lead to eutrophication, which can lower dissolved oxygen concentrations below those needed to support healthy fisheries. Excess nutrients are also believed to promote the widespread infestation of arundo, which appears better able to take advantage of anthropogenically enriched N levels in riparian ecosystems, allowing it to out-compete native riparian species (Coffman 2007). Excess bacteria can result in incidences of pathogenic outbreaks to aquatic organisms and people who contact the water during recreation. Salts (TDS and chloride) can damage agricultural crops, impact aquatic species, and impair drinking water.

While the specific impacts of poor water quality on biota in the lower Santa Clara River are currently not well-understood, the level of impairment and types of pollutants found in the lower Santa Clara River (see Table 3-2) imply that water quality potentially limits at least some life stages of many aquatic organisms (Kelley 2004, AMEC 2005). Effects of poor water quality on aquatic and terrestrial biota can be direct or indirect and, depending on the level of the pollutant, chronic (*i.e.*, reproductive interference and/or decreased vitality) or acute (*i.e.*, lethal). Indirect effects of toxicity due to poor water quality may be a significant factor influencing the manner in which ecosystems respond to other anthropogenic stressors, including deviations from natural temperature and flow regimes and response to resource competition from introduced species (Preston 2002, Fleeger et al. 2003). Additionally, certain pollutants can bioaccumulate in the food web, resulting in concentrations in biota that are orders of magnitude greater than in ambient water concentrations (Weiner *et al.* 2003). If water quality impairments are limiting aquatic species populations in the lower Santa Clara River, many process- or engineering-based restoration strategies will be unable to fully meet their objectives to improve habitat quality conditions for native aquatic species.

Fortunately, monitoring and improving water quality for multiple beneficial uses is already a priority of several organizations. The ultimate goal of the TMDL process is to develop and implement a plan to restore healthy water quality conditions. As a part of the TMDL process, the CRWQCB (Los Angeles Region) has initiated studies of, and intends to reduce the discharge of, those constituents listed in Table 3-2 with approved TMDLs by implementing Best Management Practices (BMPs) for new developments within municipal stormwater discharge systems (VSQMP 2000). BMPs typically include post-implementation monitoring to ensure the desired water quality standards are attained (VSQMP 2000). Los Angeles County Sanitation Dis-

tricts and LAWQCB have initiated agriculture/chloride threshold, ground/surface-water interaction, and endangered species/chloride threshold studies as a part of the upper Santa Clara River chloride TMDL (CH2MHill 2006). In 2007, the House of Representatives granted $1 million to improve water quality in the upper Santa Clara River related to wastewater treatment and hazardous waste contamination of groundwater (Ryan 2007). The Friends of the Santa Clara River organization is monitoring temperature, pH, dissolved oxygen, turbidity, flow, and several nutrient parameters at six sites along the river in support of the Nitrogen TMDL (FSCR 2007). These efforts to assess and improve water quality in the Santa Clara River should benefit native aquatic species and help other restoration strategies to maximize their ecological benefits.

3.6 Existing Habitat and Protected Property

Despite the degradation of the lower Santa Clara River ecosystem as a result of water and flood management, aggregate mining, and encroaching urban development, the fact that the river is not entirely channelized (as so many other coastal southern California rivers are) presents one of the greatest opportunities for implementing effective process-based restoration strategies.

Specifically, the comparatively intact floodway and riparian corridor of the lower river present critical opportunities to conserve existing habitat or conduct habitat enhancement activities, such as revegetation and non-native species removal, to both enhance ecosystem functions and protect sensitive species populations. In addition, the growing extent of publicly-owned, protected property within the 500-year floodplain presents opportunities to fulfill the goal of the Parkway project to create a continuous 25-mile long corridor that provides habitat and movement corridors for wildlife and multiple ecosystem and human benefits (Figure 3-4).

Figure 2-18 illustrates the extent of currently available habitat for Parkway focal species (see Section 2.4.2). There are 7,894 ac of existing habitat suitable for use by multiple focal species. The Below Sespe and County Line Reaches (6 and 11) and lower Piru Creek provide potential habitat for the greatest number of focal species and the greatest current potential habitat areas (Stillwater Sciences 2007c). These reaches also contain the greatest areas of mixed riparian and mixed willow scrub and cottonwood-willow forest, which support the greatest number of focal species. These areas are opportunities to conserve existing high-quality habitat patches that are known to be critical to native species populations (Stillwater Sciences 2007c). In addition, these areas provide focal points for implementing terrestrial restoration strategies, such as revegetation and non-native invasive species removal, to enhance the quality of these existing habitats. For example, building from conservation in the Below Sespe and County Line Reaches (6 and 11) and

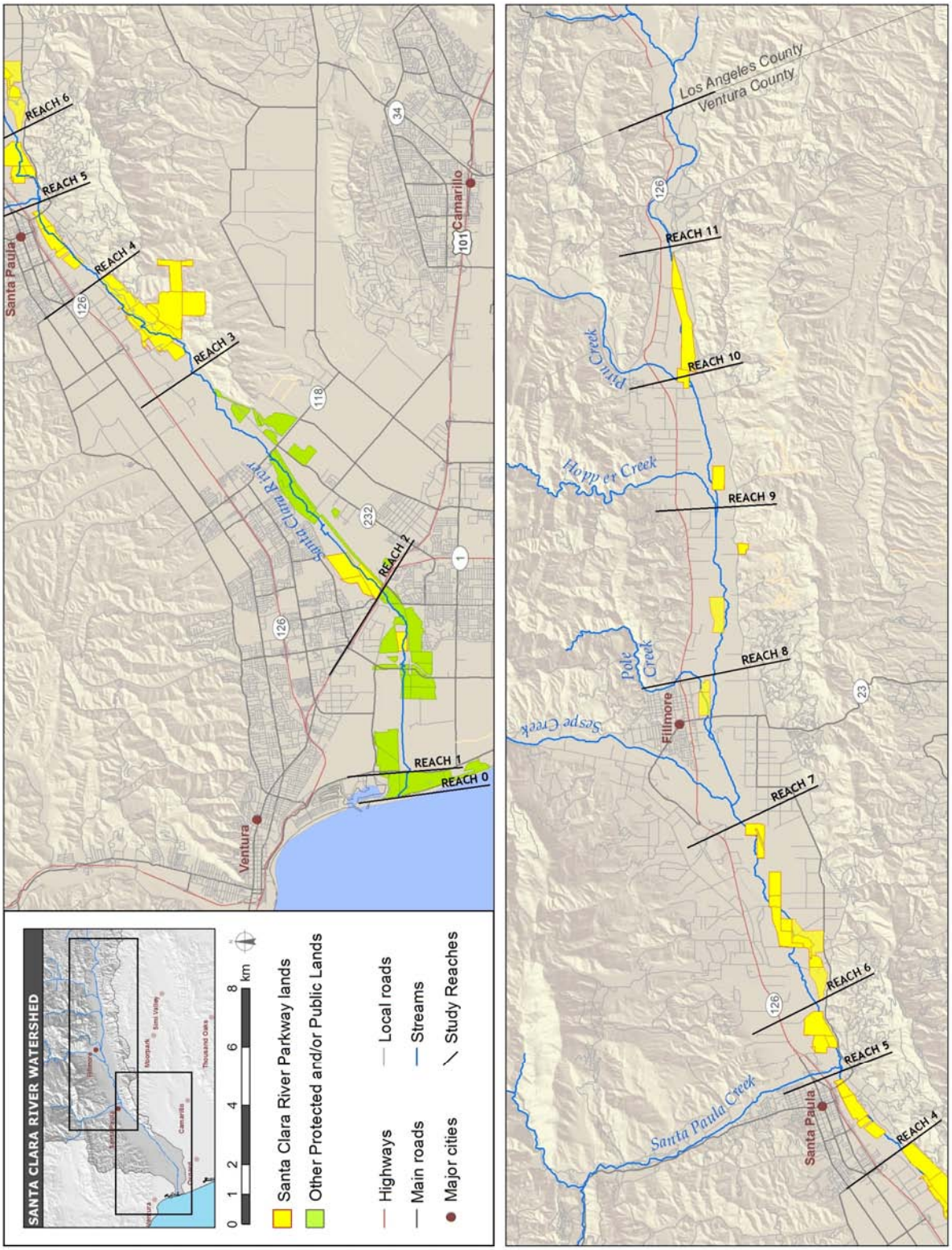

Figure 3-4. Public and/or protected property in the lower Santa Clara River (Source: TNC, unpublished data).

lower Piru Creek, there are restoration opportunities for non-native species eradication along the Above Sespe, Hopper and County Line Reaches (7, 8, and 11), that are highly infested by arundo and tamarisk. Restoration and conservation in these reaches would allow formation of habitat corridors along the Santa Clara River and along Santa Paula Creek to the Sierra Madre Range, which were identified in Penrod *et al.* (2001) as severely threatened habitat corridors. The restoration strategies developed for this report, particularly land acquisition, revegetation, and non-native species removal (see Sections 4.1, 4.3 and 4.4), have been designed to take advantage of the obvious opportunities presented by existing habitat within the lower Santa Clara River.

The existing, and growing, extent of public protected lands in the Santa Clara River watershed provides clear opportunities for implementing and maximizing the ecological benefits of restoration strategies. There is currently a total of 5,530 acres of publicly-owned, protected land within the 500-year floodplain of the lower Santa Clara River (Figure 3-4). This land includes approximately 326 acres of California State Parks and 3,250 acres of land owned and/or managed by the Coastal Conservancy, The Nature Conservancy and the Friends of the Santa Clara River. The Below Sespe and Above Piru Reaches (6 and 10), in particular, present opportunities to implement restoration strategies in protected areas where the ecological benefits of the actions can be optimized. In addition, they provide centers upon which additional property acquisition can build, eventually helping to achieve the goals of the Parkway project, providing movement corridors for wildlife and recreational opportunities for the public.

3.7 Regulatory Considerations

Implementation of the non-acquisition restoration strategies described in this report (levee removal or setback, floodplain re-contouring, non-native invasive plant removal, and active revegetation) will have to be done in compliance with all applicable federal, state, and local regulations and permit requirements. These regulations and permits require that certain measures be incorporated into the project design and implementation to minimize direct and indirect impacts on the environment, project neighbors, and nearby communities. The primary implications for restoration presented by most environmental regulations and permits include: 1) the time necessary to develop the required documents and navigate the permit process; and 2) particular measures that may have to be incorporated into the restoration design and actions and/or areas that may have to be avoided to minimize short-term impacts. For example, compliance with California Environmental Quality Act (CEQA) and National Environmental Protection Act (NEPA) will require significant interaction with the regulating agencies, development of an Initial Study and one of several environmental review documents, and a lengthy

public review and approval process, all prior to restoration implementation. Acquiring a Streambed Alteration Agreement and Clean Water Act Section 401 permit will likely require that particular actions be taken or avoided during project implementation; the Streambed Alteration Agreement may specify work windows for sensitive species in the area, and the Section 401 permit may specify maximum increases in turbidity allowed during project activities.

The long-term ecological benefits provided by the restoration strategies will help mitigate any short-term adverse impacts of project implementation and facilitate regulatory compliance. It is likely, however, that required regulatory measures will affect the design and implementation of most restoration strategies and must be considered carefully when developing final restoration designs. Appendix B of this report presents: 1) the required governmental reviews and permits that will likely be triggered by particular restoration strategies; 2) a summary of the environmental regulations and permits that the restoration strategies will likely have to comply with and/or acquire; and 3) a discussion of programmatic permitting approaches, as an alternative to piece-meal permit acquisition. Together, these discussions should assist future restoration strategy planners in developing appropriate schedules and approaches to permit acquisition.

4 RESTORATION STRATEGIES & FEASIBILITY

4.1 Restoration Overview & Objectives

For the purposes of this study, acquisition and restoration strategies that are feasible and appropriate for implementation on the lower Santa Clara River must:

- be considered a practical and effective method to achieve the ecological objectives of the Parkway project (see Section 1);
- be technically appropriate given the physical and biological attributes and human uses of the river corridor (see Section 2);
- work within current and foreseeable constraints and build from opportunities for acquisition and restoration in the lower river corridor, including legacy effects (see Section 3); and
- work toward the flood control objectives of the Parkway project.

These criteria were used jointly to screen potential acquisition and restoration efforts and resulted in six restoration strategies, as discussed below.

Restoration Strategies:

1) Parcel acquisition from willing sellers of threatened and/or high-value habitat that is currently prone to regular flooding;
2) Levee setback and removal, floodplain recontouring, and floodplain infrastructure modification;
3) Non-native invasive species removal;
4) Active and passive revegetation;
5) Creation of a network of water quality treatment wetlands, and
6) Aquatic habitat enhancements.

These strategies seek to restore physical functioning and improve ecological conditions, recognizing that watershed-wide impacts of grazing, urban development, instream mining, infrastructure, and surface and groundwater regulation preclude a complete return to presumed historical conditions (see Section 2). The objectives of the restoration strategies are as follows:

- the land acquisition strategy will provide long-term, protected and sustainable venues for restoration strategies to be implemented in a cost-effective and environmentally-maximized condition;
- the levee removal and setback and infrastructure modification strategy will improve physical functioning of the river to the extent feasi-

ble given existing flow and infrastructure conditions, to naturally create and sustain riparian habitats;

- revegetation will increase riparian habitat quantity and quality in currently degraded or newly restored areas and contribute to ecosystem functions;
- non-native species removal will help improve riparian habitat quality for native species, as well as remove limitations to some special-status species populations;
- ecosystem-based placement of water quality treatment wetlands will maintain a range of chemical parameters that support healthy native assemblages of aquatic species and meet water quality criteria; and
- aquatic habitat enhancements will increase instream habitat quantity and quality and help maximize the benefits provided by other restoration strategies.

These strategies are defined broadly to provide guidance to the Coastal Conservancy and other organizations involved in the lower Santa Clara River and serve as a means of prioritizing future funding, planning, design, and implementation efforts. These strategies are also process-based, in that they focus on conserving and/or restoring rates and magnitudes of geomorphological, hydrological, and biological processes that sustain natural habitat quality and quantity and so support biological productivity and a diverse assemblage of native species. The implementation of conservation and process-based restoration strategies should provide multiple ecosystem benefits and reduce the types and number of piecemeal restoration actions that need to be implemented. For example, land acquisition will conserve tracts of riparian-floodplain habitats and stands of existing native plant assemblages that already exist within the 500-year floodplain (Section 4.1). Levee removal and setback will increase the floodplain area and restore the process of floodplain inundation that is critical to meeting substrate and water requirements for the recruitment and survival of native riparian vegetation (Section 4.2). Non-native invasive plant removal will provide the opportunity for native vegetation to become established in place of non-natives and improve the quality of riparian habitat for various wildlife species (Section 4.3). Improvements to water quality will occur through the use of treatment wetlands to remove excess nutrients from the river, helping to discourage the recruitment and growth of arundo and restoring aquatic habitat conditions more conducive to natural assemblages of freshwater organisms (Section 4.5).

4.2 Land Acquisition

As the population of Ventura County grows, the pressure to convert agricultural and natural areas to urban and suburban land uses will increase (Fulton *et al.* 2003). When converted to urban land uses, not only are agricultural and

natural areas lost permanently, but remaining adjacent habitats become increasingly degraded and fragmented. The value of preserved natural oases in a mosaic of urban land uses are limited by their connectivity to other natural landscapes, particular for those species requiring large areas for habitat and gene flow between populations. Urban development in and near the lower Santa Clara River floodway will also result in increased flood risk to nearby developments and greater dependence on large-scale levees for flood control.

Public acquisition of floodway property by conservation organizations protects these parcels of land in perpetuity. Conservation easements can also be used to protect floodway lands for a wide range of timeframes, as well as preserve agricultural land uses that are more consistent with ecological objectives for the lower river than urban development. Strategic location of acquired or easement parcels protects valuable natural resources, provides connectivity between locally- and regionally-important landscapes for terrestrial and aquatic species (such as those identified by Penrod *et al.* 2006), protects populations of sensitive species, and provides technically appropriate, long-term venues for implementing restoration actions.

4.2.1 Strategy Concept & Feasibility

The general approach is to acquire, or to a lesser extent place under long-term conservation easement, properties within and adjacent to the 500-year floodplain of the lower Santa Clara River that: 1) conserve important habitat (*e.g.,* rare, threatened, or focal species habitat); 2) allow natural fluvial processes; 3) provide flood control benefits; and 4) are geographically, hydrologically, geomorphically, and ecologically appropriate to implement restoration strategies. Several investigations conducted as part of this Feasibility Study informed development of this restoration strategy, including riparian vegetation mapping (Stillwater Sciences and URS Corporation 2007), geomorphic assessment (Stillwater Sciences 2007a), riparian vegetation dynamics analysis (Stillwater Sciences 2007b), and focal species habitat assessment (Stillwater Sciences 2007c). In addition to the Coastal Conservancy, strategic land acquisition for the purposes of conserving existing high-quality habitat areas, providing connectivity between protected areas, and protecting native species populations is also the focus of extensive planning, acquisition and management efforts by TNC and the Friends of Santa Clara River. The concepts and strategies described in TNC's planning documents for the lower Santa Clara River (TNC 2006 and 2007) were integrated into this Feasibility Report in order to maintain consistency between Coastal Conservancy and TNC acquisition efforts. It should be noted that the term "acquisition" is used to indicate both fee-title purchase and conservation easement of entire or portions of parcels.

In addition to providing the benefits described below, the Coastal Conservancy has established the goal of acquiring a *continuous* corridor (rather than scattered parcels), because of the recreational benefit of a continuous river trail system and the practical problems created by intermittent gaps in the corridor. Intermittent gaps in the Parkway corridor would compromise (although not prevent) the Conservancies' ability to restore the river by:

- limiting biological connectivity;
- limiting flood management continuity;
- threatening the Parkway with potentially conflicting land uses in the future; and
- requiring additional publicly-funded construction and management costs.

Moreover, no undeveloped property in the floodway is so compromised by past use that it would not provide substantial benefits to the overall process-based restoration strategy; all of the non-urbanized property in the Parkway area meets some of the proposed criteria for acquisition (see Table 4-1). Nevertheless, given currently available funds and currently willing sellers, the

Table 4-1. Criteria for acquiring property for restoration strategy implementation purposes in the lower Santa Clara River.

Category	Criteria
Conservation	• Property contains high-quality and/or a large-extent of aquatic or terrestrial habitat that is used by focal species.
	• Property contains rare or threatened habitat type.
	• Property would provide connectivity to, or synergistic effects with, other preservation or restoration projects.
	• Acquisition of property would protect floodplain from urban encroachment.
Fluvial Processes	• Property, and upstream and downstream parcels, are of adequate size and set in landscapes suitable to support channel changes and potential increase in channel meander width.
	• Removal of levees, floodplain recontouring, or infrastructure modification on property would provide fluvial process and ecological improvements.
Flood Management	• Acquisition of property would reduce flood risk and/or reduce maintenance costs following floods.
	• Existing infrastructure on property can be modified or removed to reduce risk of damage from natural river processes or to be more compatible with ecological processes.
Implementation	• Property is of adequate size to provide balance between ecological benefits and negotiation effort and cost.
	• Property lacks infrastructure that would require maintenance or protection or that is incompatible with natural physical and ecological processes.
	• Groundwater levels are sufficient to eliminate or minimize the need for long-term irrigation of restoration plantings.
	• Bank-edge levees on property can be passively (via flood breaches) or actively (via heavy equipment) removed or set back without increasing flood risk to upstream or downstream developed parcels.
	• Land uses adjacent to the property do not compromise the integrity or objectives of implemented restoration.

Conservancies will choose, with the assistance of this study, to pursue acquisition of those reaches and properties first that will provide the greatest benefits.

The criteria listed in Table 4-1 can be used to identify and prioritize the acquisition of parcels falling within the four categories described above. They were selected to be compatible with criteria that might be used to prioritize property acquisition for habitat preservation purposes (see Cox *et al.* [2001] for specific examples). Of course, identifying and working with willing sellers is the top priority, and necessary precursor, for any acquisition effort.

Significant thought and consideration must be given to how best to apply and measure each criterion, and how much weight each holds in light of achieving restoration objectives. These criteria were used develop reach-specific recommendations for restoration strategy implementation (Section 4.8).

4.2.2 Anticipated Benefits

Acquiring land in the riparian corridor of the lower Santa Clara River for conservation and restoration purposes provides myriad ecological benefits in perpetuity. In general, protected parcels act as buffers between river processes and wildlife habitat and incompatible adjacent land uses. This allows the river to function more naturally (*e.g.*, inundate the floodplain and scour and deposit sediments) and wildlife to colonize and utilize patches of riparian habitat without risking flood damage to nearby land uses or compromising the ecological benefits of conservation and restoration actions. Specific to the other restoration strategies described in this report, acquired lands provide technically appropriate and protected venues for implementing restoration actions.

Obtaining conservation easements for agricultural areas within the 500-year floodplain can also provide benefits to the lower river. Ventura County has some of the most productive farmland in the world, but it is threatened by the increasing demand for housing and urban development (Ventura County Agricultural Land Trust and Conservancy 1996). Keeping lands within the 500-year floodplain in agricultural production through conservation easements not only preserves a valuable economic resource for the County, but also is far more compatible with the ecological objectives of the Parkway project than more developed land uses. Frequently, agricultural conservation easements have conditions limiting the extent of maintenance done following flood damage. In this way, less productive flood-prone lands can be naturally reclaimed by the riparian corridor, while allowing agricultural practices to continue.

4.2.3 Uncertainties

Several issues affect the feasibility of acquiring land within the 500-year floodplain of the lower Santa Clara River or the effectiveness of a purchased property in achieving desired ecological benefits. As stated previously, there must be a willing seller for land acquisition to be feasible. Property values, crop productivity, land maintenance costs, and prevailing attitudes towards restoration all contribute to a landowner's willingness to sell and cannot be easily controlled.

Given the high cost of land in coastal Ventura County, significant funding is necessary to purchase property for conservation and restoration. The fiscal feasibility of acquiring property in the Parkway will depend largely on available funding mechanisms and the cost of land at the time.

Land use conversions are dictated by county zoning ordinances, which can change over time. While current Ventura County zoning and growth ordinances provide clear opportunities for riparian conservation (see Section 3.2), it is difficult to anticipate what future administrations will write into legislation or how residents will vote as urban growth pressure increases after the current growth boundaries expire in 2013–2018.

4.3 Levee Removal & Setback

As discussed in Section 2, channel confinement by privately and publicly maintained levees and channel alteration by aggregate mining are two of the most severe impacts limiting geomorphic and hydrologic functioning of the lower Santa Clara River, especially below the confluence of Santa Paula Creek (Simons, Li & Associates 1983, Stillwater Sciences 2007a). In addition to altering the river's morphology, the levees have reduced floodplain habitat use opportunities for a variety of species within the lower watershed. Bozkurt *et al.* (2000) outlined levee impacts on ecological systems whereby a decrease in floodplain inundation and channel migration generally leads to reductions in habitat formation and maintenance, and ultimately to loss of biodiversity with a potential decline of many species populations. Although the levee system is an integral part of the flood control efforts along the river, its integrity is regularly threatened by winter high flow events, which, in conjunction with alterations to the channel morphology, has led to significant levee failures requiring costly repairs (Simons, Li & Associates 1983, URS 2005). Levee damage occurred both in the 1969 and 2005 flood events. As a result, there is a strong need to improve the effectiveness of the current flood control system to reduce maintenance costs, in addition to restoring geomorphic and ecological processes that have been adversely affected by the channel-constraining levees. This need is underscored by the recently published Federal Emergency Management Agency (FEMA) floodplain maps of the Santa Clara River, which concluded that significant lengths of the existing

levee system, particularly near Fillmore and Oxnard, do not meet FEMA certification standards (Sullivan 2008).

4.3.1 Strategy Concept & Feasibility

This restoration strategy involves some combination of the following actions either singularly or in combination: the active or passive removal of existing channel-confining levees, construction of setback levees away from the river channel, re-contouring of the restored floodplain area where there have been impacts by aggregate mining and other land uses, and removal or modification of infrastructure.

On properties acquired for conservation uses, passive or active levee removal may be feasible. Passive removal would be appropriate primarily for privately maintained agricultural levees that are not highly engineered, as are common along the lower Santa Clara River, particularly in the upper reaches. Passive removal implies allowing failure or breaching to occur naturally during large flood events but without subsequent repair. Active removal requires heavy equipment to dismantle the levee. In locations where levees are allowed to fail or breach, consideration should be given to whether restoration would benefit from the subsequent removal of the remaining levee structure.

In areas that require continued flood protection of development or agriculture on the floodplain, bank-edge levees could be replaced by setback levees constructed to provide the same level or better flood protection while still providing lateral connection between the river and its floodplain, thus encouraging natural fluvial processes and habitat development. A setback levee is placed landward some distance away from the active channel margin, which allows the restored floodplain area between the setback levee and the river's edge to be occasionally inundated during seasonal high flow events (Mount 1995, USACE 2002) (Figure 4-1). Levee setback strategies should be focused on the Hwy 101, Below Freeman, and Above Freeman Reaches (1, 2, and 3), where existing levees severely constrain the floodplain

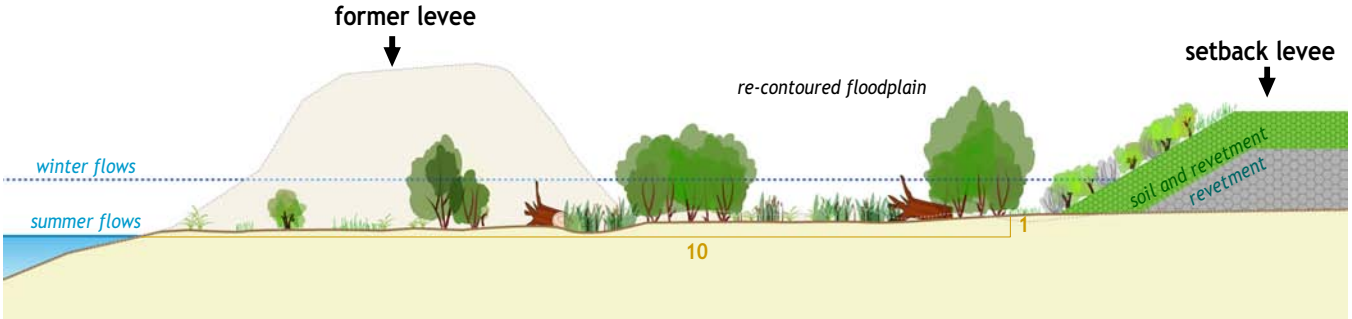

Figure 4-1. Diagram of setback levee strategy.

width and opportunities for setback exist. Some opportunities also exist in the upper reaches. The recent FEMA floodplain mapping of the Santa Clara River presents a strategic opportunity for setting back levees: when levees are reconstructed to meet FEMA certification standards, they can be simultaneously setback. Because they increase the floodway width and so inherently increase the river's flood conveyance capacity, setback levees need not be as high as bank-edge levees and are much less disruptive to high-flow processes.

Following removal of existing levees or construction of setback levees, some areas may require re-grading of the floodplain surface that is now part of the active floodway. This procedure, also called floodplain re-contouring, may involve filling in any abandoned gravel-mining pits, or other man-made depressions that could present stranding issues for salmonids and increased predation by avian or fish species (CDWR 2006). Lowering or sloping of the floodplain towards the river channel may also be required to increase the potential for seasonal inundation, especially along incised reaches where the elevation of the floodplain in relation to the channel bed has dramatically changed from pre-development conditions (*i.e.*, especially in reaches 1-4). Similar to other restoration projects involving floodplain re-contouring, such as on the Merced River (CDWR 2006), the restored riparian corridor would be re-vegetated with native plant species to provide habitat for wildlife. Floodplain re-contouring may also be necessary in the few areas where levee removal or setback would connect former mining or industrial areas with the floodplain.

Another activity associated with levee removal and/or setback is the modification or removal of infrastructure in the floodway. As the floodplain is widened and the channel is allowed to migrate, existing infrastructure may have an increased risk of damage by bank erosion or flood flows. In most cases, infrastructure is modest, consisting primarily of fencing, concrete debris, power lines, and pumping facilities. In other cases, such as McGrath State Beach, it would be prudent to relocate camping and day use facilities farther away from the river mouth to allow the river to move away from the Ventura Water Reclamation Facility and reduce maintenance costs following high flows. In more extreme cases, modifying bridges or relocating wastewater treatment facilities would be necessary to improve fluvial processes and reduce flood risk to these structures.

4.3.2 Anticipated Benefits

Implementation of this restoration strategy would potentially provide numerous benefits to riparian habitat conditions and geomorphic processes that have been substantially altered due to the presence of the existing channel-confining levees. These myriad benefits provide justification for process-based restoration strategies. The primary ecological benefit of this restoration

strategy is the re-establishment of a seasonally inundated floodplain. The river's re-connection to its floodplain will allow for an exchange of water, sediment, and nutrients between the river and its floodplain, and an increase in riparian habitat patch size and quality. Constructing setback levees would, where necessary, maintain flood protection for the surrounding developments outside of the Parkway area. An enlarged river corridor would enhance landscape linkages, providing movement corridors for wildlife between protected lands. Additionally, a wider floodway should increase the residence time of flood waters on the floodplain and so increase groundwater recharge (Poole *et al.* 2002, Kazama *et al.* 2007). It should be noted that while levee setback and removal may need to be implemented in a parcel-by-parcel fashion due to land acquisition and funding constraints, the larger benefits of this restoration strategy, particularly flood control and landscape linkages, as well as cost efficiencies, will not be fully realized until larger extents of levees are setback or removed.

Re-initiation of fluvial processes, such as bank erosion, bar growth, channel migration and width increases to the active channel bed, would be an expected outcome following implementation of this restoration strategy. During flood events in a braided-meandering river similar to the Santa Clara River, bank erosion naturally occurs at the outer banks of a river bend where velocities are greatest, or near perturbations on the channel bed, such as mid-channel bars, that can topographically steer the flow against the adjacent bed or banks causing higher shear stresses to scour the channel boundaries (Leopold *et al.* 1964). Deposition of sediment occurs in slower portions of the channel and contributes to the formation of point bars, mid-channel bars, and natural sedimentation processes. The re-initiation of this process would not only restore a dynamic physical characteristic of the Santa Clara River but also would benefit in-channel and riparian habitat diversity (see Section 4.7) (Bozkurt *et al.* 2000).

The long-term trend of channel incision within the downstream-most reaches could potentially slow or cease following implementation of this restoration strategy, because the flood waters would be allowed to spread out upon the reconnected floodplain, thus increasing the river's flood capacity and effective flood width. Also, because floodplain discharge has low velocities due to frictional resistance from vegetation and other roughness features on the floodplain, sufficiently broad floodways can attenuate flood flows, thus diffusing the potential for deep, high velocity flows to scour the channel bed. An additional benefit from the seasonal inundation of the restored floodplain is recharge of groundwater into the basin's aquifers, which are a major source of fresh water for the many land-use activities in the valley, especially agriculture. The amount of groundwater recharge by inundated floodplains depends on several factors, the most critical of which are the residence time of the water on the floodplain, the permeability of the floodplain substrates,

and depth to the water table. For these reasons, arid-region rivers dominated by sporadic high flow events such as the lower Santa Clara River, have greater potential for groundwater recharge because their floodplains are often composed of coarse sediments with high permeability, and the groundwater table is usually well below the channel (G. Wallace, Pacific Groundwater Group, pers. comm., 2008). Short residence time, low porosity, and a shallow groundwater table inhibit groundwater recharge. For example, the Oxnard Plain groundwater basin has several clay strata that inhibit effective infiltration of floodwater. However, the majority of the groundwater basins underlying the lower Santa Clara River (see Section 2.3.8) occur in recent and relatively deep alluvial deposits that are very porous and allow easy infiltration of floodwater.

A final benefit from this action is improved flood protection for the various developments located throughout the lower Santa Clara River valley. Hydraulic modeling of levee setback scenarios in the lowest reaches of the river suggests that water surface elevations and velocities for high-magnitude flow events could be greatly reduced. A simple simulation showed that setting back south bank levees between Victoria Ave Bridge and Harbor Blvd Bridge decreased water surface elevation by approximately 6 to 7 ft and decreased flow velocity by approximately 3 to 7 ft/sec for the 10- , 50- and 100-year flood events when compared to existing conditions (Stillwater Sciences 2007f). Flood protection can be further enhanced by new setback levees by building them according to the latest engineering and FEMA certification standards. Setback and properly constructed levees should also reduce levee maintenance and other public works and private property costs associated with flood damage.

4.3.3 Uncertainties

One of the uncertainties involved with this restoration strategy is the local change in channel hydraulics and sedimentation resulting from a parcel-based strategy of levee removal or setback. Depending on land uses surrounding the conservation parcel, it may be necessary to model flood flows (and resultant shear stresses as a guide to erosion and deposition trends) to ascertain any potentially negative upstream or downstream effects. Maximizing the levee setback distance from the river would be expected to offer the greatest number of benefits to re-establishing dynamic channel processes, attenuating flood flows, and improving habitat conditions (Bozkurt *et al.* 2000) without generating potentially negative effects A regional-level evaluation using hydraulic models should be conducted for the Parkway area to assess the overall potential flood management benefit of this restoration strategy.

Related to the hydraulic uncertainties discussed above is the effort to acquire required environmental compliance documents and permits. Restoration

actions that have the potential to impact the river channel, banks, floodplain, and wetland areas within the floodplain are subject to considerable scrutiny under a number of environmental statutes (see Section 3.7 for more details). Restoration planners will have to work within regulatory constraints and secure all necessary permits and approvals prior to implementation which could increase the cost and timeframe of restoration significantly. Fortunately, flood conveyance improvements and ecological benefits of this restoration strategy should facilitate the acquisition of necessary environmental documentation and permits.

Another significant uncertainty related to levee setback is the cost of implementation. Additional Parkway acquisition would be necessary to provide a sufficient amount of land for the successful restoration of a functional, seasonally inundated floodplain and riparian corridor. Costs associated with the removal of existing levees, construction of setback levees, and floodplain re-contouring can be significant. For example, a cost estimate for a proposed setback levee project on the Sacramento River was at $2,000 per linear foot ($10.5 million per mile) (M. Dietl, USACOE, pers. comm., 2007). This estimate included all associated project costs, including engineering, permitting, removal of the existing levee section, and construction of a setback levee. Costs associated with setting back agriculture levees on the Santa Clara River are likely to be far lower, and passive removal of agricultural levees would require almost no cost. At numerous locations on the Santa Clara River, natural terrace formations or a perceptible lateral floodplain gradient may mitigate against the need to replace a bank-edge agricultural levee.

While an increasing number of levee setback projects in California can provide some guidance and insight, the specific outcomes of levee removal and setback along the lower Santa Clara River are still uncertain. To date, there have been proposed setback levee projects for several California streams, including the American River (Jones & Stokes 2005), Deer Creek (DCWC 2002, Jones & Stokes 2005), Berryessa and Coyote creeks (urban watershed) in Santa Clara County (SCVWD 2005), Lower Calleguas Creek (Coastal Conservancy 2007), and Ventura River (Coastal Conservancy 2004). However, because none of these projects occur in analogous settings, and long-term monitoring has yet to be carried out, detailed understanding of how the lower Santa Clara River might change as a result of setback levee and floodplain re-contouring is limited.

4.4 Passive & Active Revegetation

The significant loss of riparian vegetation in the lower Santa Clara River equates with a similarly significant loss in habitat quality, quantity and ecosystem functioning. Conservation is particularly important for regionally or locally rare vegetation types, such as coastal sage scrub and desert riparian

scrub, and species, such as Nevin's barberry (*Berberis nevinii)* and Slender-horned spineflower (*Dodecahema leptoceras)*. Used in conjunction with other proposed restoration strategies, active and passive revegetation of native riparian plant species can increase the extent and improve the quality of riparian habitat and contribute to ecosystem functioning.

4.4.1 Strategy Concept & Feasibility

Other process-based restoration strategies described in this chapter are integral to a successful revegetation strategy. In a survey of revegetation projects in semi-arid river systems, Briggs (1992 as cited in Briggs 1996) found that successful revegetation projects nearly always incorporated the implementation of process-based restoration strategies in addition to, or in lieu of, active revegetation (*e.g.,* replanting native species using horticultural techniques). Where improvements to riparian vegetation composition and extent are desired but not necessarily expected by implementing other process-based restoration strategies (see discussion under Section 4.1), active revegetation should be considered.

In areas where floodplain inundation occurs across a wide area and/or groundwater levels are high, revegetation should rely primarily on natural recruitment, although lower cost active revegtation actions (*e.g.*, planting cuttings without irrigation in areas of high groundwater) might also be appropriate in some of these areas. Vegetation mapping of the lower Santa Clara River in 2005 and 2006 documented a large number of willow and cottonwood seedlings in the river corridor (Stillwater Sciences and URS Corporation 2007). Clearly, natural seed sources are adequate for natural recruitment in many reaches, although physical conditions may not support the continued growth and survival of those seedlings (as evidenced by the Below and Above Piru Reaches [9 and 10] that are largely devoid of vegetation). Natural recruitment generally should not be presumed where flood flows do not inundate at least once every year or two, or where groundwater levels are documented or suspected of being inadequate to sustain plants during the growing season. Levee removal and setback should increase the area of the lower Santa Clara River that is appropriate for passive revegetation strategies by increasing the available floodplain area and facilitating inundation of floodplains by slow-moving floodwaters during high flow events (see Section 4.2).

Correlations between physical variables and vegetation types can be used to predict what species are likely to naturally recruit in an area based on physical information from a site (Stillwater Sciences 2007b). Revegetation in the most active or dynamic portions of the floodway (*i.e.*, those portions of the river that are scoured by floods every one to two years), should generally not be a high priority for restoration actions. Natural recruitment of vegetation is likely to occur in these areas without any intervention, although removal of

newly established vegetation through scour during subsequent floods is also likely to occur. The most appropriate restoration action in such active areas would most likely be removal of arundo propagules following a major flood (both to control the spread of arundo density and to facilitate establishment of seedlings of native riparian species by removing a potentially dominant competitor).

Where natural recruitment or seedling survival is not expected to achieve revegetation goals, perhaps because of a lack of upslope or upstream seed supply, less reliable surface inundation, or shallow groundwater levels, active revegetation should be implemented. Active revegetation consists of planting, and potentially irrigating, native species seedlings, cuttings and/or seeds.

Priorities for active revegetation projects should use the following guidelines:

- For willow, cottonwood, and mixed riparian forest and scrub habitat types, focus on areas outside the active floodway (*i.e.*, where significant and frequent scouring would not be expected) and in gaining reaches of the river (Reaches 1, 2, 3, 5, 8, and 11; see Table 1.1), where active revegetation is most likely to be successful (Briggs 1996).
- For desert riparian scrub habitats (*e.g.*, *Artemisia tridentata* and *Lepidospartum squamatum* alliances), focus on areas outside the active floodway and in drier, losing reaches (Reaches 7, 9, and 10 and lower Sespe Creek).
- When restoring acquired parcels that were former agricultural areas or that are disturbed (see Figure 2.4-5), use active revegetation to accelerate the recruitment of native species and the establishment of a dense canopy of vegetation.
- Following large-scale arundo removal projects (except if in the active floodway), use active revegetation to replace lost nesting habitat. Least Bell's vireo and southwestern willow flycatcher, both endangered bird species found in the lower Santa Clara River, nest in arundo now that it has largely replaced the willow scrub that they typically nest in (Labinger and Greaves 2001). Large-scale arundo removal should be followed by revegetation of native scrub species in order to replace the structural habitat needed for these birds during breeding season (Labinger and Greaves 2001). Planting cuttings of willow and cottonwood, which are relatively inexpensive, is more appropriate in areas that receive intermediate levels of scour from flood flows to replace the loss of structure following arundo removal and to help compete with arundo regeneration.

Planting just prior to the rainy season can reduce the need for irrigation (although it may increase the chances for scour by winter floods), but given the

semi-arid climate and lowered groundwater table in some portions of the lower Santa Clara River corridor, irrigation should be anticipated for most upland surfaces that are not inundated frequently or do not have groundwater conditions that support the germination or early growth of restoration plantings. In these instances, drip irrigation should be considered as it helps conserve water and limit the establishment of weedy species that can compete with planted seedlings, cuttings, and seeds (Stillwater Sciences 2007e).

Determining the suite of native species to plant and the conditions under which planting is most likely to be successful are critical parts of revegetation planning (Briggs 1996). Regionally or locally rare vegetation types, such as desert riparian scrub and coastal sage scrub, and those that provide habitat for multiple species, such as mixed riparian and mixed willow scrub and forest, should be priorities for revegetation projects on the lower Santa Clara River (Stillwater Sciences 2007c, Stillwater Sciences and URS Corporation 2007). Finding locations suitable for restoration of these plant communities generally depends on the ecological requirements of the dominant species. Appendix C lists a selection of native dominant tree and shrub species that are currently found in the lower Santa Clara River and that are appropriate for active revegetation projects. Appendix C also identifies the ecological requirements of the species to provide guidance for revegetation planning.

4.4.2 Anticipated Benefits

Acquiring land, setting back levees, and allowing passive revegetation or actively replanting former agricultural areas or disturbed areas will increase the extent and density of the riparian vegetation, improve habitat conditions for native species, and increase the buffer between the river and adjacent land uses.

Intact corridors of riparian vegetation have been demonstrated to provide the following benefits to native species:

- breeding, foraging, and refuge habitat for numerous native terrestrial species, particularly neotropical migrant birds (Gaines 1974, Laymon *et al.* 1997, RHJV 2004);
- corridors through which wildlife can migrate over long distances (Penrod *et al.* 2006);
- noise and odor reduction from nearby land uses that might discourage native species from inhabiting the riparian corridor (Corbett and Lynch 1985);
- habitat heterogeneity, habitat structure and cover in the form of large woody debris, and lower late-summer water temperatures (McDade *et al.* 1990, Opperman and Merenlender 2004);
- shade and cover in near-bank aquatic habitats, which is important for some species of fish (Beschta 1991, Johnson and Ryba 1992); and

- a natural food source to the river in the form of leaf litter and terrestrial insects (Vannotte *et al.* 1980).

In addition, riparian buffers of adequate width can provide the following ecosystem services:

- trapping and removing up to 75% of sediment from runoff (Trimble and Sartz 1957, Doyle *et al.* 1977, Gough 1988, NRCS 2000) (see Figure 4-2);
- trapping and removing up to 50% of nutrients and pesticides and 60% of pathogens from runoff (Petersen *et al.* 1992, NRCS 2000) (see Figure 4-2); and
- stabilizing streambanks and reducing erosion (NRCS 2000).

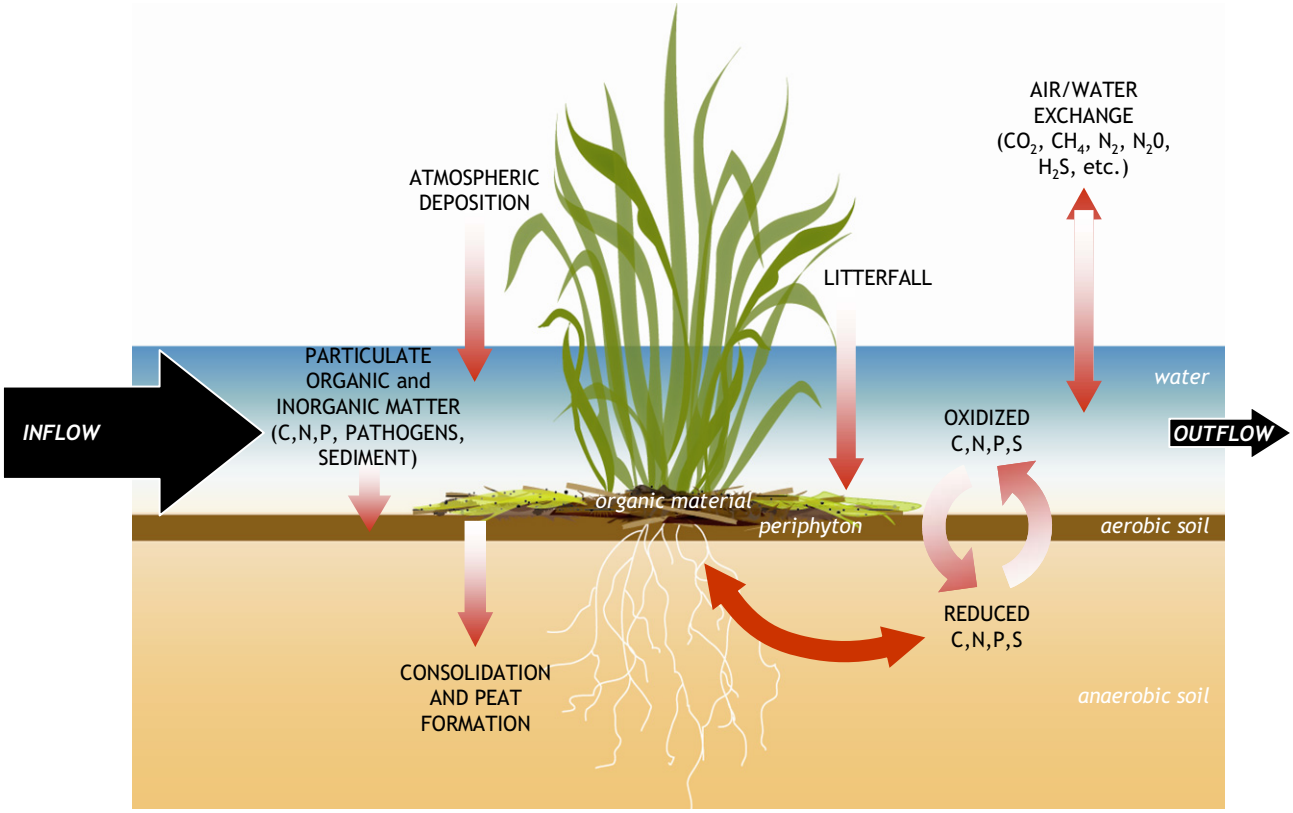

Figure 4-2. Simplified nutrient and sediment cycling diagram illustrating the various processes that can filter runoff.

4.4.3 Uncertainties

There are two primary uncertainties related to the successful implementation of both passive and active revegetation projects on the lower Santa Clara River: groundwater levels and non-native invasive species. Available groundwater data from the 500-year floodplain of the lower river is so variable, in terms of both period of record and recorded water-table depths, that it is difficult to identify any spatial or seasonal patterns in groundwater lev-

els, particularly at a level of detail suitable for restoration planning. This lack of understanding makes it difficult to predict whether plant roots will be able to reach groundwater within a year or two, a key to long-term successful revegetation. The best clue of where groundwater levels are suitable for revegetation comes from mapping of gaining and losing reaches of the river (*i.e.*, reaches where groundwater moves toward and contributes to surface flows versus reaches where surface flow infiltrates the channel bed and contributes to groundwater), but this is largely based on the quantity and quality of existing vegetation rather than groundwater monitoring data (USGS 1999, SCREMP 2005). SCREMP (2005) mapping indicates that Reaches 1, 2, 3, 5, 8, and 11 are primarily gaining reaches, suggesting that approximately 21 mi, or 60%, of the lower river is potentially suitable to sustain restoration of more water-loving riparian vegetation types (*e.g.*, cottonwood and willow forest and scrub, floodplain wetlands) over the long term. The rest of the river corridor may be more suitable for vegetation types that can tolerate drier conditions (*e.g.*, desert riparian scrub). In areas where large active revegetation efforts are being considered, installing and monitoring shallow groundwater wells can guide restoration planning and improve the success rate of replanting efforts.

The continued introduction, spread, and growth of non-native invasive plant species, particularly arundo, is another uncertainty to the long-term success of revegetation in the lower Santa Clara River. In passive revegetation areas, arundo propagules (vegetative fragments) and tamarisk seedlings may be just as likely to recruit as native willows and cottonwoods (Stillwater Sciences and URS Corporation 2007). While tamarisk survival past the seedling stage appears to be limited in most parts of the lower river corridor, arundo propagules often grow faster and out-compete seedlings of native trees and shrubs, particularly in nutrient-rich areas (Coffman 2007, Stillwater Sciences and URS Corporation 2007). The risk of arundo and tamarisk invasion in passively revegetated areas will continue to be an issue for revegetation planners until sufficient amounts of arundo and tamarisk are removed, and upslope and upstream propagule sources become diminished. In actively revegetated areas, non-native plant propagules could be introduced from upslope or from upstream sources during occasional floods. The use of irrigation could encourage the recruitment and growth of weed species, particularly in former agricultural areas. While drip irrigation should minimize this problem, in more fertile areas, unless active control measures are implemented, agricultural weeds could grow faster and out-compete planted seeds, seedlings, cuttings, and container stock.

4.5 Non-native Invasive Species Removal

Non-native invasive plant and animal species can contribute to the degradation of native ecosystems by preying upon or out-competing native species in

environments where they have few, if any, natural predators. Human disturbances to the ecosystem typically provide the opportunities for non-native invasive species to establish and invade native habitats. In the lower Santa Clara River, increased nutrient supply from adjacent land uses, changes in the natural fire regime and development adjacent to the riparian corridor have encouraged the spread of several non-native invasive plant and animal species that are threatening native species populations and habitats. This restoration strategy primarily addresses two non-native invasive species that are considered to have the greatest impact in the lower Santa Clara River—arundo and tamarisk—although other non-native plants, brown-headed cowbird (*Molothrus ater*), and African clawed frog (*Xenopus laevis*) are also discussed. These species are discussed in more detail in Appendix B. By creating larger buffers between riparian habitat and adjacent development and enhancing natural riverine processes and habitat development, it is expected that land acquisition and the implementation of process-based restoration strategies by the Parkway project will partly remedy the conditions that currently encourage these non-native species. Direct removal of some of these species is expected to be necessary however, given their level of establishment in the lower Santa Clara River, and this is the focus of the recommended restoration strategy.

4.5.1 Strategy Concept & Feasibility

Arundo and Tamarisk

Their wide distribution in the Santa Clara River watershed, rate of spread, and impacts to the ecology of riparian areas have made arundo and tamarisk the focus of a large-scale eradication effort in the upper and lower watersheds (VCRCD 2006b, N. Cabanting, Wildscape Restoration, *pers. comm.*, 2007). A primary focus of this restoration strategy is to support the Ventura County Resource Conservation District in their large-scale eradication efforts, as they have already identified many priority areas for removal and appropriate removal methods (see Section 1.5). However, recent research by Coffman (2007) on the ecology and impact of arundo on the lower Santa Clara River specifically provides guidelines for prioritizing arundo removal projects that should be incorporated to the extent feasible in arundo and tamarisk removal projects supported by the Parkway project.

- Removal projects should generally be conducted from upstream to downstream and in tributaries. These areas have lower risk of re-infestation and reduce the supply of propagules to downstream areas.
- Upland or transition zones between riparian areas and upland areas should be priority areas for removal projects to reduce the supply of propagules to lower areas and to reduce the fire risk to the riparian corridor and adjacent vegetation types.

- Riparian areas that are adjacent to fire-prone shrub lands should be priority areas for removal projects to reduce the risk of arundo infestations serving as a corridor for transmission of fires from adjacent vegetation types into or through the riparian habitats.
- Watersheds with low nutrients should be priority areas for removal projects, as these areas would be less likely to favor the reestablishment of arundo over native species.
- Removal projects should be conducted in the summer following flood event when biomass has already been washed downstream and it is easier to access, cut and treat the plants. This would provide a cost-effective means of controlling arundo and is likely to facilitate natural recolonization by native species.
- Removal projects should be conducted after fires to take advantage of the loss of biomass and to suppress rapid arundo regrowth following fires (see Section 2.3.3). Without such action, arundo is likely to re-establish rapidly and out-compete native riparian species which are typically slower to recover after fire (Coffman 2007).

While arundo and tamarisk removal is considered a priority action to enhance endangered avian habitat conditions in the lower Santa Clara River, it should be done outside the breeding season (mid-March to late September) of species, such as least Bell's vireo and southwest willow flycatcher, that may use arundo and tamarisk as nesting habitat (Labinger and Greaves 2001). In addition, where large tracts of arundo or tamarisk are to be removed, projects should be immediately followed by revegetation with native riparian species to quickly replace structural habitat for scrub-nesting species of bird (Labinger and Greaves 2001). Administratively, the Parkway project should encourage and/or fund longer-term contracts for arundo and tamarisk removal projects. Successful removal and eradication projects require pre- and post-project monitoring and typically involve multiple treatments (DiTomoso and Healy 2007). One- to three-year contracts are not generally long enough to allow for pre-project monitoring, treatment, post-project monitoring, and subsequent maintenance or retreatment, given that removal projects in riparian areas with sensitive species can only be conducted during particular seasons.

Other Non-native Invasive Plant Species

A wide variety of non-native herbaceous species occur in the lower Santa Clara River (Stillwater Sciences and URS Corporation 2007). These range from low-impact agricultural or horticultural weeds to high-impact yellow starthistle, sweet fennel, and perennial pepperweed (see Section 2.4.2). Many of these species do not present significant threats to native riparian habitats, where they are shaded out by native shrubs and trees. However, in open or disturbed habitats these species can quickly dominate the vegetation and displace native species that provide foraging or structural habitat for native

species (DiTomoso and Healy 2007). Removal projects focused on non-native herbaceous species should be prioritized in sensitive open to shrub-dominated habitats, particularly if those habitats support threatened, endangered, or sensitive plant or animal species. For example, non-native herbaceous plant removal projects could be implemented, using appropriate techniques, in open sandy areas that are used by the San Diego horned lizard. Care would need to be taken that removal methods and project timing do not impact non-target species.

Non-native invasive plant removal projects should also be prioritized for higher-impact species that currently have limited distributions. For example, only small patches of perennial pepperweed currently occur in the tidal marsh habitat at the mouth of the lower Santa Clara River. This member of the mustard family is an aggressive invader that forms dense monospecific stands and changes soil conditions to inhibit the growth of native plant species (DiTomoso and Healy 2007). Eradication of this species while its distribution is still small is much more likely to be successful and will require less effort. This same strategy would also be appropriate for pampas grass, cape-ivy, Spanish broom, and tree tobacco, which all currently have fairly limited distributions within the 500-year floodplain of the lower Santa Clara River (Stillwater Sciences and URS Corporation 2007).

African Clawed Frog

Originally discovered in the upper watershed in 1974 and in the estuary in 1995, African clawed frogs are now present throughout the Santa Clara River and its small tributaries and barrancas (Lafferty and Page 1997; Lannoo 2005; B. Orr, Stillwater Sciences, *pers. obs.*, 2005; S. Sweet, UCSB, *pers. comm.*, 2006). Most efforts to eradicate clawed frogs in California have not been successful, although a number of control methods exist, including poisoning, draining ponds, seining, gill netting, gigging, and electrofishing (Lannoo 2005). Little has been published comparing control effort methodologies, which may be to due difficulties in comparing control efforts in different geographic locations. The single successful eradication effort was located on the University of California Davis campus, where the colonized habitat was a discrete, limited body of water where frogs were restricted to an area they could be poisoned effectively (Lannoo 2005). African clawed frogs left the water during unsuccessful attempts to use Rotenone poison at Vasquez Rock, the site of one of the first populations detected in the upper Santa Clara River (Lannoo 2005). Additional efforts to develop effective protocols for poisoning clawed frogs in the Santa Clara River were unsuccessful (Lannoo 2005).

Acquiring and enhancing riparian habitat in the lower Santa Clara River and implementing process-based restoration actions should assist in reducing African clawed frog populations. Increasing the extent of protected riparian habitat will increase the number of native predators of African clawed frogs,

including two-striped garter snakes, great blue herons, green herons, black-crowned night herons, common ravens, and western gulls (Stebbins 2003, Lannoo 2005). Bullfrogs, bass, and sunfish, all non-native species in Santa Clara River, are also predators of African clawed frogs (Stebbins 2003, Lannoo 2005). Improvements in water quality, temperature, and aquatic habitat diversity resulting from process-based restoration actions (see Section 4.5), should reduce the extent of suitable habitat for African clawed frogs, which prefer warm, slow-moving water, although the estuary is always likely to provide suitable habitat, as this species is salt tolerant (Lafferty and Page 1997, Lannoo 2005). Active eradication projects should be implemented from upstream to downstream, as this is how African clawed frog has been demonstrated to disperse in the lower Santa Clara River (Lanoo 2005), and should focus on isolated areas to increase the chances of success.

Brown-headed Cowbird

Cowbird parasitism in the lower Santa Clara River was more common in areas where no cowbird trapping was being conducted (Labinger and Greaves 2001). Cowbird removal is believed to be one of the factors responsible for increases in several southern California vireo populations (USFWS 1998). An annual cowbird control program on the lower Santa Clara River implemented by the California Department of Fish and Game, which includes the trapping and killing of adults and removal of eggs from host nests, appears to be increasing least Bell's vireo productivity (Labinger and Greaves 2001).

Parkway project efforts to acquire, protect, and restore riparian habitat in the lower Santa Clara River should assist in decreasing brood parasitism by brown-head cowbirds by increasing the extent of continuous riparian habitat (*i.e.*, increasing the distance between cowbird foraging and breeding areas). The Parkway project should also support and/or fund cowbird control programs, such as those implemented by CDFG in the lower watershed and by California Department of Transportation (Caltrans) in the upper watershed, to protect populations of endangered bird species.

4.5.2 Anticipated Benefits

Habitat conservation and enhancement, process-based restoration, and removal of non-native invasive species will provide multiple, synergistic benefits. Property acquisition and enhancement of existing habitats, and removal of non-native species, particularly arundo, will conserve and restore continuous tracts of riparian habitat in the lower Santa Clara River. This, in turn, should decrease the rate of brood parasitism by brown-headed cowbird and improve native bird productivity, particularly endangered least Bell's vireo.

Implementation of process-based restoration projects, such as levee removal and setback, will enhance riverine processes such as floodplain inundation, channel meandering, and sediment transport. These processes will create

and sustain aquatic habitats that should discourage African clawed frog, which prefer warmer, lentic or low velocity lotic habitats.

Direct removal of arundo will decrease the risk of fire in the riparian corridor and to adjacent habitat types. Direct removal of African clawed frog will protect populations of native prey species, such as tadpoles and juveniles of multiple amphibians, arroyo chub, unarmored three-spined stickleback, and tidewater goby. Direct removal of brown-headed cowbird adults and eggs will improve the productivity of host species, including least Bell's vireo.

4.5.3 Uncertainties

There are several uncertainties related to the removal and eradication of non-native invasive species. The primary uncertainty related to all non-native species is whether the timing and extent of control efforts are sufficient to overcome the rate of expansion of existing infestations or introduction of new non-native species. Control projects require several years to acquire permits, implement, monitor, and re-treat if necessary and are typically very expensive. Budget or schedule delays allow time for infestations to grow, becoming increasingly more expensive to control. The VCRCD's coordinated permits for multiple arundo and a tamarisk control project are good examples of ways to decrease the time to implementation. Treating infestations while the species is still fairly limited in distribution is another way to decrease the effort and cost associated with control projects.

The lack of success in eradicating African clawed frog from the lower Santa Clara River is an example of when the extent of the project may not be adequate to achieve successful control. When one area is treated, the species simply moves to a nearby area (Lanoo 2005). However, given the negative impacts of potentially poisoning the entire lower Santa Clara River to eradicate African clawed frog, the impacts of the non-native species must clearly be carefully weighed against the impacts of the control effort. This is also true for arundo control projects; while fewer large projects may be more effective and efficient than a large number of smaller projects, removal of large tracts of arundo in a single season results in a lack of structural habitat needed for nesting bird species during the subsequent breeding season (Labinger and Greaves 2001). Minimizing or mitigating for impacts to non-target species is critical to implementing large-scale control projects that are successful in both removing the non-native species and benefiting native species.

Sources and treatment of excess nutrients that encourage the invasion of arundo are just one of the uncertainties related to its successful control. If excess nutrient sources go untreated, arundo growth and colonization will continue to be encouraged over that of native species (Coffman 2007). Whether or not native species have the competitive abilities to colonize

quickly after arundo control project is another uncertainty. If site conditions (*e.g.*, low groundwater table or excess nutrients) limit the recruitment and growth of native species, they may not be able to provide the structural habitat needed for breeding birds or suppress subsequent introductions or regrowth of arundo.

The lack of understanding of what is currently limiting tamarisk in the lower river corridor is another uncertainty related to successful control. Cohorts of newly recruited tamarisk seedlings were observed in both summer 2005 and 2006, suggesting a strong recruitment potential downstream of the few mature stands of tamarisk currently established in the County Line Reach (11) (Stillwater Sciences and URS Corporation 2007). Monitoring is necessary to determine how many of these seedlings survive to maturity and identify what may or may not be limiting their survival. If groundwater levels or channel scour patterns are currently limiting the survival of tamarisk, and these physical variables change as a result of development or restoration in the watershed, tamarisk could become a much larger problem for the river ecosystem and a challenge to control efforts.

4.6 Treatment Wetlands for Water Quality Improvement

As discussed in Section 3.4, point and nonpoint source pollution in the lower Santa Clara River watershed has resulted in a number of water quality limited segments of the river (Figure 3-3). The following strategy describes the use of water quality treatment wetlands in the 500-year floodplain of the lower Santa Clara River to help maintain a range of instream and floodplain chemical parameters that meet water quality criteria and support healthy native assemblages of aquatic and riparian biota.

4.6.1 Strategy Concept & Feasibility

The overall strategy for improving water quality in the lower Santa Clara River is two-fold. First, the water quality strategy will utilize the combined effects of land acquisition and the process-based restoration strategies of levee setback or removal and active and passive revegetation of the floodplain (see Table 4-3) to increase the potential for attenuation and treatment of a wide range of nonpoint source pollutants. However, while the re-establishment of natural wetlands and riparian vegetation in the floodplain is expected to help increase instream and estuary water quality through their general functioning as environmental biogeochemical transformers, river segments that are currently 303(d)-listed for regular exceedances of contaminants such as ammonia, coliform, TDS, sulfate, and trace organics are expected to require more targeted strategies to remove constituents of concern.

Therefore, a second water-quality improvement strategy is recommended, one that actively complements the ongoing TMDL process (see Section 3.4)

by creating water quality treatment wetlands, strategically placed at the confluence of barrancas with the mainstem Santa Clara River to remove non-point source pollutants before they enter the mainstem itself. While treatment wetlands offer a low-cost alternative to large-scale treatment of non-point source pollution in particular (Horne and Fleming-Singer 2006), they also can successfully treat a variety of point sources. Functioning at rates one to two orders of magnitude greater than natural riparian buffer strips and floodplain vegetation (Fleming-Singer and Horne 2005, Hill 1996, Horne 1995, Bilby 1988, Lowrance *et al.* 1984), treatment wetlands are a proven technology for ameliorating a wide range of pollutants including TDS, nutrients (*e.g.*, nitrogen and phosphorous; Mitsch et al. 2000), metals (*e.g.*, chromium, copper, selenium), trace organic compounds (pesticides such as atrazine, chlorpyrifos, and endosulfan; Rodgers and Dunn 1992, Alvord and Kadlec 1996, Moore 2000, Schulz and Peall 2001) and pathogens (total and fecal coliform, bacteriophages, and protozoans; Kadlec and Knight 1996, Karpiscak *et al.* 1996, Quinonez *et al.* 1997).

In a recent study funded by the Los Angeles Regional Water Quality Control Board and the Coastal Conservancy, eight southern California treatment wetlands were included among a total of 40 freshwater urban wetlands in an evaluation of wildlife benefits, toxicity exposure, and water quality treatment effectiveness (Sutula *et al.* 2008). While none of the eight treatment wetlands evaluated are located in the Santa Clara River watershed, all experience a semi-arid to arid climate, similar to that of the Santa Clara River basin, as well as potentially higher concentrations of urban runoff contaminants as compared with that of temperate climates (Schiff and Sutula 2004, Sutula and Stein 2003, Caraco 2000 as cited in Sutula *et al.* 2008). Although determination of actual treatment effectiveness for the eight wetlands was not uniformly possible due to lack available flow data, results indicated that, averaged across wet and dry weather and season, the eight southern California treatment wetlands reduced concentrations of total and dissolved metals (e.g., copper, lead, zinc, selenium), nutrients (e.g., nitrate, ortho-phosphorous), total suspended solids (TSS), and bacteria (e.g., *Enterococccus, Eschericha coli*, fecal and total coliform) ($p<0.01$ for each constituent) (Sutula et al. 2008). Additionally, while sediment contaminant concentrations were found to be elevated above probable effects concentrations (PECs) in some instances, as a group the southern California treatment wetland sediments were not significantly elevated compared with sediments in either habitat wetlands or multi-purpose wetlands (used for both habitat and water quality treatment) throughout the 40 wetlands surveyed (Sutula et al. 2008). The same was true for aquatic toxicity of the amphipod *Hyalella azteca* and the larval midge *Chironomus tentans* (Sutula *et al.* 2008).

In the lower Santa Clara River, treatment wetlands could be integrated with the overall process-based Parkway restoration design by locating facilities

outside the active floodway to avoid significant and frequent scouring. Similar to plans developed for the San Diego Creek watershed in southern California (GeoSyntec 2005), the wetlands can be designed to treat storm flows and summer runoff from both urban and agricultural areas. Preliminary review of regional conditions suggests that application of treatment wetlands would be particularly useful in gaining reaches of the lower Santa Clara River (Table 1-1) where groundwater quality is also of concern.

Individual treatment wetland designs must be tailored to local conditions and constraints; however, general design criteria may include:

- plug flow configuration,
- gradual slope for maintaining low water velocity,
- varied depth to support a variety of vegetation types and related treatment functions,
- multiple cells to prevent short circuiting, and
- inlet and outlet structures.

Development of water quality models prior to installation would allow for estimation of the performance of individual and collective treatment wetland facilities. Evaluation of alternative configurations and operation periods would be carried out to discern to what extent the facilities would contribute to load reductions of water quality pollutants to the Santa Clara River. For example, a research and demonstration project at the Hedrick Ranch Nature Area (HNRA) is currently ongoing along the Santa Clara River between Santa Paula and Fillmore, in Ventura County (URS 2003). The demonstration project is being carried out to investigate the potential for nutrient and pesticide removal from agricultural runoff using a slightly different type of non-point source pollution natural treatment system termed a bioswale. Bioswales function in a manner similar to typical surface-flow treatment wetlands, however they are more shallow (approximately 1 ft deep) and have a generally shorter residence time as compared with most wetland designs. The HNRA bioswales contain a mixture of summer and winter variety grasses selected to withstand the wet and dry conditions of the Santa Paula climate and to be tolerant to high salinity conditions (Keller and Clark 2008). Deeper (> 2 m) bioactive trenches are also included in the HNRA project, which are natural treatment facilities configured, in this instance, to intercept groundwater as it moves from upslope fields towards the Santa Clara River in both anaerobic and aerobic test cells (Keller and Clark 2008). Alternative designs, such as those implemented at HRNA, would be considered along with strategic placement of treatment wetlands within the lower Santa Clara River floodplain to best address water quality challenges.

4.6.2 Anticipated Benefits

Treatment wetlands are a type of natural treatment system, and as such offer secondary benefits including habitat creation and enhancement, aesthetics,

recreation, and education (GeoSyntec 2005). The primary benefit of the wetland treatment units will be improved water quality. As discussed in Section 3.4, benefits of improved water quality for aquatic species include direct and indirect effects (Preston 2002) and depending on the level of the pollutant, may be localized and dramatic (*e.g.*, acute effects) or geographically broad and more subtle (*e.g.*, long-term, chronic effects). Although the specific impacts of poor water quality resulting from point and nonpoint source contaminants on biota in the lower Santa Clara River and estuary are not well-understood (Kelley 2004, AMEC 2005), the overall health of all aquatic organisms is expected to benefit from improved water quality.

As an example, tidewater gobies spend their entire lifecycle in the estuarine environment (Swift *et al.* 1989, Lafferty *et al.* 1999), feeding on a variety of small invertebrate organisms such as mysid shrimp, gamarid amphipods, and chironomid midge larvae (Swift *et al.* 1989, Swenson 1999, Moyle 2002), and providing prey for a variety of larger fish and piscivorous birds (Swenson and McCray 1996). Their wide range of food sources, foraging techniques, and broad function as prey to multiple predator species leaves them well-positioned to transfer toxicants between trophic levels and contribute to bioaccumulation of particular contaminants. Thus, benefits to the tidewater goby from improved water quality have the potential to positively affect multiple species in the aquatic food web. Lessening indirect effects of toxicant exposure will also potentially improve the ability of tidewater goby populations to recover from heavy predation by introduced piscivorous fish, particularly sunfishes (*Lepomis* spp.) and basses (*Micropterus* spp.) which have been have been introduced in or near coastal lagoons and estuaries throughout California (USFWS 2005).

Upstream of the estuary, aquatic species are expected to benefit from decreased total ammonia concentrations in the lower Santa Clara River, which currently exceed Basin Plan water quality objectives (CRWQCB 2006). Ammonia toxicity to fish is temperature and pH dependent, with recommended water quality criteria for acute (1-hr average) exposure in reaches having a salmonid presence at roughly 24 mg N/L, assuming pH 7.0 (CRWQCB 2005). Prolonged exposure to sub-lethal levels can lead to skin and gill hyperplasia, respiratory problems, stress, and conditions which support proliferation of opportunistic bacteria and parasites, thus chronic (30-day average) water quality criteria for ammonia is lower. For example, for reaches with early life stages of fish present, assuming pH 7.0 and ambient water temperature at 20 C, the chronic criterion is 4.15 mg N/L (CRWQCB 2005). Improved water quality is also expected to benefit organisms by decreasing chronic or episodic acute exposure to pesticides (*e.g.*, chlorpyrifos and diazinon) and general toxicity, which currently occurs in several reaches of the lower Santa Clara River (Figure 3-3). Identification of species-specific benefits to improved water quality requires further study (see Section 4.9).

4.6.3 Uncertainties

The primary uncertainty related to the successful implementation of treatment wetlands for water quality improvement is the availability of suitable locations at or near the confluence of barrancas with the mainstem lower Santa Clara River. While uncertainties involving general land acquisition (Section 4.3.3) apply to potential sites for treatment wetlands, choosing appropriate sites for the proposed treatment facilities must also include consideration of topography that allows gravity flow into and out of the wetland, sufficient acreage to achieve reasonable detention times, and (where possible) locations within existing or planned water quality detention basins.

The magnitude of dry-weather flows in barrancas, or other strategically identified locations for treatment wetlands, that could be potentially treated by the wetland facilities is also uncertain. While initial review of regional conditions indicates that locating these facilities in gaining reaches is most likely to supply year-round water (including low-quality groundwater, where applicable) and highest treatment efficiencies, the magnitude of off-channel summertime flows requires further investigation.

Additionally, further study is needed to help reduce the uncertainty in assessing the habitat value of treatment wetlands or multipurpose wetlands, and to determine whether habitat value can be improved through changes in physical structure or management approach. As discussed in the Sutula *et al.* (2008) review of 40 southern California freshwater urban wetlands, multipurpose wetlands, or those wetlands and riparian areas created to serve the dual objectives of habitat and water quality improvement, exhibited significantly higher plant species richness and diversity than did exclusively habitat or treatment wetlands. However, it was noted that the higher plant richness and diversity observed was being artificially maintained at these sites, because the majority of multipurpose wetlands are also mitigation wetlands which require native plants as a component of permit conditions. The California Rapid Assessment Method (CRAM) physical structure scores at the multipurpose wetlands were lower than at the habitat wetlands (Sutula *et al.* 2008), suggesting that habitat quality may actually be lower at the multipurpose wetlands.

The San Joaquin Wildlife Sanctuary (SJWS) is one example of a treatment wetland located in southern California that has been actively managed for both habitat value and water quality treatment effectiveness. While classified in the Sutula *et al.* (2008) review as a treatment wetland, the SJWS was conceived of as a multipurpose facility, and as such includes design elements and management specifications for promoting nitrate removal from inflowing San Deigo Creek water as well as maximization of avian habitat. Design elements such as 90% open water area, bulrush stands limited to pond pe-

rimeters by deep predator trenches, and bi-weekly drawdown of ponds on a rotating basis provide habitat for waterfowl and foraging sites for shorebirds, while differing carbon amendments promote high rates of denitrification. Fleming-Singer and Horne (2006) report high nitrogen removal efficiency (60% total nitrogen, 80% total inorganic nitrogen), seasonal nitrate removal rates of 350-500 mg/m^2/d (April-May), and high avian species richness (65-76 species/mo) and avian species abundance (65-83 birds/ha/mo) for the SJWS during 1999-2002. Overall, results indicate that SJWS avian habitat design features did not appear to inhibit high rates of denitrification during the study period.

Finally, implementation of certain rehabilitation actions (*e.g.*, removal and/or construction of setback levees, removal of barriers to fish passage) will be constrained by state and federal regulations designed to protect Basin Plan Beneficial Uses and associated Water Quality Objectives (CRWQCB 2006). Potential detrimental effects on water quality, long-term or temporary, caused by rehabilitation construction activities will require appropriate permitting (see Section 3.7) and implementation of Best Management Practices (BMPs) to contain and minimize the extent of contamination. Although the permitting process will be a non-trivial component in the overall cost of rehabilitation, the ultimate protection of Basin Plan Beneficial Uses will result in a net benefit to the ecosystem.

4.7 Passive and Active Aquatic Habitat Enhancements

As previously discussed, while many large coastal southern California rivers have been confined to concrete channels in their lower reaches, the Santa Clara River riparian corridor has retained patches of high-quality aquatic and riparian habitat and currently supports, to varying degrees, several threatened and endangered native aquatic species (CDFG 2005, Stillwater Sciences 2007c). Despite its relatively intact status compared with other coastal rivers in the region, flood protection infrastructure, roads, agriculture, aggregate mining, and urbanization on the Santa Clara River have resulted in riparian and aquatic habitat loss or degradation (Section 1.4). Inclusion of aquatic habitat enhancements in the overall restoration approach for the lower Santa Clara River will ultimately support the long-term preservation or, in some cases, recovery of sensitive species populations.

4.7.1 Strategy Concept & Feasibility

Based on reviews of existing habitat availability for sensitive aquatic species on the lower Santa Clara River and its tributaries (Court *et al.* 2000,AMEC 2005, Stillwater Sciences 2007c), the restoration strategy for aquatic habitat enhancements, like that of floodplain revegetation (Section 4.3), includes both passive and active components. Passive aquatic habitat enhancements are those improvements to connectivity and instream, floodplain, and estuarine

habitat availability that are expected to arise from the process-based restoration approach (Section 1.4). The strategy is founded upon the premise that dynamic habitat formation will occur within a floodplain sustained by natural rates and magnitudes of geomorphologic and hydrologic processes.

The strategy for active aquatic habitat enhancements involves primarily improving instream passage for native anadromous and resident fish species through the redesign of the fish ladders at Vern Freeman Diversion Dam and Harvey Diversion Dam. While the active amelioration of water quality degradation is necessary to achieve significant enhancements in aquatic habitat for species in the lower Santa Clara River and estuary, it is a strategy in its own right and is therefore addressed more specifically in Section 4.6. The remainder of this section presents a general discussion of the feasibility of facilitating instream passage and passive improvements to aquatic habitat.

(top) Looking upstream, and (bottom) downstream at the at the Vern Freeman Diversion Dam fish ladder (2003).
(photograph by Stillwater Sciences)

Improve Instream Passage

The National Marine Fisheries Service has stated that improvement of fish passage in the lower Santa Clara River requires the re-operation, and potentially re-design, of the denil fish ladder at Vern Freeman Diversion Dam. This is to accommodate the timing, duration, and magnitude of flow events that anadromous fish require for upstream migration (Stoecker and Kelley 2005). Additionally, the fish ladder at Harvey Diversion Dam on Santa Paula Creek needs to be repaired, reconfigured or removed to assure continuous passage for anadromous fish species from the mainstem Santa Clara River to the headwaters of Santa Paula Creek. The modification of these two complete or partial fish passage barriers is expected to be a feasible, albeit lengthy and expensive, approach for improving connectivity in the Above Freeman and Above Santa Paula Reaches (3 and 5) and to improve steelhead access to spawning grounds in tributaries. In addition, there is the potential to improve fish passage and/or aquatic habitat connectivity by modifying other potential barriers in the major tributaries (Sespe and Santa Paula creeks, in particular) (Stoecker and Kelley 2005).

Improve Aquatic Habitat Availability and Diversity

In the lower river, allowing floodplain inundation, bed scour, bank erosion and sediment deposition to occur at natural rates in an expanded floodway is expected to be a feasible approach to supporting the creation and maintenance of aquatic habitat for native plants and animals with minimal human intervention. For example, in the lower Santa Clara River, where watershed conditions such as erodible banks, abundant supply of sediment, and rapid and frequent variations in stream discharge promote the formation of a low-flow, braided channel system (Stillwater Sciences 2007a), the network of small channels and islands in an expanded floodway will offer seasonally abundant, shallow, low-velocity flow conditions with vegetative cover and a riparian buffer for water quality improvement. Under higher flow scenarios (*e.g.*, rainy season high flows) when the mainstem switches to a single-thread meandering channel (Stillwater Sciences 2007a), higher velocity main channel conditions will prevail and a better-defined sequence of contiguously wetted and connected deep and shallow water features can be supported.

In the estuary, the predominant strategy for accomplishing the self-sustaining formation of aquatic habitat is upstream levee setback or removal with floodplain re-contouring where needed, as in the case of abandoned floodplain aggregate mining pits or other potential landscape features that may cause channel incision.

4.7.2 Anticipated Benefits

The modification of the two identified migration barriers on the Santa Clara River (*i.e.*, Vern Freeman and Harvey Diversion Dams) will improve access by southern California coast steelhead and Pacific lamprey to upstream spawning habitats (but see Section 4.7.3) and also benefit resident fish such as Santa Ana sucker, Arroyo chub, and unarmored threespine stickleback, which might also be currently prohibited from longitudinal movement along the lower river corridor and certain tributaries.

Passive aquatic habitat enhancements supported by the proposed restoration activities are expected to benefit several sensitive species residing in the 500-year floodplain of the Santa Clara River and/or the estuary. For example, increasing riverine habitat availability and connectivity is anticipated to benefit adult migrating steelhead by providing deep pools for resting and holding to minimize their energetic outputs (Puckett 1975, Roelofs 1983, as cited in Moyle *et al.* 1989, Stoecker and Kelly 2005). These benefits could be expected during ENSO years in particular (which are predicted to increase as a result of global climate change), when the Santa Clara River experiences higher peak flows (see Section 2.3.2).

The estuarine aquatic community is also expected to realize benefits from passive upstream restoration actions. For example, successful tidewater

goby reproduction requires relatively unconsolidated, clean, coarse sand in shallow waters (USFWS 2005) for burrow construction and egg deposition. The availability and quality of spawning habitat for tidewater gobies could improve through a general increase in recently deposited sediments due to upstream levee removal and decreased hyperpycnal flows (see Section 2.3.6).

Adult and juvenile tidewater gobies in the estuary may be adversely affected by early seasonal breaching of the estuary mouth. Early breaching of the estuary due to freshwater discharges from the Ventura Water Reclamation Facility could prevent access to preferred habitat but would generally not be expected to affect reproductive success. Even if early breaching events occur, salinity is generally expected to remain within the preferred range for spawning (≤15 ppt [Swenson 1999, USFWS 2005]) and the timing of these events is not expected to coincide with the peak spawning period. The highest intensity of spawning activity occurs early in the summer (April to June, [USFWS 2005]), whereas discharges from the wastewater treatment facility predominantly occur during late summer and fall (August to October). However, because tidewater gobies are not marine-adapted, early estuary breaching could be problematic if the fish are not able to seek refuge in brackish estuarine habitats and are instead displaced into the ocean where they are not likely to survive (Swift *et al.* 1989, Lafferty *et al.* 1999). Expanding available estuarine habitat diversity may offer a refuge for tidewater gobies if continued early breaching events occur. Southern California coast steelhead smolts are also expected to benefit from increased habitat availability in the estuary, as they require time to gain size and adjust to increased salinity in tidal lagoons or estuaries before migrating to the ocean. Examples of anticipated benefits to aquatic species from improved water quality are discussed in Section 4.6.2.

Table 4-2 presents the variety of aquatic habitats, using a hierarchical classification scheme (Cowardin *et al.* 1979, Hawkins *et al.* 1993), that are expected to be sustained by the proposed restoration efforts and that will support multiple instream aquatic species at different life-history stages. A variety of obligate and facultative aquatic birds as well as river-riparian species will also benefit from proposed aquatic habitat enhancements.

Table 4-2. Aquatic habitat classes and associated instream species expected to benefit from Santa Clara River Parkway Project restoration strategies.

Aquatic habitat class[1] to be supported following rehabilitation activities		Sensitive aquatic species expected to benefit from habitat enhancements (A=adult, J=juvenile)
Level I	**Level II (Level III examples)**	
ESTUARINE[2]		
Subtidal[2]	Unconsolidated bottom	Arroyo chub (A, J) Southern California coast steelhead (A, J-smolt)
	Aquatic bed (algal, seagrasses)	
Intertidal[2]	Unconsolidated shore (boulder, cobble, mud, sand)	Tidewater goby (A, J)
	Unconsolidated bottom (tidal pond, slackwater sloughs)	Arroyo chub (A, J) Tidewater goby (A, J) Southern California coast steelhead (J-smolt)
	Emergent wetland (fresh water marsh, salt marsh)	Arroyo chub (A, J) Tidewater goby (A, J) Southern California coast steelhead (J-smolt)
RIVERINE		
Fast water	Turbulent (chute, rapid, riffle)	Pacific lamprey (A) Southern California coast steelhead (A, J) Santa Ana sucker (A)
	Non-turbulent (sheet run)	Pacific lamprey (A) Southern California coast steelhead (A, J) Santa Ana sucker (A, J) Arroyo chub (A, J)
Slow water	Scour pool (bank eddy, mid-channel scour pool, lateral scour pool)	Pacific lamprey (ammocoetes) Southern California coast steelhead (A, J) Arroyo chub (A, J)
	Dammed pool (backwater, abandoned or slow-moving side channel, oxbow)	Pacific lamprey (ammocoetes) Unarmored threespine stickleback (A, J) Western pond turtle (A, J) Arroyo toad (A, J) California red-legged frog(A, J) Two-striped garter snake (A, J)
Riparian	Open, non-vegetated gravel/sand bars inside meander bend, point bar	Arroyo toad (A, J-larval)

[1] Applicable estuarine habitat classes from Cowardin *et al.* 1979 and riverine habitat classes from Hawkins *et al.* 1993.

[2] The estuary functions as a muted tidal lagoon rather than a traditional estuary (Stillwater Sciences 2007a), thus Level I habitat estuarine classifications may not strictly hold.

4.7.3 Uncertainties

The strategy for passive aquatic habitat enhancements relies on the process-based rehabilitation approach, and it is therefore largely dependent on the successful implementation of the other five rehabilitation strategies. In general, uncertainties for the other five strategies also apply to passive aquatic habitat enhancement, but in particular levee setback or removal (Section

4.3.3), active and passive revegetation of the floodplain (Section 4.4.3), and treatment wetlands for water quality (Section 4.6.3) must be broadly successful to significantly improve aquatic habitat and water quality in the river and estuary. Without improvements in water quality, the ecological benefits and effectiveness of increased passage and connectivity in the lower river and improvements to the estuary will be limited (see Section 3.4). Additionally, the success of improvements to the fish ladders at Freeman and Harvey Diversion Dams is critical to improving overall connectivity and passage for instream aquatic species.

The timetable for aquatic habitat formation and maintenance under the process-based design is uncertain, as large floods are required to induce the channel changes and erosion/sedimentation required for aquatic habitat formation (Stillwater Sciences 2007a). While creation of riparian habitat through active revegetation of the floodplain will provide shading and complexity of edge habitats within a more certain timeline (*i.e.*, three to five years following successful planting), the location and degree of instream aquatic habitat formation via channel morphologic change is dependent on the occurrence of large floods. Analysis of ENSO patterns indicates that these large flood events typically take place every three to seven years, but future frequency is unknown. Better estimates of long-term coarse sediment load would also assist in the prediction of timing for habitat forming processes such as beach replenishment and littoral transport (Stillwater Sciences 2007a).

One of the most significant uncertainties associated with aquatic habitat enhancements is how and when biota will respond to improvements in physical habitat conditions. For example, modifications to the fish ladders at the Vern Freeman and Harvey Diversion dams may not contribute to increases in the southern California coast steelhead population if the fish are not entering the Santa Clara River from the ocean. If lack of access to high-quality spawning habitat is not one of the factors most limiting southern California coast steelhead populations, then passage improvements may not be expected to result in significant increases in the steelhead population. Even if lack of spawning habitat is a critical limiting factor, it may take several steelhead generations to begin seeing population benefits associated with fish passage improvements, as progressively greater numbers of adult steelhead are able to reach high-quality spawning habitats in upstream reaches. Interactions with non-native fish and other invasive species may also interfere with, to varying degrees, the ability of native fish species to take advantage of improved or restored habitat. These uncertainties are beginning to be addressed through a variety of fisheries, flow, and temperature studies being conducted or planned by United Water Conservation District and others on the river (UWCD 2007).

4.8 Reach-Specific Recommendations for Strategy Implementation

The reach-specific recommendations described below are intended to provide guidance for the next phase of implementing strategic restoration actions along the lower Santa Clara River corridor. Table 4-3 summarizes the recommended restoration strategies and identifies particular reaches where each of these strategies would be most appropriate, feasible, and expected to be effective (*i.e.*, restoration strategies correspond to reach-specific geomorphic functions and habitat conditions). For example, levee setback strategies are focused on the lowest reaches where the floodway is most constrained, while passive levee removal is emphasized in the middle reaches. Land acquisition, revegetation, and invasive species removal strategies dominate in those reaches with the greatest amount of existing focal species habitat or with the greatest threat of development. (Arundo and tamarisk are the only non-native species identified for removal at this time as they are the only species for which spatially-explicit data is available.)

The following descriptions for each reach are intended to expand on the information presented in Table 4-3 by briefly describing the general strategy for restoration in each reach.

Table 4-3. Recommended restoration strategies for the lower Santa Clara River.

Reach	Primary reach issues	Recommended restoration strategy						
		Land acquisition	Levee removal or setback	Revegetation	Non-native, invasive species removal	Treatment wetlands	Aquatic habitat enhancement	Other
0	• Right bank and upstream levees increase occurrence of hyperpycnal flow and estuary scouring. • Wastewater treatment facility presents physical constraint to restoration, may impair water quality, and increases the duration and frequency of summer and fall sandbar breaching. • Facilities at McGrath State Beach occur in the historic estuary zone and constraint southward migration of the river mouth.		✓ (infrastructure modification)					
1	• Levees eliminate or reduce lateral channel migration and aquatic habitat diversity, and contribute to channel incision. • Victoria Ave and Harbor Blvd bridges and left bank landfills present physical constraints to restoration.	✓ (to implement strategies)	✓ (levee setback and floodplain re-contouring)	✓ (following levee setback)		✓ (to treat agricultural and urban runoff)		
2	• Levees eliminate or reduce lateral channel migration and aquatic habitat diversity • Aggregate mining pits on floodplain and Hwy 101 bridge present physical constraint to restoration. • Freeman Diversion Dam contributes to channel incision.	✓ (to implement strategies and conserve habitat)	✓ (levee setback and floodplain re-contouring)	✓ (following levee setback)		✓ (to treat agricultural and urban runoff)		✓ (mining reclamation planning)
3	• Individual homes present physical constraint to restoration. • Freeman Diversion Dam impedes upstream fish passage to this reach. • Low groundwater decreases habitat connectivity in low flow years and may limit effectiveness of revegetation efforts without irrigation.	✓ (to implement strategies and conserve habitat)	✓ (levee setback and passive levee removal)	✓ (following levee setback)	✓ (arundo)	✓ (to treat agricultural runoff)	✓ (fish passage improvement)	
4	• Floodplain aggregate mining pits, airport, and left bank geology present physical constraints to restoration. • Low groundwater decreases habitat connectivity in low flow years and may limit effectiveness of revegetation efforts without irrigation.	✓ (to implement strategies and conserve habitat)	✓ (passive levee removal)	✓ (following levee removal)	✓ (arundo)	✓ (to treat agricultural and urban runoff)		

Reach	Primary reach issues	Recommended restoration strategy						
		Land acquisition	Levee removal or setback	Revegetation	Non-native, invasive species removal	Treatment wetlands	Aquatic habitat enhancement	Other
5	• Levees at confluence with Santa Paula Creek eliminate or reduce lateral channel migration and aquatic habitat diversity. • Damaged fish passage structure at Harvey Diversion Dam does not allow fish passage.	✓ (to conserve habitat)	✓ (floodplain recontouring)	✓ (in degraded habitats)	✓ (arundo)	✓ (to treat agricultural runoff)	✓ (fish passage improvement)	
6	• Lack of channel incision, gaining groundwater, and unregulated flows result in the highest-levels of natural fluvial processes and existing focal species habitat in the study area.	✓ (to conserve habitat)	✓ (passive levee removal)	✓ (following levee removal)	✓ (arundo)	✓ (to treat agricultural runoff)		
7	• Levees on Sespe Creek and the mainstem Santa Clara River, particularly in the vicinity of Fillmore, eliminate or reduce lateral channel migration and aquatic habitat diversity. • Bridge presents physical constraint to restoration.	✓ (to implement strategies and conserve habitat)	✓ (passive levee removal and infrastructure modification)	✓ (following levee removal)	✓ (arundo)	✓ (to treat agricultural runoff)		
8	• Relatively small, privately-owned agricultural levees confine the channel in some locations • Sediment input from Piru Creek contributes to channel aggradation. • Flow regulation in Piru Creek impacts hydrology. • Fish hatchery presents physical (infrastructure) constraint to restoration on the northern edge of the floodplain	✓ (to implement strategies and conserve habitat)	✓ (passive levee removal and infrastructure modification)	✓ (following levee removal)				
9	• Low groundwater contributes to the limited extent of riparian vegetation in this reach.	✓ (to conserve habitat)		✓ (in degraded habitats)	✓ (arundo)	✓ (to treat agricultural runoff)		
10	• Low groundwater contributes to the limited extent of riparian vegetation in this reach.	✓ (to conserve habitat)		✓ (in degraded habitats)	✓ (arundo)			
11	• Higher groundwater supports increasing extent of riparian vegetation, especially cottonwood forest (compared with reaches 9 and 10) • Narrow canyon morphology is significantly different from lower reaches.	✓ (to conserve habitat)		✓ (in degraded habitats)	✓ (arundo and tamarisk)			

Estuary Reach (0)

Restoration should be fairly limited in the Estuary Reach, as it is expected to benefit from upstream actions. The geomorphic functioning and habitat quality of the reach is expected to benefit from upstream implementation of levee setback and treatment wetland strategies. While removal of arundo and other non-native, invasive species would be beneficial, reintroduction of arundo from upstream sources is likely during moderate to large floods. Therefore, arundo removal or control in the estuary is a low priority until upstream control efforts are successful in reducing the sources of propagules likely to reinvade the Estuary Reach. Modification or relocation of key infrastructure at McGrath State Beach would allow the river mouth to migrate southward, away from the Ventura Water Reclamation Facility.

Hwy 101 Reach (1)

The Highway 101 Reach is a critical reach for implementing the levee setback strategy due to constrained channel migration, channel incision, and reduced riparian habitat that now result from the narrow configuration of levees. Property would be acquired primarily to secure areas for setting back levees. By focusing these actions on the right bank, the left floodplain could largely be left alone, decreasing costs and effort. Areas that are reconnected to the floodplain following levee removal, but that are not expected to experience significant flood inundation and scour, should be actively revegetated. Hwy 101 Reach has a barranca on the right bank that would be a potentially suitable site for construction of a treatment wetland to retain and filter agricultural and urban runoff. Removal of non-native invasive species is generally a low priority in this reach until upstream control efforts are successful.

Below Freeman Reach (2)

Below Freeman Reach is severely impacted by both levee confinement and channel incision downstream of Freeman Diversion Dam. Property acquisition would be conducted both to secure areas for implementing levee setbacks and to expand conservation areas beyond the existing TNC parcels in the reach. Levee setback would be prohibitively expensive on the left bank of the river in this reach due to floodplain aggregate mining and urban development; therefore, as in the Hwy 101 Reach, levee setbacks should focus on the right bank. Areas that are reconnected to the floodplain, but not expected to experience significant flood inundation and scour, should be actively revegetated. This reach presents an opportunity to integrate mining reclamation with riparian restoration efforts: aggregate mining reclamation projects should incorporate floodplain re-contouring and revegetation to improve riparian habitat conditions. Below Freeman Reach has several barrancas along the right bank that are potentially suitable to construct treatment wetlands to retain and filter agricultural and urban runoff. Removal of non-native invasive species is a low priority in this reach until upstream control efforts are successful.

Above Freeman Reach (3)

Access to Above Freeman Reach, and upstream reaches, by anadromous fish has been impaired by Freeman Diversion Dam. As a result, improving fish passage facilities at the dam (such as those improvements currently being considered by United Water Conservation District in consultation with the National Marine Fisheries Service) should be the highest priority restoration action for this reach. In addition, property acquisition in this reach should focus on securing areas for implementing levee setback and fish passage improvement projects. At the upstream end of the reach, property acquisition could be used to expand the extent of protected parcels that conserve existing agricultural land uses and habitat. In addition, preserving wildland connections with South Mountain should be considered a priority to maintain potential landscape corridors for wildlife movement. Levee setback strategies should focus on the right bank, where physical constraints to restoring connectivity to historical floodplain areas are less of an issue. Active revegetation should follow. Above Freeman Reach has several barrancas along the right bank that are potentially suitable to construct treatment wetlands to retain and filter agricultural and urban runoff. Removal of non-native, invasive arundo should be implemented at the base of South Mountain in the reach to eliminate upslope propagule sources in the riparian-upland transition zone and reduce the risk of arundo serving as a conduit for fire transmission within the riparian corridor.

Below Santa Paula Reach (4)

Below Santa Paula Reach is constrained by floodplain mining, an airport located along the right bank, and naturally hard geology on the left bank. In this reach, property acquisition should be focused on the left bank to conserve existing habitat and allow the channel to migrate away from the airport (acquiring and removing the airport would be prohibitively expensive and would not secure a significant amount of floodplain). Property acquisition could be used to expand the extent of protected parcels that conserve existing land uses and habitat. Active revegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels. The mouth of Fagan Canyon, along the right bank, is potentially suitable site for construction of a treatment wetland to retain and filter agricultural and urban runoff. As in the Above Freeman Reach, removal of non-native, invasive arundo should be implemented at the base of South Mountain to eliminate upslope propagule sources in the riparian-upland transition zone and reduce fire risk.

Above Santa Paula Reach (5)

Above Santa Paula Reach, which includes the confluence with Santa Paula Creek, provides an opportunity to expand the relatively high-quality geomorphic functioning and habitat conditions in Below Sespe Reach (6). In this reach, property acquisition should be focused on conserving existing habitat, protecting the floodplain from development, and linking existing protected

parcels that conserve existing land uses and habitat. In addition, preserving wildland connections with South Mountain and with Santa Paula Creek should be considered a priority to maintain potential landscape corridors for wildlife movement. Active revegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels. The mouth of Orcutt Canyon, along the right bank, is a potentially suitable site for construction of a treatment wetland to retain and filter agricultural runoff. Removal of non-native, invasive arundo should be implemented at the base of South Mountain to eliminate upslope propagule sources in the riparian-upland transition zone and reduce fire risk. Fish passage improvements should be made to Harvey Diversion Dam on lower Santa Paula Creek to allow fish access to the high-quality habitats located upstream.

Below Sespe Reach (6)

Below Sespe Reach is the most naturally functioning, least incised, and largely unregulated reach in the lower Santa Clara River. Property acquisition should be focused on conserving existing habitat, protecting the floodplain from development, and linking existing protected parcels by acquiring the numerous large parcels that span both the active channel and sensitive floodplain habitats. There are patches of scalebroom vegetation in this reach that particularly important to conserve. Revegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels. Several barrancas occur on the right bank of this reach are potentially suitable to construct treatment wetlands to retain and filter agricultural runoff. Removal of non-native invasive arundo should be implemented at the base of South Mountain to eliminate upslope propagule sources and reduce fire risk.

Above Sespe Reach (7)

Like the Above Santa Paula Reach, Above Sespe Reach, which includes the confluence with Sespe Creek, provides an opportunity to expand the relatively high-quality geomorphic functioning and habitat conditions in Below Sespe Reach. Property acquisition in this reach should focus on protecting sensitive habitats and flood-prone areas along both the mainstem and Sespe Creek from floodplain development as the town of Fillmore expands and so reduce the pressure to construct more levees along lower Sespe Creek. In addition, preserving existing riparian-floodplain habitats and connectivity with Sespe Creek should be a priority to maintain potential landscape corridors for wildlife movement. Active revegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels. A barranca on the left bank of this reach is potentially suitable site for constructing a treatment wetland to retain and filter agricultural runoff. Removal of non-native invasive arundo should be implemented along Sespe Creek where arundo is relatively limited in distribution, to eliminate upstream propagule sources.

Hopper Reach (8)

Hopper Reach is impacted by flow regulation on Piru Creek. Property acquisition in Hopper Reach should focus on protecting floodplain habitats from floodplain development upstream of the town of Fillmore. In addition, property acquisition in this reach can be used to conserve or enhance wildlife migration linkages between upland habitats and conserved areas in the river corridor. Opportunities to allow passive levee removal and modify or relocate fish hatchery and farming infrastructure in this reach should be pursued to improve geomorphic functions. Active revegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels. Removal of non-native, invasive species is a low priority in this reach until upstream control efforts are successful.

Below Piru Reach (9)

Below Piru Reach is a losing reach and supports almost no riparian vegetation as a result. Property acquisition should focus on acquiring flood-prone parcels to reduce flood damage, and conserving upland and desert riparian scrub vegetation types. In addition, preserving wildland connections with the Santa Susana Mountains and with Hopper Creek should be considered priorities to maintain potential landscape corridors for wildlife movement. Active revegetation with upland (rather than riparian) vegetation types should be implemented in former agricultural areas and in disturbed areas of acquired parcels. Several barrancas along the right bank of this reach would be potentially suitable sites for constructing treatment wetlands to retain and filter agricultural runoff. Removal of non-native invasive arundo should be implemented to eradicate the relatively small patches that occur in this reach.

Above Piru Reach (10)

Like Below Piru, Above Piru is a losing reach and supports very little riparian vegetation. Property acquisition should focus on acquiring flood-prone parcels to reduce flood damage, and conserving upland and desert riparian scrub vegetation types. In addition, property acquisition in this reach can be used to conserve or enhance wildlife migration linkages between upland habitats and conserved riparian areas, and should include maintaining good connectivity with riparian habitats along Piru Creek. Active revegetation with upland vegetation should be implemented in former agricultural areas and in disturbed areas of acquired parcels, and following arundo removal. Removal of non-native invasive arundo should be implemented to eradicate the relatively small patches that occur in this reach.

County Line Reach (11)

County Line Reach occurs in a narrow canyon, more similar to the upper watershed than to the rest of the reaches in the lower river. Property acquisition should focus on conserving existing habitat and wildlife migration linkages between upland habitats and conserved riparian areas. Active revegetation

should be implemented in former agricultural areas and in disturbed areas of acquired parcels, and following arundo removal. Removal of non-native invasive arundo should be implemented to eradicate the relatively small patches that occur in this reach. In addition, the isolated patches of tamarisk in this reach should be eradicated promptly.

4.9 Information Gaps & Potential Future Studies

While describing the conditions of the lower river and developing feasible restoration strategies for this report, gaps in information or lack of understanding of the river system became evident. The following additional studies are recommended to increase the understanding of the lower Santa Clara River system and assist in developing more detailed restoration plans:

- Groundwater monitoring in reaches of planned large-scale revegetation, conducted for long enough and over a broad enough area to characterize groundwater levels at scales suitable to evaluate project suitability.
- Hydraulic modeling of levee removal and setback scenarios to estimate the likely flood attenuation of different restoration actions.
- Water quality monitoring to characterize existing threats to the conservation of native biota.
- Water quality and quantity monitoring at the Ventura Water Reclamation Facility to identify the magnitude and timing of water quality impacts to native biota, and to identify effects of treated effluent on seasonal patterns of salinity in the estuary and the timing of breaching.
- Water quality monitoring in the Estuary Reach (1) to identify the magnitude and chemical composition of discharge from landfills.
- Long-term monitoring of selected restoration sites and high-quality reference sites for both aquatic and riparian habitat. In particular, monitoring of the effectiveness of different types of restoration and revegetation strategies relative to environmental conditions in the parkway area (*e.g.*, gaining versus losing reaches, time since last disturbance from flood or fire) would help guide and increase the success rate of future restoration efforts.

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APPENDIX A

Non-native Invasive Plant and Animal Species in the Lower Santa Clara River

The lower Santa Clara River riparian corridor, like most California landscapes, is host to many non-native, invasive plant and animal species. Invasive plants and animals can threaten natural habitat value by displacing native plant species and associated animal species, and disrupting food web dynamics and ecological processes. The most highly invasive species documented in the lower Santa Clara River corridor and the locations where they were observed are described below (Sections A.1–A.8), along with some less invasive but widely distributed plant species (Sections A.9–A.12), and two invasive animal species (Sections A.13–A.14).

A.1 Arundo (*Arundo donax*)

Arundo is a highly aggressive, naturalized landscape plant that invades riparian zones by establishing dense, monospecific clonal stands (DiTomoso and Healy 2007). This species is drought- and fire-tolerant (its foliage is highly flammable) and re-sprouts vigorously after fire by quickly exploiting released nutrients (Coffman 2007). Arundo is also shade-tolerant, establishing under established canopies and exposing the dominant trees to increased fire threat. The species does not propagate by seed (all plants in the U.S. have been found to be sterile), and establishment occurs exclusively by vegetative propagules — most often rhizomes that wash downstream from eroded banks (DiTomoso and Healy 2007). Giant reed is a strong competitor in systems with increased nutrient supply, and heave fertilizer use may be an important factor aiding its dominance in many California riparian areas (Coffman 2007). Most commonly, the plant colonizes disturbed areas such as roads, revetted banks and bridge abutments where native vegetation has been cleared. Along the Santa Clara River, arundo occurs primarily in dense monocultures typically 2-5 meters tall (Stillwater Sciences and URS Corporation 2007). It also occurs in a co-dominant role with mulefat (*Baccharis salicifolia)*, narrowleaf willow *(Salix exigua)*, myoporum *(Myoporum laetum)*, red willow (*S. laevigata)*, and arroyo willow *(S. lasiolepis)*. Arundo is found, to some extent, in 5,242 ac, or 73%, of the total mapped vegetation of the lower Santa Clara River corridor (Stillwater Sciences and URS Corporation 2007). Arundo removal is a priority restoration action for the lower Santa Clara River specifically, and the coastal southern California region.

A.2 Pampas grass (*Cortaderia jubata*)

Pampas grass is a large, densely tufted perennial grass with wind dispersed seeds that may spread up to 20 miles from the host population (DiTomoso and Healy 2007). Viable seeds can develop without fertilization and seedlings will readily establish on bare, disturbed soil, although seeds are not long lived in the field (less than 6 months) and a persistent seedbank does no accumulate. Individual plants can survive up to 15–20 years (DiTomoso and Healy 2007). Its habitat includes disturbed areas, dunes, bluffs, roadsides, road cuts and logged forests (CalIPC 2007). Populations can be controlled by hand pulling seedlings, manually cutting or chopping out mature plants from below the crown or planting desirable vegetation on bare sites to reduce seedling establishment. Along the lower Santa Clara River corridor, pampas grass was found growing in low density in one patch along with *Salix lasiolepis* (Stillwater Sciences and URS Corporation 2007).

A.3 Cape-ivy (*Delairea odorata*)

Cape-ivy is a vigorous perennial vine that is especially noxious in riparian areas though it can also invade coastal bluffs and scrubs, seasonal wetlands, moist canyons, oak woodlands, coastal grasslands and various forests (CalIPC 2007). Vines can form dense mats over trees and shrubs and smother underlying vegetation. Cape ivy reproduces vegetatively from rhizomes, stolons and fragments of rhizomes, stolons and stems. Manual removal with follow-up to remove resprouts can control infestations (DiTomaso and Healy 2007). Along the lower Santa Clara River corridor, Cape Ivy was found growing in low density in one patch along with *Salix laevigata* (Stillwater Sciences and URS Corporation 2007).

A.4 Spanish broom (*Spartium junceum*)

Spanish broom was originally introduced into North America in the 1900's as an ornamental for soil stability along highways (DiTomaso and Healy 2007). Its habitat includes open, disturbed sites (logged or burned areas, roadsides and pastures), undisturbed grasslands, coastal scrub, oak woodlands, riparian forests and open forests (CalIPC 2007). Infestations of Spanish broom can increase fire hazard and decrease the use of rangeland (DiTomaso and Healy 2007). Its seeds are long lived in the field and can distribute over large areas by water, soil movement, vehicles, animals and human activities (DiTomaso and Healy 2007). Spanish broom will resprout when it is cut so mechanical treatment alone is generally not effective. Chemical treatment can successfully control large infestations with several years of follow-up treatment (chemical or manual pulling) (DiTomaso and Healy 2007). Spanish broom is found in small numbers in coastal sage scrub communities of the lower Santa Clara River corridor (Stillwater Sciences and URS Corporation 2007).

A.5 Tamarisk (*Tamarix ramosissima*)

Tamarisk is an aggressive invader that disperses seeds by wind and water. It can spread quickly in riparian areas and often develops into dense monoculture stands. It has a deep, extensive root system and a high evapotranspiration rate which, when present in large stands, can greatly reduce underground water tables along riparian corridors (DiTomaso and Healy 2007). Tamarisk leaves excrete salts which increases local soil salinity and inhibits the growth, survival and recruitment of desired, native vegetation. Chemical treatment is required to control infestations with follow-up seedling removal in successive years to prevent regrowth (DiTomaso and Healy 2007). Its extent in the upper Santa Clara River watershed, rate of spread and impacts to the ecology of riparian areas have made it the focus of a large-scale eradication effort, along with giant reed, in the upper watershed (VCRCD 2006b). Currently, mature tamarisk is sparsely distributed in the lower watershed. It is most abundant in County Line Reach (11), the upstream-most reach in the riparian vegetation mapping area, presenting a great risk of further infestation in downstream reaches (Stillwater Sciences and URS Corporation 2007). Cohorts of newly recruited tamarisk seedlings were observed in both summer 2005 and 2006, suggesting a strong recruitment potential downstream of the few mature stands of tamarisk currently established in County Line Reach (11), although future monitoring would be required to determine how many of these seedlings survive to maturity (Stillwater Sciences and URS Corporation 2007).

A.6 Tocalote and yellow starthistle (*Centaurea melitensis and C. solstitialis*)

Ubiquitous in southern California grasslands, tocalote and yellow starthistle are low-growing, small-flowered herbaceous species which invade disturbed areas, pastures, and roadside clearings (CalIPC 2007). Yellow starthistle is considered one of the most serious rangeland weeds in the western United States (CalIPC 2007). Natives of southern Europe, tocalote and yellow starthistle were introduced in California between 1848 and 1869. As of 1995, yellow starthistle it is estimated to have invaded 10–12 million acres in California (Bossard *et al*. 2000). Infestations of tocalote and yellow starthistle can displace native plants and animals, deplete soil moisture reserves in annual grasslands, interfere with grazing, and reduce land values (DiTomaso and Healy 2007). Infestations can be controlled with grazing, mowing, burning and cultivation over a period of at least 2-3 years. Tocalote was common in disturbed areas and herbaceous vegetation types thought the lower Santa Clara River corridor, while a small amount of yellow star thistle was observed growing with *Populus balsamifera* and other non-native herbaceous species (Stillwater Sciences and URS Coprporation 2007).

A.7 Sweet fennel (*Foonicculum vulgare*)

Sweet fennel is common along roadsides and disturbed areas, particularly in coastal regions of central and southern California (CalIPC 2007). It also invades grasslands, riparian areas and other natural communities. It is a prolific seed producer and seeds can be dispersed with water, soil movement, animal, and human activities (DiTomaso and Healy 2007). Small population can be controlled by manually removing individual plants, although larger populations may require a more integrative management scheme including repeated mowing, burning, and chemical applications (DiTomaso and Healy 2007). Sweet fennel was found in several locations along the lower Santa Clara River corridor, primarily in disturbed, scrub vegetation in the lower reaches of the river (Stillwater Sciences and URS Corporation 2007).

A.8 Perennial pepperweed (*Lepidium latifolium*)

Perennial pepperweed is a highly competitive plant that often forms dense patches and can displace native vegetation and wildlife (DiTomaso and Healy 2007). Its habitat includes wetlands, riparian areas, meadows, vernal pools, salt marshes, floodplains, sand dunes, roadsides and irrigation ditches as well as alfalfa fields, orchards, vineyards and irrigated pastures (CalIPC 2007). It reproduces vegetatively from creeping roots and root fragments and by seeds (DiTomaso and Healy 2007). Both the root fragments and seeds float and the plant can disperse across great distances by flooding, soil movement, agricultural practices and other human activities (DiTomaso and Healy 2007). A small stand of perennial pepperweed was observed in 2005 in the tidal marsh habitat in Estuary Reach (0) (Stillwater Sciences and URS Corporation 2007).

Other, lower impact non-native invasive plant species but that are relatively widely distributed in the lower Santa Clara River corridor include eucalyptus (*Eucalyptus* spp.), tree tobacco (*Nicotiana glauca*), Peruvian peppertree (*Schinus molle*), and castor bean (*Ricinus communis*). These species may be easier to eradicate from the watershed than the aggressive invaders described above, since they currently have limited distributions or low rates of infestation.

A.9 Eucalyptus (*Eucalyptus* spp.)

Eucalyptus species have become slow, though widespread, invaders throughout California. Once established, the trees can make their microenvironment hostile to native species by altering soil chemistry and reducing the availability of light, water, and nutrients (DiTomaso and Healy 2007). Blue gum (*Eucalyptus globulus*) is the most common eucalyptus species in California and is widely planted as an ornamental or as a wind break. It habitat includes disturbed areas, especially riparian areas, coastal grasslands, and forests (CalIPC 2007). Blue gum reproduces from seeds and can disperse great

distances by water and soil movement and human activities (DiTomaso and Healy 2007). Eradication of eucalyptus is straightforward given adequate incentive and funding, though its fast growth and clonal root sprouting often necessitate multiple treatments (DiTomaso and Healy 2007). In the lower Santa Clara River corridor, eucalyptus is generally found in disturbed areas and occurs as small, but widely distributed patches (Stillwater Sciences and URS Corporation 2007).

A.10 Tree tobacco (*Nicotiana glauca*)

Tree tobacco is rated as a moderately invasive species in coastal scrub, grasslands and riparian areas in California (CalIPC 2007). All parts of this plant are highly toxic to humans and livestock when ingested. It grows in open, sandy or gravelly sites, especially along roadsides and in fields, disturbed areas, washes, and riparian areas. Tree tobacco reproduces by seeds which disperse with water, soil movement, and human activities (DiTomaso and Healy 2007). Stands of tree tobacco are currently found along Sespe Creek, Piru Creek and downstream of Piru Creek on the mainstem Santa Clara River in Above Piru Reach (10) (Stillwater Sciences and URS Corporation 2007). The presence of tree tobacco in these upstream areas presents a potential risk for downstream invasion.

A.11 Peruvian peppertree (*Schinus molle*)

Peruvian peppertree is listed as a limited invasive species that occurs generally in washes, on slopes, and in dry fields (CalIPC 2007). Peruvian peppertree is found throughout the lower Santa Clara River corridor as a co- or subdominant canopy species with cottonwood, eucalyptus species, western sycamore, California black walnut, arroyo willow, red willow, blue elderberry (*Sambucus mexicana*), and coast live oak (*Quercus agrifolia*) (Stillwater Sciences and URS Corporation 2007).

A.12 Castor bean (*Ricinus communis*)

Castor bean is a widespread summer annual or perennial shrub in coastal scrub and riparian areas in southern California (Cal-IPC 2007). Its habitat includes roadsides, fields, riparian areas and disturbed waste places (CalIPC 2007). Castor bean reproduces by seed and populations can be spread across large distances by human activities, soil, and water movement (DiTomaso and Healy 2007). The seeds and foliage of castor bean are highly toxic to humans and animals when ingested. Castor bean infestations can be controlled with periodic removal of seedlings or with systemic herbicides (DiTomaso and Healy 2007). Castor bean is found in disturbed sites throughout the lower Santa Clara River corridor, including many of the barrancas (small tributary streams) that cross agricultural zones, and is often found growing with shortpod mustard (*Hirschfeldia incana*) and ripgut grass (*Bromus diandrus*) (Stillwater Sciences and URS Corporation 2007).

A.13 African clawed frog (*Xenopus laevis*)

African clawed frogs are native to southern Africa, and were introduced in California and other places as laboratory animals (Nieukoop and Faber 1994, Lannoo 2005). Because African clawed frogs can easily adapt to a variety of habitats and locations, they have been able to successfully establish populations on multiple continents (Lannoo 2005). African clawed frogs are able to locate living prey easily, even when prey are concealed in mud and detritus (Lafferty and Page 1997, Beck and Slack 2001). Because they prefer warm stagnant ponds that are highly muddy, or turbid, and often covered in green algae, African clawed frogs have also evolved the ability to locate prey by smell. As a "sit and wait" predator, adult African clawed frogs in introduced areas feed on essentially whatever prey/food items are available. This may include a wide range of aquatic invertebrates and vertebrates, (*e.g.*, tadpoles and juveniles of multiple amphibians, arroyo chub, mosquito fish, unarmored three-spined stickleback, and tidewater gobies) (Lafferty and Page 1997, Stebbins 2003, Lannoo 2005). Additionally, African clawed frogs can live off of non-living food items as scavengers—a rare adaptation in frogs—and one which often gives this species a significant advantage when transplanted to other parts of the globe (Lafferty and Page 1997, Beck and Slack 2001, Lannoo 2005). Because they breathe through highly developed lungs and can survive up to a year burrowed in deep mud, African clawed frogs are able to survive drought conditions much more successfully than native frog species (Simmonds 1985, Kaplan 1995, Lannoo 2005). Originally discovered in the upper watershed in 1974 and in the estuary in 1995, African clawed frogs are now present throughout the lower Santa Clara River corridor and its small tributaries and barrancas (Lafferty and Page 1997; Lannoo 2005; B. Orr, Stillwater Sciences, pers. obs., 2005; S. Sweet, UCSB, pers. comm., 2006).

A.14 Brown-headed cowbird (*Molothrus ater*)

Brown-headed cowbirds are native to North America, although they are fairly recent arrivals in the western United States, where they are believed to have increased in population following the development of the west in the early 20th century (Morrison *et al.* 1999, Friedmann 1963 as cited in Labinger and Greaves 2001). The brown-headed cowbird is one of North America's most notorious nest parasites. Cowbirds use other bird species as nest hosts, laying their eggs in host nests and having the host bird incubate and feed the cowbird chicks (Morrison *et al.* 1999). Female cowbirds are capable of laying up to 30 eggs in one breeding season (Morrison *et al.* 1999). The young cowbirds often out-compete the other nestlings and may lower the reproductive success of the host bird species (Halterman and Laymon 1997, Morrison *et al.* 1999). Cowbird chicks have been successfully reared by over 150 host species, with songbirds comprising the majority of the hosts (Morrison *et al.* 1999, Friedmann *et al.* 1977 as cited in Labinger and Greaves 2001). Rates of parasitism depend on the proximity of cowbird foraging areas (grasslands,

agricultural lands, pastures, grazing yards, and grain silos) to the host breeding sites (Rothstein *et al.* 1984 as cited in Labinger and Greaves 2001, Halterman and Laymon 1997). Partners in Flights (1997) found that large, contiguous forests sustained lower rates of cowbird parasitism that fragmented forests, suggesting the cowbirds search for hosts along forest edges. Fragmented forests have more edge habitat, often alongside agricultural or pasture areas, and species within these areas are more susceptible to cowbird parasitism (Partners in Flight 1997).

Cowbird parasitism has been documented throughout the lower Santa Clara River corridor in least Bell's vireo, Hutton's vireo, yellow warbler, common yellowthroat, yellow-breasted chat, and song sparrow nests (Labinger and Greaves 2001). Parasitism was more common in areas where no cowbird trapping was being conducted, and cowbird host species were less abundant in areas of high cowbird abundance (although this may also be related to habitat quality and land use patterns) (Labinger and Greaves 2001). Cowbird removal is believed to be one of the factors responsible for increases in several southern California vireo populations (USFWS 1998). An annual cowbird control program on the lower Santa Clara River corridor implemented by the California Department of Fish and Game, which includes the trapping and killing of adults and removal of eggs from host nests, appears to be increasing least Bell's vireo productivity (Labinger and Greaves 2001).

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APPENDIX B
Regulatory Considerations and Permitting Requirements

Implementation of the non-acquisition restoration strategies presented in this report will trigger multiple, yet slightly different sets of environmental review and permit requirements. Potential jurisdictional agencies for the four restoration strategies include: the U.S. Army Corp of Engineers (USACE), U.S. Fish and Wildlife Service (USFWS), NOAA Fisheries Service (also known as the National Marine Fisheries Service, or NMFS), California Department of Fish and Game (CDFG), Regional Water Quality Control Board (RWQCB), Ventura County Watershed Protection District (VCWPD), and California Coastal Commission (CCC) (the jurisdictional areas and activities of these agencies are discussed in Section B.4). This section, modified from examples provided in the Ventura County Planning Division's (2006) Wetland Project Permitting Guide, identifies the triggering activities associated with certain restoration strategies and the likely permits and approvals that will be required. It should be noted that the permits and approvals identified in the tables below are not listed in order of when they should be acquired; timeframes and approaches to permit acquisition are discussed in Sections B.4 and B.5, respectively. Requirements of each permit/approval identified in the tables below are discussed in more detail in Section B.4.

B.1 Levee Removal/Setback and Floodplain Re-contouring

Levee removal/setback and floodplain re-contouring restoration strategies will likely involve temporarily diverting the Santa Clara River away from the work area, heavy equipment working in the active channel, removal or movement of material from the floodplain, removal of vegetation, and potentially may occur in the vicinity of protected species. The location of the Santa Clara River and scope and location of the restoration activities would place the project under the jurisdiction of the USACE, CDFG, RWQCB, VCWPD, and potentially CCC. Project triggers and likely required permits or approvals for levee removal/setback and floodplain re-contouring projects are listed in Table B-1. Table B-1 assumes the project area is greater than 10 acres (if it were less, a USACE 404 Nationwide Permit [NWP] would be required rather than an Individual Permit [IP]), that federally and state-protected species have the potential to occur within the project area, and that the project will be conducted within the coastal zone.

Table B-1. Triggers and likely required permits and approvals for levee removal/setback and floodplain re-contouring restoration strategies.

Primary Trigger	Additional Triggers	Permit/Approval	Associated Requirements
Moving material into or within the river	Project area over 0.5 acre	USACE 404 IP	• RWCQB 401 Certification[1] • CEQA compliance • wetland delineation
Altering a stream, disturbing riparian vegetation		CDFG Streambed Alteration Agreement (SAA)	CEQA compliance
Federally protected species		• USFWS or NMFS Section 7 Consultation • Section 10 Incidental Take Permit	
State protected species	CDFG Streambed Alteration Agreement (SAA) required	CDFG Section 2081 Permit Consultation	
Grading in a stream or wetland		VCWPA Grading Permit	CEQA compliance
Discretionary approval required[2]	• USACE 404 IP required • CDFG Streambed Alteration Agreement (SAA) required	CEQA compliance	• Initial Study • Negative Declaration or Mitigated Negative Declaration
Disturbing >1 acre of soil		State Water Board Construction General Permit & Stormwater Pollution Prevention Plan	
Pumping or releasing water		RWQCB Wasted Discharge /National Pollution Discharge Elimination System (WDR/NPDES) Permit	
Working in VCWPD red-line stream		VCWPD Encroachment and/or Watercourse permit	
Removing or trimming protected tree		VCPD Protected Tree Permit	
Working in coastal zone		• CCC Letter of Concurrence • VCPD Land Use/Coastal Zone Permit	CEQA compliance
Working within a California State Park		California State Parks consultation	

[1]In March 2007, the State Water Resources Control Board approved a general 401 water quality certification order for small habitat restoration projects that greatly reduces 401 certification requirements for eligible projects; see Section B.4.2 for more details.
[2]Discretionary approval involves the exercise of judgment on the part of a regulatory agency.

B.2 Non-native, Invasive Plant Removal

Non-native, invasive plant removal restoration strategies will likely involve spraying herbicides and removing live and dead vegetation with a tractor. Again, the location of the Santa Clara River and scope and location of vegetation removal would place the project under the jurisdiction of the USACE, CDFG, RWQCB, VCWPD, and potentially CCC. Project triggers and likely required permits or approvals for non-native, invasive plant removal projects are listed in Table B-2. Table B-2 assumes that federally and state-protected species have the potential to occur within the project area and that the project will be conducted within the coastal zone. In addition, Table B-2 provides guidance in the case that the project is, or is not, eligible for a USACE 404 Regional General Permit (RGP). Removal of non-native, invasive plants is one of several activities covered under USACE 404 RGPs, the simplest and quick

Table B-2. Triggers and likely required permits and approvals for non-native invasive plant removal.

Primary Trigger	Additional Triggers	Permit/Approval	Associated Requirements
Moving material into or within the river		USACE 404 RGP 41	
404 permit required		RWQCB 401 Certification	CEQA compliance
Altering a stream, disturbing riparian vegetation		CDFG Streambed Alteration Agreement (SAA)	CEQA compliance
State protected species	CDFG Streambed Alteration Agreement (SAA) required	CDFG Consultation	
Federally protected species		• USFWS or NMFS Section 7 Consultation • Section 10 Incidental Take Permit	
Grading in a stream or wetland		VCWPA Grading Permit	CEQA compliance
Discretionary approval required	• USACE 404 IP required • CDFG Streambed Alteration Agreement (SAA) required • VCWPA Grading Permit required	CEQA compliance	• Initial Study • Negative Declaration or Mitigated Negative Declaration
Disturbing >1 acre of soil		State Water Board Construction General Permit & Stormwater Pollution Prevention Plan	
Working in VCWPD redline stream		VCWPD Encroachment and/or Watercourse permit	
Working in coastal zone		• CCC Letter of Concurrence • VCPD Land Use/Coastal Zone Permit	CEQA compliance
Working within a California State Park		California State Parks consultation	

est type of 404 permits (see Section B.4.1). RGPs often include pre-approved 401 Certification and USFWS and NOAA Fisheries endangered species consultations. To be eligible for the RGP, the purpose of non-native, invasive plant removal projects must include both habitat recovery and flood control. The items in Table B-2 that appear in grayed-out text are those permits that would not need to be acquired if the work is eligible for a RGP.

B.3 Re-vegetation

Active re-vegetation restoration strategies will involve planting native plants with hand-tools or smaller types of heavy equipment on stream banks and the floodplain. Re-vegetation work will most likely occur above the ordinary high water mark but within the floodway, putting the work within the jurisdiction of CDFG and VCWPD, but outside the jurisdiction of USACE. Project triggers and likely required permits or approvals for active re-vegetation projects are listed in Table B-3. Table B-3 assumes that federally and state-protected species have the potential to occur within the project area and that the project will be conducted within the coastal zone.

Table B-3. Triggers and likely required permits and approvals for active revegetation.

Primary Trigger	Additional Triggers	Permit/Approval	Associated Requirements
Altering a stream, disturbing riparian vegetation	Working above the Ordinary High Water mark and inside of floodway	CDFG Streambed Alteration Agreement (SAA)	CEQA compliance
Discretionary approval required	• USACE 404 IP required • CDFG Streambed Alteration Agreement (SAA) required • VCWPA Grading Permit required	CEQA compliance	Notice of Exemption
Federally protected species		USFWS or NMFS Section 7 Consultation	
State protected species	CDFG Streambed Alteration Agreement (SAA) required	CDFG Section 2081 Permit Consultation	
Working within floodway of VCWPD red-line stream		VCWPD Encroachment and/or Watercourse permit	
Working in coastal zone		• CCC Letter of Concurrence • VCPD Land Use/Coastal Zone Permit	CEQA compliance
Working within a California State Park		California State Parks consultation	

B.4 Regulatory Statutes and Implementing Agencies

This section describes the regulations and permits identified in the tables above in more detail. Regulatory requirements of each statute and/or implementing agency are described with the assumption that each permit would be acquired on a project-by-project basis. Requirements would be modified if a programmatic approach to environmental compliance that includes all restoration strategies for the entire river is taken. Programmatic approaches are discussed in Section B.5.

B.4.1 USACE Section 404 Permit

The USACE regulates activities that involve discharge of dredged and fill material into "Waters of the United States", including wetlands, under Section 404 of the federal Clean Water Act (CWA) (CWA 1977). Waters of the United States include navigable waters, interstate waters; all other waters where the use or degradation or destruction of the waters could affect interstate or foreign commerce, tributaries to any of these waters, and wetlands that meet any of these criteria or that are adjacent to any of these waters or their tributaries. The jurisdiction of the USACE over non-tidal waters covers the bank-to-bank portion of a river along its entire length and extends up to the "ordinary high-water mark" as well as adjacent wetlands. The ordinary high-water mark is defined by the USACE (2007) as "a line on the shore established by the fluctuations of water and indicated by physical characteristics, or by other appropriate means that consider the characteristics of the surrounding areas."

A USACE Section 404 Permit is triggered by any activity that adds material to or disturbs the bed of a water body or wetland, even if the area is dry at the time the activity takes place. There are three types of Section 404 Permits that may be required for any particular project depending on the size and overall complexity of the project, listed in order of increasing complexity and requirements:

- Regional General Permits (RGPs)
- Nationwide Permits (NWPs)
- Individual Permits (IPs)

The specific details of the three types of USACE Section 404 Permits are described below.

Regional General Permit

RGPs are region-specific permits that have already been prepared for a small number of project categories. These permits may be issued for general maintenance-related activities with minimal environmental impacts and are therefore the simplest and quickest permits to receive from the USACE (VCPD 2006). If applicable, RGPs often include pre-approval from the RWQCB for a

CWA Section 401 Certification, USFWS and NMFS Endangered Species Act consultations or permits, and a CCC Letter of Concurrence for those projects located in the Coastal Zone (VCPD 2006). The processing time for an available RGP is approximately one month. For projects that require development of new categories of RGPs for routine maintenance activities, the processing time may take 6 to 12 months. There are currently no application fees for RGPs, although some RGPs have associated review and processing fees. RGP 41 could potentially be utilized for non-native, invasive plant removal projects. Projects eligible for RGP 41 include those whose purpose is both habitat recovery and flood control. The permit review and processing fee for RGPs is $60.

Nationwide Permit

NWPs are another type of USACE-issued permit required for any project that: 1) involves discharging or moving material into or within a river; 2) has a permanent impact area less than 0.5 acres; and 3) does not meet the criteria for a Section 404 RGP. Similar to RGPs, NWPs are pre-written permits for authorized categories of activities, except that they are available nationwide. NWPs provide an expedited authorization process for activities that have minimal individual and cumulative impacts on the aquatic environment provided that the project satisfies the terms and conditions of the associated NWP. There are currently about 50 types of NWPs, including: maintenance, bank stabilization, survey activities, minor dredging, stormwater management, flood control maintenance, and wetland restoration for the benefit of improving wildlife habitat (USACE 2007)

Depending upon the scope and location of a project, he NWP process may require: 1) a biological review with estimates of expected impacts to water and wetlands to be completed; 2) pre-authorization for RWQCB 401 Certification; 3) USFWS or NMFS ESA consultation or permits; 4) a CCC Letter of Concurrence for projects located in the Coastal Zone; and 5) a wetland delineation to determine the lateral extent of USACE jurisdiction for projects conducted in wetlands beyond the stream channel (VCPD 2006). Some NWPs do not require submission of a pre-construction notification to the USACE prior to initiating work, provided that all permit conditions are satisfied. Other NWPs, that do require pre-construction notification, may take three to four months to process while the USACE determines if the proposed work is eligible for NWP authorization. There are no application fees for NWPs (VCPD 2006).

Individual Permit (IP)

IPs are the most complex type of the Section 404 Permits issued by the USACE. IPs are required for projects that impact greater than 0.5 acre of USACE jurisdictional area through discharging or placing materials into or within a river. Similar to a NWP, an IP may have additional requirements, including: 1) a biological review; 2) RWQCB 401 Certification; 3) USFWS or NMFS ESA consultation or permits; 4) a CCC Letter of Concurrence for projects located in the Coastal Zone; and 5) a wetland delineation for projects conducted in wetlands beyond the stream channel (VCPD 2006). A project may be issued an IP as a standard permit or as a Letter of Permission (LOP). A standard permit includes public review and is issued following a case-by-case evaluation of the proposed project. The processing time of a standard permit could take up to one year or longer due to the need for public review and the complexity of the permitting process (VCPD 2006). Projects having only minor or routine work with expected minimum impacts and objections may qualify for a LOP, which can be issued quickly because a public review is not required (USACE 2007).

B.4.2 RWQCB 401 Certification

The State Water Resources Control Board (State Water Board), through its RWQCBs, is the lead agency charged with protecting the quality of the State's surface and groundwater supplies, per the federal CWA (1977) and the California Porter-Cologne Water Quality Control Act (2006). Section 401 of the CWA is implemented by the RWQCB to protect and minimize impacts to the quality of the surface waters of the State. Surface waters of the State include wetlands, riparian zones, streambeds, and lakes. Anyone proposing to conduct activities resulting in a discharge to surface waters is required to obtain a RWQCB Certification or Waiver. Certifications are issued in association with a USACE CWA Section 404 Permit.

Depending on the complexity of a project, 401 certification may require: 1) a biological review with estimates of expected project impacts to water or adjacent wetlands; and 2) documentation of CEQA compliance or exemption. These documents are usually prepared by a State or local agency or by the State or Regional Board when there is no other CEQA lead agency (see Section B.4.4; State Water Board 2003). The permitting process time may take 3 to 4 months (VCPD 2006). Permit fees begin at $500, and range upward depending on the spatial extent of the proposed impact and the technical complexity of the project (State Water Board 2003).

In March 2007, the State Water Board authorized a general 401 Water Quality Certification Order for small habitat restoration projects, exempting eligible projects from the certification requirements described above (State Water Board 2007). Eligible small habitat restoration projects must: 1) be categorically exempt from CEQA (Class 33 exemption; see Section B.4.4); 2) be less

than five acres or 500 linear feet of stream bank or coastline; 3) not be a compensatory mitigation project; 4) have the primary purpose of habitat restoration; and 5) take less than five years to construct. To apply for the Certification Order, the project proponent must provide the State Water Board and appropriate RWQCB with a Notice of Intent (NOI), along with a $60 fee, and Monitoring Plan at least 30 days prior to the proposed project. The level of detail on the Monitoring Plan and associated reporting depends on the scope and size of the project, but at a minimum must include: 1) functions of the impacted water resources; 2) project purpose and goals; 3) measurable performance standards appropriate to each goal; 4) timeframe and responsible party for determining attainment of performance standards; and 5) appropriate reporting schedule (at least annually for the period stated in performance standards). Monitoring reports which summarize monitoring findings, identify and discuss problems with attaining performance standards, propose corrective measures, and present collected data, must be submitted annually to the appropriate RWQCB. Finally, a Notice of Completion must be submitted to the appropriate RWQCB within 30 days of project completion.

B.4.3 CDFG Streambed Alteration Agreement

Under Chapter 6 of the California Fish and Game Code, CDFG is charged with the protection and conservation and the State's fish, wildlife, and plant resources, and their habitats. Fish and Game Code Sections 1600-1616 regulate activities that would "divert, obstruct, or change the natural flow or bed, channel, or bank of any river, stream, or lake designated by the CDFG in which there is at any time an existing fish or wildlife resource or from which those resources derive benefit, or will use material from the streambeds designated by the department". CDFG requires a Streambed Alteration Agreement (SAA) for any project that may alter the bed, banks or channel or a stream, or the adjacent riparian vegetation. A SAA is a written document that includes a description of the project or activity and project conditions necessary to protect fish or wildlife resources. Routine, non-invasive monitoring activities, such as surveying and sampling, do not require a SAA.

Fish and Game Code Section 1602 requires that CDFG be notified, on a standardized notification form (FG 2023) and project questionnaire (FG 2024), of any activity that will take place in or in the general vicinity of a river, stream or lake, including rivers or streams that only flow periodically. Following review of the completed notification package, CDFG determines whether the project requires a SAA. A field meeting with a CDFG representative is recommended after submitting the application materials (VCPD 2006). If CDFG determines that a proposed project may substantially adversely affect existing fish or wildlife resources, a SAA must be obtained and the proposed project, unless otherwise exempt, must comply with CEQA (see Section B.4.4). SAAs include project-specific conditions that must be satisfied as part of the agreement between the applicant(s) and the CDFG. These conditions are re-

lated to project techniques and any measures that will be incorporated into the project to mitigate or compensate for project-related impacts to fish, wildlife, and plant resources. The SAA process may take three to four months, provided that CEQA compliance is complete (VCPD 2006). A permitting fee is required and the amount is dependent on the cost of the project and the term of the agreement.

B.4.4 CEQA Compliance

CEQA requires California's state and local agencies to: (1) identify the significant environmental effects of their actions, independently, and with consideration of other reasonably foreseeable projects; and, (2) either avoid those significant environmental effects, where feasible, or mitigate those significant environmental effects, where feasible (CEQA 1970). CEQA applies to any action other than those exempted by law that requires a permit or entitlement from a California public agency (*i.e.*, "discretionary approval"), or is funded or undertaken by a California public agency. CEQA compliance can also be required by other permits and/or certifications prior to issuance; within Ventura County CEQA compliance in required for VCPD Land Use/Coastal Zone Permits, VCPWA Grading Permits, CDFG SAAs, and RWQCB 401 Certification (VCPD 2006).

Several types of projects are exempt from complying with CEQA either by law or because they are in a category of projects deemed to not have significant effects on the environment. There are three forms of exemptions: complete exemptions, partial exemptions, or exemptions that apply to the timing of NEPA compliance (CEQA Guidelines 2006). Examples of projects that are typically exempt include resource and environmental protection actions by regulatory agencies, wildlife habitat acquisition, small habitat restoration (less than five acres or 500 linear feet of stream channel), and maintenance activities. Examples of small habitat restoration projects that are typically exempt from CEQA include: 1) revegetation of disturbed areas with native plant species; 2) wetland restoration to improve waterfowl and other wetland species habitat; 3) stream or river bank revegetation to improve amphibian or native fish habitat; 4) restoration projects carried out primarily with hand labor rather than mechanized equipment; 5) stream or river bank stabilization with native vegetation or bioengineering techniques to reduce erosion and sedimentation; and 6) culvert replacement done in accordance with CDFG and NOAA Fisheries guidelines to improve habitat or reduce sedimentation (State Water Board 2007).

The public agency with the greatest authority over the project generally assumes the role of lead agency. The lead agency is the single agency responsible for determining the type of environmental analysis required by CEQA and preparing the required environmental review document (CEQA Guidelines 2006). In most cases, the project proponent prepares a draft of the re-

quired environmental review documents for lead agency review and adoption. In cases where compliance with both NEPA and CEQA is required, a joint document can be prepared if there is agreement by the lead agencies.

Unless it is determined a priori that an Environmental Impact Report (EIR) will be prepared for the project, compliance with CEQA requires a lead agency to complete an Initial Study that identifies the environmental impacts of the proposed project and determines whether those impacts are significant. Depending on the level of impact, the lead agency must prepare one of three environmental review documents. If the Initial Study finds that a project will have no significant impacts on the environment, a Negative Declaration (Neg Dec) can be prepared. A Neg Dec describes why a proposed project will not have significant effects on the environment and thus does not require an EIR to be prepared. If the Initial Study finds that a project will have impacts, but that those impacts can be mitigated to less-than-significant levels, then a Mitigated Negative Declaration (Mitigated Neg Dec) is prepared. A Mitigated Neg Dec describes the potential impacts of the proposed project and the conservation and/or mitigation measures to be implemented to reduce the impacts to less-than-significant levels. An EIR must be prepared if the project will result in significant environmental impacts. The purpose of an EIR is to: 1) inform public agencies and the public about any adverse effects that the proposed project may have on the environment; 2) present any minimization measures that may lessen the impact of the project; and 3) indicate alternatives to the project. If it is stated in an EIR that significant environmental impacts cannot be feasibly reduced to less-than-significant levels, then the lead agency must issue a statement of overriding consideration before it can approve the project (CEQA Guidelines 2006).

The time frame of processing either a Neg Dec or Mitigated Neg Dec is estimated at 180 days from the date the project application is accepted as complete by the lead agency. An EIR may take one year following application acceptance (VCPD 2006). The project proponents may be required to pay fees to the lead agency to compensate them for costs associated with CEQA compliance and document preparation, and for mitigation monitoring or reporting (VCPD 2006).

B.4.5 USFWS or NMFS Section 7 Consultation and Section 10 Incidental Take Permit

Both the USFWS and NMFS share responsibility for implementing the federal Endangered Species Act (ESA); USFWS generally manages land and freshwater species, while NMFS manages marine and anadromous species. Sections 7 and 10 of the ESA charge federal agencies to aid in the conservation of listed species, and require federal agencies to consult with USFWS or NMFS to ensure that project actions will not jeopardize the continued existence of any listed species or their habitats. In general, Section 7 consultation

and/or the need for a Section 10 Incidental Take Permit is triggered when a project's Initial Study (per CEQA) or biological survey indicates that a federally listed or protected plant or animal species likely occurs within a project area. Federally listed species that have been documented to occur within the Santa Clara River watershed and could potentially trigger the need for Section 7 consultation or a Section 10 Incidental Take Permit during restoration strategy implementation are discussed in Section B.4.3. As an example, when federally-listed southern California steelhead are present in a proposed project area, the following actions trigger NMFS Section 7 consultation or a Section 10 Incidental Take Permit: 1) working in or near a stream channel between December 1 and June 15; 2) diverting water in a stream channel; 3) catching and relocating steelhead; and 4) grouting riprap along stream bank revetments (VCPD 2006).

Section 7 Consultation is specifically triggered when the project has a "federal nexus", which would often exist when the project requires another federal permit (*e.g.*, USACE Section 404 Permit). If the lead federal agency determines that a project may adversely affect a listed species or their habitat, USFWS or NMFS will require formal consultation followed by issuance of a biological opinion (BO) on whether the proposed action would likely jeopardize the survival of the listed species or adversely impact their habitat. The BO may include a statement of incidental take based on the anticipation of USFWS or NMFS that the proposed action may lead to harassing, harming, capturing, or killing listed species, but will not jeopardize the continued existence of the listed species. The extent of take allowed will be clearly specified. The set consultation period is to last no longer than 90 days and the subsequent BO is to be prepared within 45 days.

A Section 10 Incidental Take Permit is specifically triggered when non-federal entities such as states, counties, local governments, and private landowners propose a project action that might incidentally, but not intentionally, "take" a listed species. A Habitat Conservation Plan (HCP) must first be submitted prior to receiving this permit. A HCP is designed to offset harmful effects a proposed project action might have on listed species. The processing time for a Section 10 Incidental Take Permit may take 18 months or longer (VCPD 2006).

B.4.6 CDFG Section 2081 Incidental Take Permit

CDFG administers the California Endangered Species Act (CESA) (California Fish and Game Code §2050, et seq.). CESA serves to protect and preserve native plant and animal species, and associated habitats, threatened with extinction or that are experiencing significant population declines which, if not halted, would lead to a threatened or endangered designation. Section 2081 of CESA allows CDFG to require an Incidental Take Permit if: 1) a project's Initial Study (per CEQA) or SAA indicates that a plant or animal species that

is state-listed as threatened or endangered likely occurs within a project area; and 2) the proposed project will potentially adversely affect the state-protected plant or animal or their habitat. The take of species that are "fully protected" and "specified birds" is never authorized (Fish and Game Code §3505, 3511, 4700, 5050, 5515, and 5517). Conversely, an Incidental Take Permit is not required for California Species of Concern (CSC), since they are not listed under either the federal ESA or CESA. CSC species protection is often addressed as part of a SAA, if applicable. A CDFG Section 2081 Incidental Take Permit may take 6 to 8 months for processing and will only be issued if the impacts of the authorized take are minimized and fully mitigated and the project will not jeopardize the continued existence of the species (VCPD 2006). State-protected species that have been documented to occur within the Santa Clara River watershed and could potentially trigger the need for a Section 2081 Incidental Take Permit during restoration strategy implementation are discussed in Section B.4.3.

B.4.7 State Water Board Construction General Permit and Storm Water Pollution Prevention Plan

The State Water Board and nine RWQCBs regulate discharges that may adversely impact surface and ground water. Their authority is derived from the federal CWA and the Porter-Cologne Water Quality Control Act (California Water Code). The State Water Board issues the General Permit for Discharges of Storm Water Associated with Construction Activity (Construction General Permit 99-08-DWQ) to projects that could result in wastewater discharges. Construction activities that are required to obtain a State Water Board Construction General Permit include those that disturb at least one acre of soil, the total of several individual developments equal at least one acre, or there is significant impact to water quality. Examples of construction projects that are subject to this permit include clearing, grading, and disturbances to the ground such as stockpiling or excavation. Depending on the nature of the construction activity and the decision of the RWQCB representative, additional Waste Discharge Requirements or National Pollution Discharge Elimination System permits may not be required (see Section B.4.8 below).

Discharges must initially notify the State Water Board of any wastewater discharges by submitting a Notice of Intent (NOI) to obtain coverage under the permit. The permit also requires that a Storm Water Pollution Prevention Plan (SWPPP) be developed and implemented. The SWPPP is a document that outlines Best Management Practices (BMPs) to avoid and minimize movement of sediment and pollutants into waters. The SWPPP must also contain a comprehensive monitoring program to be implemented if there is a failure of BMPs. The SWPPP and NOI should be prepared one month prior to construction activities begin (VCPD 2006). A waste discharger's identification (WDID) number will be issued to the discharger upon receipt of a com-

plete NOI. Following construction activities, dischargers are required to file a Notice of Termination (NOT) with the RWQCB to certify that all State and local requirements have been satisfied in accordance with the Construction General Permit. Annual updates with the RWQCB may be required for long-term projects. A Construction General Permit may take one month for processing and will only be issued if the authorized discharge meets certain conditions (VCPD 2006).

B.4.8 RWQCB Waste Discharge Requirements and National Pollution Discharge Elimination System Permits

All wastewater discharges in the state, including land and surface and ground waters, are subject to regulation under the California Water Code and the CWA. The RWQCB will issue Waste Discharge Requirements (WDRs) to projects that discharge wastewater to land and groundwater. Discharges to surface waters from point sources require implementation of portions of the CWA, specifically the National Pollution Discharge Elimination System (NPDES) program. The RWQCB has the authority to issue a joint NPDES/WDR permit for discharges to surface waters from a point source. Several types of project activities may require either of these permits, including pumping or releasing water, diverting water in a stream, and dewatering. A Report of Waste Discharge (Form 200) is required for all discharge types. A project is not required to obtain an NPDES permit for discharges of dredged or fill material into water of the United States provided that the dredging or filling is authorized by a permit issued by the USACE or an EPA-approved state under Section 404 of CWA. The majority of WDRs and joint NPDES/WDRs are treated as project-specific Individual Permits which may take 6 to 8 months to process (VCPD 2006).

B.4.9 CCC Coastal Zone Development Permit

The California Coastal Act (CCA) and the Federal Coastal Zone Management Act are implemented by the CCC. The Coastal Zone encompasses some 1.5 million acres of land in California and extends inland about 3 miles, but can extend up to 5 miles in less-developed areas. The lower X miles of the Santa Clara River are within the Coastal Zone. A Coastal Zone Development Permit is required by any project that is a regulated land use or activity and occurs within the Coastal Zone. Many coastal cities and counties issue Coastal Zone Development Permits through their own Coastal Program (see Section B.4.10 below), but in certain coastal environments, such as lagoons, estuaries, and harbors, and public trust lands, Coastal Zone Development Permits are issued directly by the CCC (VCPD 2006). The time required to process this permit may take 6 to 8 months or longer depending on the project scope.

B.4.10 VCPD Land Use/Coastal Zone Permit

The Ventura County Planning Division (VCPD) is a division of the Ventura County Resource Management Agency. The VCPD regulates land uses ac-

cording to the county's General Plan, Coastal Plan, and Coastal and Non-coastal Zoning Ordinances. Projects located in unincorporated Ventura County that involve regulated land uses may require a VCPD Land Use Permit. This permit is triggered if a project is within a stream or wetland and is part of a broader construction project, such as a residential or commercial development. Any projects in the Coastal Zone also require VCPD Land Use Permits that simultaneously serve as Coastal Zone Development Permits (VCPD 2006). Compliance with CEQA will generally be required for a VCPD Land Use/Coastal Zone Permit, and if applicable, the VCPD will serve as the lead agency. Permit processing may take between 6 to 8 months for small projects with limited environmental effects and several years for larger developments in sensitive areas (VCPD 2006).

B.4.11 VCWPD Encroachment and Watercourse Permits

The Ventura County Watershed Protection District (VCWPD) is charged by Ventura County Ordinance FC-18 to regulate activities in red-line streams. To this end, the VCWPD issues two types of permits: an Encroachment Permit and a Watercourse Permit (VCPD 2006). The need for these permits is triggered by projects that occur in a VCWPD red-line stream and that will alter the bed, bank, or channel of the stream or is located within the floodway (VCPD 2006). Projects that are in a VCWPD right-of-way or facility require an Encroachment Permit; projects that are not require a Watercourse Permit. The permit processing takes about one month and projects must demonstrate that project activities will not negatively impact the flood conveyance capacity of the red-line stream to be issued a permit (VCPD 2006).

B.4.12 VCPD Protected Tree Permit

The Ventura County Non-coastal Zoning Ordinance (Sections 8107-25) identifies several tree species that are protected from damage or removal. Protected trees are defined as any heritage or historical tree of significant size that are usually associated with streams and wetlands. A Protected Tree Permit issued by the VCPD is required if tree damage or removal is part of a project requiring a discretionary permit. Specifically, a VCPD Protected Tree Permit is triggered when a project involves pruning, trimming, removal or disturbance either within the drip line (canopy perimeter) of protected trees or that exceeds the allowed minimums of trunk or branch circumference as well as other measures (VCPD 2006). Discretionary permits may take at least three months depending on the scope of the project and the associated effects to protected trees. A Ministerial Tree Permit may be approved by the Planning Director and issued in one day provided that all application requirements have been completed and one of several potential situations are present, including emergency actions to safeguard human safety and infrastructure. Trees protected under the Venture County Non-coastal Zoning Ordinance are listed in Table B-4.

Table B-4. Trees protected by the Ventura County Planning Division.

Tree	Species
Heritage Tree	All species
Historical Tree	Any species
Alder *(Alnus)*	All species
Ash *(Fraxinus)*	All species
Bay *(Umbellularia californica)*	This species only
Cottonwood *(Populus)*	All species
Elderberry *(Sambucus)*	All species
Big Cone Douglas Fir *(Pseudotsuga macrocarpa)*	This species only
White Fir (*Abies concolor)*	This species only
Juniper (*Juniperus californica)*	This species only
Maple (*Acer macrophyllum)*	This species only
Oak (*Quercus)*	All species
Pine *(Pinus*)	All species
Sycamore (*Platanu*s)	All species
Walnut (*Juglans)*	All species

Source: VCPD (2006)

B.4.13 VCPWA Grading Permit

The Ventura County Public Works Agency (VCPWA) oversees construction projects in the unincorporated areas of Ventura County. The VCPWA issues Grading Permits for projects involving moving earth. The permit is issued in accordance with grading regulations in the Ventura County Building Code, Section 3306. This permit may be triggered by several activities, including: 1) excavations greater than two feet in depth; 2) excavations that cut a slope greater than five feet in height and steeper than 67%; 3) fill that is greater than one foot in depth and is on slopes that exceed 20%; and 4) fill that is greater than three feet in depth and exceeds 50 cubic yards/lot. A ministerial permit may be issued for projects that do not trigger CEQA compliance. This permit type may take one month to process (VCPD 2006). Projects that are within a waterway or wetland will trigger CEQA compliance and will therefore require a discretionary permit. Discretionary permits may take 6 to 8 months to process (VCPD 2006).

B.5 Programmatic Permitting

The project permitting examples and discussions of environmental compliance requirements in the previous sections assume that permits for restoration strategies on the Santa Clara River would be done on a project-by-project basis. However, since all restoration strategies will be occurring within the Santa Clara River watershed, many strategies will have project areas greater than 10 acres, and many of the same permits will be needed for each strategy, a programmatic approach to permitting may be preferred. A programmatic approach would involve acquiring one set of permits for all restoration

strategies, or three sets of permits for each of the primary restoration strategies, throughout the watershed. Programmatic permitting is designed to address programs of two or more actions that are not necessarily joined by interrelatedness or interdependence, and so might have been permitted separately, with predictable environmental effects, and similar requirements for project approval (NMFS 2003). Programmatic permitting analyzes the combined effects of all the actions that make up a program (in this case, levee setback, floodplain re-contouring, non-native, invasive plant removal, and active revegetation), and presents that analysis and its conclusion in a single document.

This approach would require more preparation and reporting up-front, but will likely save significant effort for the duration of restoration implementation and result in more comprehensive measures to prevent or mitigate for short-term negative impacts to the environment. NMFS (2003), using the example of ESA consultation, describes the pros and cons of programmatic approaches:

> *"The primary benefits of programmatic consultation are more consistent use of conservation measures, the ability to address the effects of multiple activities at larger scales, efficient workload management, improved internal communication, better public relations, and a sharper vision of interagency consultation overall. The primary drawback of programmatic consultation concerns the availability of appropriate information for analysis and decision making. Developing adequate information to initiate formal programmatic consultation can be time consuming. However, the programmatic consultation process can account for information gaps and include processes to ensure the agencies possess adequate information to make scientifically sound and legally defensible decisions, when those decisions are made."*

Using a programmatic approach, permits would be acquired for one large-scale restoration project that includes levee-setback, floodplain re-contouring, non-native, invasive plant removal, and active revegetation components. A project of this nature would required that all the permits identified in Table B-1 be acquired, but they would only need to be acquired once. Given the large scope of work and project area, reporting requirements for each of these permits would be extensive. For example, CEQA compliance would require the preparation of an Initial Study and most likely a Mitigated Neg Dec to demonstrate how the implementation of the restoration strategies will prevent or mitigate for short-term negative impacts on the environment. The completed CEQA document, which includes a detailed project description and analysis of impacts, would assist in acquiring a Section 404 Individual Permit from USACE, 401 Certification from RWQCB, an SAA from CDFG,

and a Grading Permit from VCPWA. The Section 404 Permit and SAA would trigger programmatic consultation by USFWS, NMFS, and CDFG to evaluate potential project impacts to federally- and state-protected species. Approaches to programmatic consultation include: 1) an informal concurrence process for "not likely to adversely affect" actions that are not reasonably expected to result in the take of a protected species; 2) a "full" programmatic approach for actions that are "likely to adversely affect" protected species and which may be exempted from take without further review; and 3) a "tiered" programmatic approach for "likely to adversely affect" actions that require subsequent project-specific review before a take exemption is applied (NMFS 2003).

In addition to the greater reporting requirements, there may also be monitoring requirements, such as tracking of incidental take of protected species, associated with programmatically permitted restoration programs, since the scope of permitting extends beyond an individual project. Programmatically acquired permits are also more likely than individual permits to require re-initiation when new information becomes available, to respond to adaptive management or new policy development, or to adjust to changes in the status of listed species or designated critical habitats (NMFS 2003).

B.6 References

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APPENDIX C
Revegetation Species Requirements

Description of column entries for Table C-1: (by column number)

Growth Form: forb, graminoid, shrub, or tree growth form

Wetland Indicator Status

- OBL (Obligate Wetland). Occur almost always (estimated probability >99%) under natural conditions in wetlands.
- FACW (Facultative Wetland). Usually occur in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
- FAC (Facultative). Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
- FACU (Facultative Upland). Usually occur in non-wetlands (estimated probability 67%-99%), but occasionally found in wetlands (estimated probability 1%-33%).
- UPL (Obligate Upland). Occur in wetlands in another region, but occur almost always (estimated probability >99%) under natural conditions in non-wetlands in the region specified.
- + Indicates a frequency toward the higher end of the category (more frequently found in wetlands)

Moisture Use: Relative moisture requirement for growth (Low, Medium, High)

Minimum Root Depth (inches): Minimum depth of soil required for good growth in inches

Precipitation

- **Minimum**: Minimum precipitation required for good growth in inches.
- **Maximum**: Maximum precipitation tolerated for good growth in inches.

Minimum Temperature (°F): Minimum temperature under which the plant will survive in degrees F.

Adaptability to Soil Types: Whether the species establishes and grows in fine/medium/coarse textured soils? (yes/no)

Nitrogen Fixation: Amount of nitrogen fixed relative to other species (None, Low, Moderate, High, Unknown (blank))

Fertility Requirement: Relative fertility requirements needed for growth (Low, Medium, High)

pH

- **Minimum**: Minimum pH under which the plant can maintain good growth.
- **Maximum**: Maximum pH under which the plant can maintain good growth.

Tolerance Levels

- **Anaerobic**: Relative tolerance of anaerobic conditions of the growth medium (None, Low, Medium, High)
- **Drought**: Relative tolerance to drought conditions compared to other plants in the same region (None, Low, Medium, High)
- **Salinity**: Tolerance to saline soil conditions (None, Low, Medium, High)
- **Hedge**: Tolerance to hedging by livestock or wildlife (None, Low, Medium, High, Unknown (blank))
- **Shade**: Relative tolerance for this plant to grow in shade conditions (Intolerant, Indeterminate, Tolerant)
- **CaCO3**: Relative tolerance of calcium carbonate in the growth medium (None, Low, Medium, High, Unknown (blank))

Table C-1. Revegetation species requirements.

Species	Growth Form	Wetland Indicator Status		Moisture Use	Minimum Root Depth (inches)	Precip.		Temperature Min. (F)	Adaptability to Soil Type			Nitrogen Fixation	Fertility Requirement	pH		Tolerance Levels					
		National	California			Min	Max		Fine	Medium	Coarse			Min	Max	Anaerobic	Drought	Salinity	Hedge	Shade	CaCO3
Bigberry manzanita (*Arctostaphylos glauca*)	shrub	UPL	UPL	L	30	8		12	N	Y	Y	*None*	L	5.9	7	*None*	H	*None*	M	Intermediate	L
White alder (*Alnus rhombifolia*)	tree	FACW	FACW	H	12	50	125	-23	Y	Y	Y	L	L	6	7.5	L	*None*	*None*	M	Tolerant	*None*
Buckbrush (*Ceanothus cuneatus*)	shrub	UPL	UPL	M	20	16	36	-13	Y	Y	Y	L	L	7.1	8.5	*None*	H	M	M	Intolerant	H
Mountain mahagony (*Cercocarpus montanus*)	shrub	UPL	UPL	L	20	10	25	-38	N	Y	Y	L	L	6	8	*None*	H	*None*	M	Intermediate	H
Yerba santa[1] (*Eriodictyon crassifolium*)	shrub	UPL	UPL	L	6	9	24	-3	Y	Y	Y	*None*	L	7	8	*None*	H	*None*	H	Intolerant	L
California sycamore (*Platanus racemosa*)	tree	FACW	FACW	M	36	14	20	7	N	Y	Y	*None*	L	5.8	7.3	M	M	*None*	*None*	Intolerant	M
Balsam popular (*Populus balsamifera*)	tree	FACU FACW	FACW	H	30	20	70	-43	Y	Y	Y	*None*	M	4.5	7	M	L	*None*	*None*	Intolerant	H
Fremont cottonwood (*Populus fremontii*)	tree	FACW-, FACW	FACW	H	32	20	26	-13	Y	Y	Y	*None*	M	6	8	M	M	L	*None*	Intolerant	M
California live oak (*Quercus agrifolia*)	tree	UPL	UPL	M	36	20	60	7	N	Y	Y	*None*	L	5.5	7.5	*None*	M	L	*None*	Intolerant	L
Valley oak (*Quercus lobata*)	tree	FAC	FAC	M	42	16	40	7	N	Y	Y	*None*	M	4.5	7.5	*None*	M	*None*	*None*	Intolerant	*None*
Narrowleaf willow (*Salix exigua*)	shrub	FACW OBL	OBL	H	20	20	30	-38	N	Y	Y	*None*	L	6	8.5	H	M	L	M	Intermediate	H
Arroyo willow[2] (*Salix lasiolepis*)	tree/ shrub	FACW	FACW	H	26	35	60	7	Y	Y	Y	*None*	M	5.5	7.5	H	*None*	*None*	M	Intolerant	L
Shining willow (*Salix lucida*)	tree/ shrub	FACW	FACW	H	10	30	60	-43	Y	Y	N	--	M	5.8	7.2	M	L	*None*	L	Intermediate	M

Species	Growth Form	Wetland Indicator Status		Moisture Use	Minimum Root Depth (inches)	Precip.		Temperature Min. (F)	Adaptability to Soil Type			Nitrogen Fixation	Fertility Requirement	pH		Tolerance Levels					
		National	California			Min	Max		Fine	Medium	Coarse			Min	Max	Anaerobic	Drought	Salinity	Hedge	Shade	CaCO3
Blue elderberry[3] (*Sambucus mexicana*)	tree/ shrub	FACU FAC	FAC	L	12	10	60	-38	N	Y	Y	*None*	L	4.9	7.5	M	H	*None*	L	Intermediate	M
Chamise (*Adenostoma fasciculatum*)	shrub	UPL	UPL	M	8	6	30	32	Y	Y	Y	--	L	4	6	*None*	H	M	H	Intolerant	L
Big sagebrush (*Artemisia tridentata*)	shrub	UPL	UPL	M	20	6	16	-43	N	Y	N	--	L	6	8.2	*None*	H	L	L	Intolerant	H
Big saltbush (*Atriplex lentiformis*)	shrub	FAC FACW	FAC	L	20	4	20	7	N	Y	N	*None*	M	7	10	H	H	H	H	Intolerant	H
Coyotebrush (*Baccharis pilularis*)	shrub	UPL	UPL	L	20	12	30	22	N	Y	Y	--	L	6	8.5	*None*	H	H	H	Intolerant	H
Mule's fat[4] (*Baccharis salicifolia*)	shrub	FACW	FACW	M	12	10	18	-3	Y	Y	Y	--	L	7	8.5	L	L	H	L	Intolerant	H
California brome (*Bromus carinatus*)	graminoid	UPL	UPL	L	8	8	20	17	N	Y	Y	--	L	5.5	8	*None*	M	M	*None*	Intolerant	M
Saltgrass (*Distichlis spicata*)	graminoid	FAC+, FACW+	FACW	M	2	5	70	-35	Y	Y	N	*None*	M	6.4	10.5	H	M	H	*None*	Intolerant	H
Western rye (*Elymus glaucus*)	graminoid	FACU	FACU	L	12	16	60	-38	Y	Y	Y	--	L	5.8	8.5	H	H	M	*None*	Tolerant	H
California brittlebush[5] (*Encelia californica*)	shrub	UPL	UPL	L	12	n/a	10	27	Y	Y	Y	--	L	7	8.5	*None*	H	*None*	H	Intolerant	H
Eastern Mohave buckwheat (*Eriogonum fasciculatum*)	shrub	UPL	UPL	L	10	8	20	7	N	Y	Y	--	L	7.5	8.5	*None*	H	M	L	Intolerant	H
Western goldentop (*Euthamia occidentalis*)	forb	FACW OBL	OBL	M	10	16	32	-28	Y	Y	Y	*None*	M	4.5	7	L	M	*None*	*None*	Intolerant	M
Salt heliotrope (*Heliotropium curassavicum*)	forb	FAC OBL	OBL	M	10	10	24	-28	Y	Y	N	*None*	L	6.5	8.5	L	M	H	*None*	Intolerant	*None*

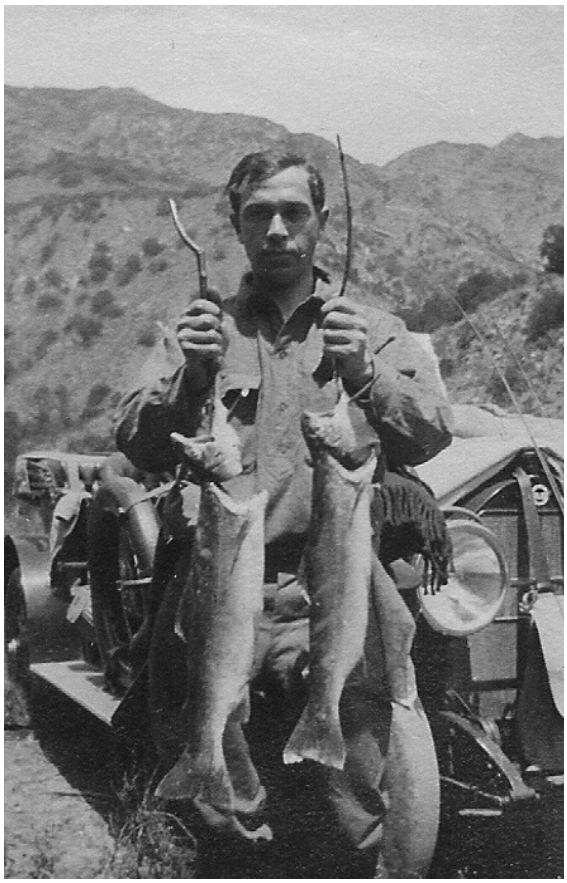
Species	Growth Form	Wetland Indicator Status		Moisture Use	Minimum Root Depth (inches)	Precip.		Temperature Min. (F)	Adaptability to Soil Type			Nitrogen Fixation	Fertility Requirement	pH		Tolerance Levels					
		National	California			Min	Max		Fine	Medium	Coarse			Min	Max	Anaerobic	Drought	Salinity	Hedge	Shade	CaCO3
Mexican rush (*Juncus mexicanus*)	grami-noid	FACW	FACW	M	8	8	20	-18	Y	Y	N	*None*	M	6.2	8.2	H	L	H	*None*	Intolerant	M
Beardless wildrye (*Leymus triticoides*)	grami-noid	FACU	FAC	H	10	7	60	-33	Y	Y	N	*None*	M	6	9	H	H	H	*None*	Intolerant	H
Hardstem bulrush[6] (*Scirpus acutus*)	grami-noid	OBL	OBL	H	14	12	60	-38	Y	Y	N	*None*	M	5.2	8.5	H	M	L	*None*	Intolerant	M
California bulrush[7] (*Scirpus californicus*)	grami-noid	OBL	OBL	H	14	40	60	17	Y	Y	N	*None*	M	4	9	H	L	L	*None*	Intolerant	M
Chapparal yucca (*Yucca whipplei*)	shrub	UPL	UPL	L	14	8	14	7	N	Y	Y	*None*	L	6.4	8.5	*None*	H	L	*None*	Intolerant	M

Source: USDA and NRCS. 2002. The PLANTS Database, Version 3.5 (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

[1] Classification information based on *Eriodictyon californicum*.
[2] Data is for the "Rogue" cultivar.
[3] Listed under *Sambucus nigra* L. ssp. *cerulea*
[4] Status taken from *Baccharis glutinosa*.
[5] Classification information based on *Encelia farinosa*.
[6] Listed as *Schoenoplectus acutus* var. *acutus*
[7] Listed as *Schoenoplectus californicus*

Key to abbreviations:
Y, N = Yes, No
H, M, L = High, Medium, Low
-- = unknown

Santa Clara River Steelhead Trout: Assessment and Recovery Opportunities



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Prepared By:

Matt Stoecker

STOECKER ECOLOGICAL™
NATURAL RESOURCE ASSESSMENT AND RESTORATION SERVICES

and

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Prepared For:
The Santa Clara River Trustee Council and The Nature Conservancy

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GIS Information:

Projection Datum: NAD 1983, UTM Zone 11N
To install project on your computer: create folder c:/SCRtrout and place all GIS project files there

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Abbreviations

ACOE	Army Corps of Engineers
Caltrans	California Department of Transportation
CDFG	California Department of Fish and Game
cfs	Cubic feet per second
ESU	Evolutionarily Significant Unit
FERC	Federal Energy Regulatory Commission
LPNF	Los Padres National Forest
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
pers. comm.	personal communication
RBT	Rainbow Trout
UCSB	University of California at Santa Barbara
USDA	United States Department of Agriculture
UWCD	United Water Conservation District
VFD	Vern Freeman Diversion

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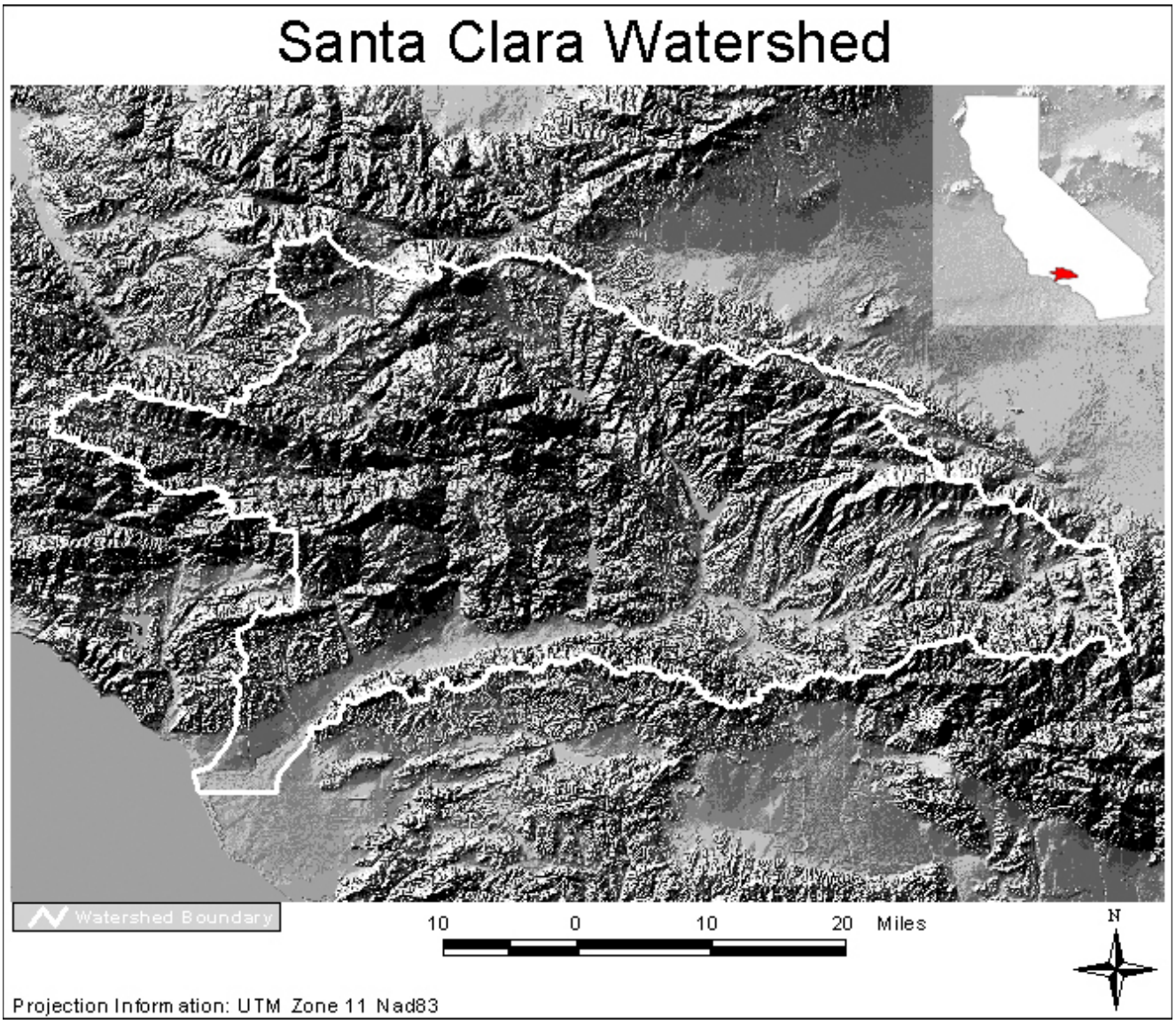
Executive Summary

The Santa Clara River watershed is located primarily in Los Angeles and Ventura Counties in California (Map 1). The watershed is large for southern California, at 1600 square miles. The purpose of this project was to analyze the habitat conditions, population status and barriers to migration for *Oncorhynchus mykiss* (steelhead trout) in the lower Santa Clara River watershed from the Piru Creek tributary downstream including significant drainages.



Map 1. The Santa Clara River watershed with topography.

Historic documentation of an important recreational steelhead fishery occurs for the Santa Clara River into the mid 1900's. Construction of dams and other migration barriers on the mainstem, Santa Paula Creek, Sespe Creek, Piru Creek, and other tributaries during the mid 1900's appear to be correlated with the demise of the steelhead run as habitat availability decreased and surface flows became highly manipulated (Capelli 1983, Moore 1980a, Outland 1971). Adult steelhead have continued to attempt to migrate up the Santa Clara River into recent times with an adult trapped at the Vern Freeman Dam in 2001. A wild, self-sustainable rainbow

trout population still exists in the headwaters of the Santa Paula, Sespe, Hopper, and Piru Creek tributaries and is producing out-migrating steelhead smolts bound for the Pacific.

Surface water diversions and groundwater pumping on the Santa Clara River reduce the river's flows, and cause barriers to migration in the forms of diversion dams, grade control structures, road crossings, and channelization projects impacting access to the river's critical spawning and rearing habitat in the tributaries. Exotic predator fish such as green sunfish and bullhead catfish observed in Sespe Creek, and other exotic gamefish in Piru Creek and other watershed reservoirs, compete with and prey upon the native steelhead and rainbow trout population.

This study commenced with a compilation and synthesis of all prior surveys for steelhead that were conducted on the Santa Clara River, and were available in either the Mark H. Capelli Southern California Steelhead Watershed Archive at the University of California, Santa Barbara (UCSB), or the U. S. Forest Service office in Santa Maria. The findings from this synthesis are located in Table C.

The tributaries that occur within the geographic boundaries of this study include: Santa Paula Creek, Sespe Creek, Pole Creek, Hopper Creek, and Piru Creek. The largest of these tributaries are Sespe and Piru Creeks. There were 702 habitat units surveyed in the Santa Clara River watershed for this study, and 129 natural and anthropogenic fish migration barriers identified. Some of the projects key findings were:

1. **Santa Paula Creek**
   a. Santa Paula Creek contained the most productive habitat in the study area for salmonids. However, the quantity of habitat is limited when compared to the amount of habitat in the Sespe Creek drainage.
   b. Santa Paula Creek appears to have greater potential to contribute to the recovery of the Southern California ESU (Evolutionarily Significant Unit) than the Hopper Creek and lesser Pole Creek tributaries.
   c. Sisar Creek accounts for 84% of the trout observed in the Santa Paula Creek drainage.
   d. Severe barriers to steelhead passage are located on Santa Paula and Sisar Creeks.
2. **Sespe Creek**
   a. Sespe Creek supports a much higher abundance of trout than Santa Paula Creek, despite the occurrence of an exotic predatory fish population. Sespe Creek also had higher numbers of larger fish than Santa Paula Creek.
   b. No individual reaches in Sespe Creek tributaries that had habitat quality scores below 5.5 had trout observed in them, and trout did not start occurring in larger numbers and with regularity until scores reached 7.0.
   c. Severe barriers to steelhead passage exist on tributaries to Sespe Creek.
3. **Pole Creek**
   a. Pole Creek had both the lowest quality estimated habitat scores and the least habitat available of all Santa Clara River mainstem tributaries measured, but could likely support a small population of *O. mykiss* with adequate fish passage in the lower reaches.
4. **Hopper Creek**
   a. Hopper Creek contains a limited amount of high quality salmonid habitat and an existing *O. mykiss* population that may contribute to the anadromous steelhead population.
   b. Severe barriers to steelhead passage occur on Hopper Creek.
5. **Piru Creek**
   a. Barriers on Piru Creek rated very highly but access would need to be developed around Santa Felicia Dam for the barriers on Piru's mainstem upstream of Santa Felicia Dam to warrant fish passage improvements.

6. **Mainstem Santa Clara**
   a. The most significant barrier to steelhead passage within the lower watershed is the Vern Freeman Diversion Dam on the mainstem of the Santa Clara River.
7. No tributaries rated low in habitat quality and high in trout abundance.
8. The average habitat quality scores and rankings for each major tributary are in Table A1. The total amount of habitat by tributary and habitat type is in Table A2.

Table A1. Average Habitat Quality Scores, in order of highest to lowest

	Habitat Quality
Santa Paula	6.45
Sespe	5.59
Piru	5.47
Hopper	5.21
Santa Clara Mainstem	4.75
Pole	3.75

The higher overall habitat quality on Santa Paula Creek may be due to almost all of the available habitat observed in the Santa Paula Creek drainage being of relatively high quality compared to Sespe Creek which contained a high amount of high quality habitat in its tributaries and portions of its mainstem, but also many dry tributaries and dry reaches in the middle and upper mainstem that reduced the overall habitat score for the drainage.

The overall high trout productivity of Sespe Creek can be accounted for by the high productivity of its tributaries, which accounted for 98% of the observed trout occurrence in the Sespe Creek drainage. Piedras Blancas Creek was observed to be the most productive followed by Howard/Rose Valley, Bear, Trout, and West Fork Sespe Creeks.

It should be noted that this study was conducted after several recent fires in the Sespe watershed, and following a five year below average rainfall period that could have differentially affected observations within watershed tributaries (e.g., the prolonged low flows in Sespe Creek created conditions favorable to the proliferation of exotic species such as bullheads which prey upon juvenile trout, a species not found in Santa Paula Creek.). There can be considerable inter-annual, decadal variability between reaches within the watershed.

Based on the findings of this study we recommend the following be priorities for revitalization of the steelhead run on the Santa Clara River.

Habitat and Population Priorities

1. Due to *O. mykiss* occurrence, abundance and habitat quality the following tributaries should receive the highest level of protection and where necessary rehabilitation:
   a. In the Sespe Creek Drainage: Piedras Blancas Creek, Howard Creek/RoseValley, W.F. Sespe Creek, Bear Creek, Lion Creek, Timber Creek.
   b. In the Santa Paula Creek drainage: Sisar Creek, and upper Santa Paula Creek.
   c. Upper Hopper Creek.
2. Protection of the highly productive mainstem reaches on Santa Paula and Sespe Creeks .

Fish Passage Priorities

1. Improved fish passage at the Vern Freeman Diversion Dam that is effective over a wider range of flows and utilizes by-pass flows more effectively to allow unimpeded upstream and downstream migration independent of water diversion operations, maintenance, debris blockage, or fish ladder damage. This dam is the most significant steelhead migration barrier within the lower Santa Clara River watershed.

2. Removal or modification of gray and red barriers in the Santa Paula, Sespe, and Hopper Creek drainages.
3. Identification and implementation of dedicated fish passage flows for the mainstem of the Santa Clara River and those reaches on Santa Paula Creek, Sespe Creek, and Piru Creek downstream of Harvey Diversion Dam, Fillmore Irrigation Diversion, and Santa Felicia Dam respectively.
4. Other high priorities are associated with many of the complex, instream migration barriers described and include; stream channel restoration, riparian restoration, removal of reservoirs harboring exotic and hatchery fish species, and elimination or reduction of erosion, pollution, and hazardous features.

Providing improved fish passage within the main tributaries of the lower Santa Clara River is a high priority to ensure that steelhead have adequate access between the critical headwater habitats and the ocean. This report outlines the specific, prioritized barriers in detail within the priority tributaries and habitat areas.

Table A2. Miles of habitat by tributary and habitat type. Approximately 17 miles of habitat were not assigned a habitat type.

	SC Mainstem	Santa Paula	Sespe	Pole	Hopper	Piru	Total
Bedrock Sheet		0.01	0.15				0.17
Cascade		0.05	0.13				0.18
Channel Confluence Pool			0.33				0.33
Corner Pool		0.02					0.02
Culvert		0.09		1.23		0.21	1.52
Dammed Pool	0.67		0.03			4.56	5.25
Dry		0.19	50.86		1.16	4.17	56.39
Glide	31.74	0.02	0.82		4.35	38.52	75.44
High Gradient Riffle			0.14				0.14
Low Gradient Riffle	0.04	0.02	0.32			0.66	1.04
Lateral Scour Pool - Bedrock Form		0.11	3.43			0.06	3.59
Lateral Scour Pool - Boulder Form		0.02	0.50				0.52
Mid Channel Pool		0.03	2.18				2.21
Plunge Pool		0.02	0.06		0.02	0.71	0.82
Pocket Water		1.24	2.88			11.66	15.77
Step Run	0.17	2.66	10.11			0.05	12.99
Step Pool		4.83	42.72	3.45	4.77	67.28	123.05
Trench Pool			0.55			0.15	0.70
Total	32.62	9.30	115.22	4.68	10.30	128.02	300.15

GROUNDWATER AND SURFACE WATER CONDITIONS REPORT - 2011

United Water Conservation District
Open-File Report 2012-02

PREPARED BY

GROUNDWATER RESOURCES DEPARTMENT
MAY 2012

UWCD OFR 2012-02

GROUNDWATER AND SURFACE WATER CONDITIONS REPORT - 2011

United Water Conservation District
Open-File Report 2012-02

Groundwater Resources Department
May 2012

THIS REPORT IS PRELIMINARY AND IS SUBJECT TO MODIFICATION

BASED UPON FUTURE ANALYSIS AND EVALUATION

Cover Photo: Recharge basin at El Rio Spreading Grounds, February 2011. By John Carman

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GROUNDWATER AND SURFACE WATER CONDITIONS REPORT - 2011

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EXECUTIVE SUMMARY / ABSTRACT

United Water Conservation District is a public agency that encompasses nearly 213,000 acres of central and southern Ventura County. The District covers the downstream (Ventura County) portion of the valley of the Santa Clara River, as well as the Oxnard Plain. The District serves as the steward for managing the surface water and groundwater resources within all or portions of eight groundwater basins. This report includes data and records from the 2011 calendar year, including basic information and discussion on the operation of the District's facilities, weather and hydrologic information, groundwater levels and available storage within the basins, and the quality of surface water and groundwater.

Major water resource issues and concerns are the driving impetus for the District's projects and programs. Projects and programs are implemented to manage, mitigate, or eliminate those issues or concerns that threaten the water resources. Those issues and concerns include, but are certainly not limited to, groundwater overdraft and the intrusion of saline water in the Oxnard Plain and Pleasant Valley basins, the gradual, long-term declining water levels in the Santa Paula Basin, water quality of the Oxnard Forebay basin and the Piru basin, and concerns related to the management of the Piru and Fillmore basin water resources.

To address those issues and concerns, United implements a wide variety of activities. Some of the activities are District-wide, for example: water levels are monitored in an extensive network of water wells thorough the District and a significant number of these wells are sampled as a part of a water quality monitoring program. In addition, stream gauging is performed periodically to quantify surface water volumes and flow rates under various hydrologic conditions. These data are important to United's habitat conservation efforts and the facilitation of fish passage at the Vern Freeman Diversion, as well as optimizing various District operations (e.g., annual conservation release, diversion of water to recharge basins or for use in-lieu of groundwater pumping by agricultural operations on the Oxnard Plain and in Pleasant Valley basin). Currently, the largest District-wide project underway by the groundwater department is the update of the Ventura County Regional Groundwater Flow Model. This is a multi-year, multi-faceted project that requires the expertise of several groundwater science specialties and relies on the District's long record of water-level, water quality, and stream gauging data. When completed, the groundwater flow model will be a primary evaluative tool for various proposed water management scenarios and will assist stakeholders with enhancing the sustainability and reliability of local water resources.

Issue-specific projects are also implemented by United to assist local stakeholders in the management of local water resources (e.g., AB3030 Piru/Fillmore Groundwater Management Plan, analyses of groundwater conditions in the Santa Paula basin as a part of the Technical Advisory Committee) or the pursuit of grant funds (e.g., Local Groundwater Assistance Program grants from CA Department of Water Resources, Fox Canyon Groundwater Management Agency Groundwater

Supply Enhancement Assistance Program) to help defray the costs of some of the groundwater projects.

The benefits of the surface water and groundwater projects and programs operated by United are shared by the many groundwater pumping entities in the District and those who receive those waters. Many of the benefits are in the background and not readily recognized or apparent to individual water users, however, the positive impacts of the District's activities are significant to the agricultural, municipal, and industrial economies of Ventura County.

1 INTRODUCTION AND BACKGROUND

United Water Conservation District (also "United" or "District") is a public agency that encompasses nearly 213,000 acres of central and southern Ventura County. The District covers the downstream (Ventura County) portion of the valley of the Santa Clara River, as well as the Oxnard Plain. The District serves as a steward for managing the surface water and groundwater resources for all or portions of eight groundwater basins (Figure 1-1). It is governed by a seven-person board of directors elected by division, and receives revenue from property taxes, groundwater extraction (pump) charges, recreation fees, and water delivery charges. The developed areas of the District are a mix of agriculture and urban areas, with prime agricultural land supporting high-dollar crops such as avocados, berries, row crops, tomatoes, lemons, oranges, flowers and ornamental nursery stock. Approximately 370,000 people live within the District boundaries, including those living in the cities of Oxnard, Port Hueneme, Santa Paula, Fillmore and eastern Ventura.

The District is authorized under its principal act (California Water Code Section 74000 et seq) to exercise multiple powers. These powers include the authority to conduct water resource investigations, acquire water rights, build facilities to store and recharge water, construct wells and pipelines for water deliveries, commence actions involving water rights and water use, prevent interference with or diminution of stream/river flows and their associated natural subterranean supply of water, and to acquire and operate recreational facilities in connection with dams, reservoirs or other District works.

This report includes general information about the District's mission and detailed data on the operation of the District's facilities, weather and hydrologic information for the past year, groundwater levels and storage within the basins, and the quality of the surface water and groundwater. Recent and current studies and investigations conducted by the District's Groundwater Department are also detailed.

1.1 UWCD MISSION STATEMENT AND GOALS

The District's mission statement is:

United Water Conservation District shall manage, protect, conserve, and enhance the water resources of the Santa Clara River, its tributaries and associated aquifers, in the most cost-effective and environmentally balanced manner.

In order to accomplish this mission, United Water Conservation District follows these guiding principles:

- Construct, operate, and maintain facilities needed now and in the future to put local and imported water resources to optimum beneficial use;

- Deliver safe and reliable drinking water that meets current and future health standards to cities and urban areas;
- Provide an adequate and economical water supply to support a viable and productive agricultural sector;
- Fight overdraft and seawater intrusion and enhance the water quality of the aquifers through the use of District programs;
- Monitor water conditions to detect and guard against problems and to report those conditions to the public;
- Seek opportunities to develop cooperative programs with other agencies in order to maximize use of District resources and promote mutually beneficial projects;
- Acquire and operate high-quality public recreational facilities that are financially self-supporting;
- Balance District operations with environmental needs to maximize use of the region's water resources; and
- Conduct District affairs in a business-like manner that promotes safe investment policy, sound financial audits and the utmost in professional and financial integrity.

The District recognizes that many of the projects and activities required to implement these guiding principles have long timelines for development and initiation, and the positive impacts of these projects and activities may be realized over many years. This is consistent with the District's mission to provide for the long-term health of the water resources within the District. To fulfill its mission, the District retains technical experts in the fields of engineering, hydrogeology, surface water hydrology, environmental science, biology, and regulatory compliance, as well as administrative personnel with specialties in accounting and finance.

1.2 UWCD HISTORY

The original founding organization for United Water Conservation District was called the Santa Clara River Protective Association. It was formed in 1925 to protect the runoff of the Santa Clara River from being appropriated and exported outside the watershed. The Santa Clara Water Conservation District was formed in 1927 to further the goals of the Association by protecting water rights and conserving the waters of the Santa Clara River and its tributaries. The District began a systematic program of groundwater recharge in 1928, primarily through constructing spreading grounds along the Santa Clara River. Sand dikes were constructed on the Santa Clara River near Saticoy to divert river water into spreading grounds in nearby upland areas.

As seawater intrusion on the Oxnard Plain was recognized in the 1940s, it was clear that the District did not have the financial ability to raise money to construct the facilities necessary to combat the problem. With the help of the City of Oxnard, a new district was organized in 1950 under the Water

Conservation District Law of 1931. The new district was called United Water Conservation District for its unification of urban and agricultural concerns. United Water then constructed a number of water conservation projects, including:

- Santa Felicia Dam (1955) to capture and store winter runoff on Piru Creek to release in controlled amounts during the dry season. The 200-foot high dam can currently store about 82,300 acre-feet (AF) in Lake Piru. The reservoir is located downstream of a State Water Project reservoir, enabling the District to receive Northern California water via flows down middle Piru Creek without the construction of expensive delivery pipelines;
- A pipeline to new spreading grounds at El Rio; and
- Wells at the El Rio spreading grounds to produce water for the Oxnard-Hueneme (O-H) pipeline (1954) that supplies drinking water to the cities of Oxnard and Port Hueneme, a number of mutual water companies, and the two Navy bases at the coast. The O-H system supplies water from the Oxnard Forebay basin (the recharge area for the Oxnard Plain basin), rather than pumping individual wells in coastal areas of the Oxnard Plain that could accelerate seawater intrusion.

Following increasing intrusion of seawater from the 1950s to the 1980s, United Water built several new facilities to increase recharge to the aquifers and to decrease groundwater pumping in areas affected by the intrusion. These facilities provide both direct present benefit, and long-term benefits, to the groundwater aquifers and to the groundwater extractors in the District. In 1958 a pipeline was completed to deliver diverted surface water to Pleasant Valley County Water District, which serves agricultural water to the Pleasant Valley basin. The Pumping Trough Pipeline (PTP) was constructed in 1986 to convey diverted river water to agricultural pumpers on the Oxnard Plain, thus reducing the amount of groundwater pumping in critical areas. The Freeman Diversion (1991) replaced the temporary diversion dikes in the Santa Clara River with a permanent concrete structure, allowing diversion of storm flows throughout the winter. A major additional benefit of the Freeman Diversion was the stabilization of riverbed elevations upstream of the facility, correcting the long-term incision of the river related to decades of in-channel gravel mining in the Saticoy vicinity.

Following the construction of the Freeman Diversion, the Noble spreading basins (1995) were constructed to store and recharge additional river water, particularly during wet periods. The Saticoy well field was constructed in 2003 to pump down the groundwater mound that develops beneath the Saticoy spreading grounds during periods of heavy spreading. In late 2009 United acquired the Ferro and Rose basins, former mining pits located in the Oxnard Forebay that will be used for future groundwater recharge activities. United intends to construct facilities to convey Santa Clara River water diverted at the Freeman Diversion to these basins. An additional use for the Ferro basin under consideration is the recharge of recycled water sourcing from the City of Ventura (Carollo Engineers, 2010) or the City of Oxnard. United anticipated that the City of Ventura might desire to move recycled water to the District's recharge basins (or alternatively, potable water

from the Forebay to east Ventura) in the future and arranged for “pipe hangers” to be added to the Highway 118 bridge over the Santa Clara River during its reconstruction in 1993.

1.3 UWCD ORGANIZATION

The District is governed by a seven-person board of directors elected by division, and receives revenue from property taxes, groundwater extraction (pump) charges, recreation fees, and water delivery charges.

1.4 UWCD OPERATIONS AND FACILITIES

United Water Conservation District operates a series of water conservation facilities from the tributaries of the Santa Clara River to the Oxnard Plain and Pleasant Valley (Figure 1-1). These facilities store winter runoff for later release during the dry season, divert water from the Santa Clara River, recharge the aquifers through spreading basins, and deliver surface water and groundwater to cities and growers so that groundwater pumping is reduced in critically overdrafted areas.

1.4.1 SANTA FELICIA DAM AND LAKE PIRU

Santa Felicia Dam was constructed in 1955 for the conservation of runoff on Piru Creek. The main function of the dam is to retain the high flows in Piru Creek during the winter and spring months, and release the stored water in the fall when the downstream basins and the facilities at the Freeman Diversion have the capability to receive the most benefit from the release. The current capacity of the dam is 82,300 AF (See Figure 1.4-1 for storage history). The operational minimum pool is set at 20,000 AF of storage.

The 2010 conservation release reduced the storage volume down to the minimum pool of 20,000 AF. An early rain in December 2010 brought the lake up to 31,000 AF of storage by January 1, 2011. Due to the above normal rainfall in 2011, the Piru watershed produced inflows totaling 61,800 AF, approximately double the historical average. The Santa Felicia Dam is fitted with a hydro electric plant that is currently not operable although a Federal Energy Regulatory Commission (FERC) License is still required. Efforts to re-license this facility are currently underway and as part of this new license, release requirements for Santa Felicia Dam were implemented this year and are discussed in more detail in section 1.6.3.

Summary of surface water hydrology at Lake Piru:

	Calendar year 2011
Minimum Storage	31,000 AF
Maximum Storage	76,400 AF
Inflow at USGS Sta. 11109600	61,800 AF
FERC License minimum releases	4,400 AF
Conservation Release	31,700 AF
State Water (Not released)	2,520 AF

1.4.2 PIRU DIVERSION AND SPREADING GROUNDS

The Piru Diversion is operated to divert surface water into the Piru Spreading Grounds for groundwater recharge. The diversion is located on the western bank of lower Piru Creek just south of the old Center Street Bridge in the town of Piru. Part of the diversion dam is built under the two roadway bridges crossing lower Piru Creek at Center Street.

The existing diversion consists of an earthen berm that extends out across the river channel, a sluice channel that can accommodate approximately 200 cfs, and a diversion structure with a trash rack and four 24-inch inlets leading to a 48-inch diversion pipe that conveys diverted water to the spreading grounds. The structure is not in compliance with National Marine Fisheries (NMFS) standards for diverting water in a stream that may possibly contain endangered southern California steelhead. Therefore the facilities have been included as part of the Habitat Conservation Plan (HCP) so that the facility will be covered for incidental take. The diversion will not be put back into operation until a take permit has been issued.

1.4.3 FREEMAN DIVERSION AND SATICOY SPREADING GROUNDS

The Freeman Diversion is located on the Santa Clara River about 10 miles upstream from its mouth at the Pacific Ocean. The concrete diversion structure was completed in 1991 and replaced the previous diversion method of building temporary sand and gravel diversion dikes, levees, and canals. The prior method of diverting water from the Santa Clara River near Saticoy had been in practice since the 1920s. The Freeman Diversion facility replaced the former method of building temporary sand and gravel diversion dikes, levees, and canals along the Santa Clara River near Saticoy. With each high flow in the river the dikes were washed out, eliminating the ability to divert water until construction crews were able to work in the riverbed. Construction of the Freeman Diversion has increased the conservation of flood flows by extending the time each year when flows can be diverted and not discharged to the ocean. The current facility consists of the following structures: diversion structure, fish passage facilities, canal, headworks, flocculation building, and

desilting basin. A total of 92,600 acre-feet of surface water was diverted from the Santa Clara River at the Freeman Diversion in calendar year 2011.

The diversion is operated to redirect surface water from the Santa Clara River to United's recharge basins located in Saticoy, El Rio and the Noble Basins for the purpose of recharge the aquifers underlying the Oxnard Forebay and Oxnard Plain. In 2011 a total of 71,960 AF was recharged to these basins. The remainder of the diverted water was delivered directly to agricultural users for irrigation purposes. These deliveries are designed to reduce groundwater pumping in areas where overdraft conditions and related water quality issues exist, such as where aquifers are most susceptible to saline water intrusion and the upwelling of saline waters. Water releases from Lake Piru and a portion of the natural runoff from the Santa Clara River are diverted by the Freeman Diversion.

1.4.4 EL RIO FACILITY AND SPREADING GROUNDS

The El Rio Spreading Grounds are located at the terminus of the El Rio branch of the main supply line, approximately two miles southwest of the Saticoy spreading grounds. Surface water diverted from the Santa Clara River is distributed to a series of ponds totaling approximately 80 acres for the purpose of groundwater recharge. During the 2011 water year approximately 37,850 acre-feet of surface water was routed to the El Rio Spreading Grounds and recharged to the Oxnard Forebay groundwater basin.

1.4.5 MUNICIPAL WATER DELIVERIES

United built the Oxnard-Hueneme (O-H) system in 1954 to move municipal groundwater extraction on the Oxnard Plain away from coastal areas subject to seawater intrusion. The well field for the O-H system surrounds the El Rio recharge basins, and water produced by the well field is a blend of recharge water that has filtered down through the aquifer, and water drawn laterally from surrounding areas. The El Rio well field includes both upper and lower aquifer wells, allowing a blending of sources for water quality purposes. In practice, the Lower Aquifer System (LAS) wells are rarely used. Water deliveries on the Oxnard-Hueneme Pipeline totaled 10,750 acre-feet for the 2011 calendar year, some 27,100 AF less than the volume of water that was spread in the nearby El Rio recharge basins over the same time frame.

The California Department of Health Services requires the publication of an annual water quality summary of water delivered by the O-H system. The 2011 Consumer Confidence Report for the O-H water delivery system is included in Appendix A. The O-H delivery system is operated as an enterprise fund, with water rates supporting operation and improvements to the system. Major customers include the City of Oxnard, the Port Hueneme Water Agency, and a number of mutual water companies in the Oxnard Forebay and the northern Oxnard Plain.

1.4.6 AGRICULTURAL WATER DELIVERIES

Water deliveries for agricultural purposes are achieved through two systems, the Pumping Trough Pipeline (PTP) System and the Pleasant Valley Delivery System. These systems are discussed separately in the following two subsections. See Figure 1-1 for locations.

1.4.6.1 PTP DELIVERY SYSTEM

The Pumping Trough Pipeline (PTP) delivery system was designed to serve surface water from the Santa Clara River to a portion of the Oxnard Plain where the Upper Aquifer System was determined to be in severe overdraft. Five Lower Aquifer System wells were constructed along the pipeline to provide additional water to the system when surface water supplies are incapable of meeting demand. During the 2011 calendar year a large conservation release from Lake Piru and greater-than-average flow in the Santa Clara River allowed 90 percent of the demand on the PTP to be met with surface water supplies (Table 1.4-2). Surface water deliveries to this system totaled 7,629 AF in the 2011 calendar year. The four UAS wells of the Saticoy well field, completed in 2004, can also provide groundwater to the agricultural pipelines when groundwater elevations are high near the Saticoy Spreading Grounds. The Saticoy well field pumped a total of 737 AF in calendar year 2011, and 261 AF this water was distributed to the PTP delivery system.

1.4.6.2 PLEASANT VALLEY DELIVERY SYSTEM

Water diverted from the Santa Clara River is delivered to the Pleasant Valley County Water District (PVCWD) via the Pleasant Valley Pipeline. The pipeline terminates at the Pleasant Valley Reservoir, located east of the Camarillo Airport near the City of Camarillo. PVCWD operates the reservoir and eleven LAS wells in the western Pleasant Valley basin, supplying water to agricultural customers via a delivery system linking the wells and the reservoir. The delivery of diverted river water to PVCWD offsets pumping of irrigation wells in the area. Surface water deliveries to PVCWD totaled 12,189 AF in the 2011 calendar year, and an additional 476 AF of water was supplied by the Saticoy well field. Deliveries in 2011 were about 1,300 AF greater than the average annual (water year) delivery since the completion of the Freeman Diversion in 1991. Since 2002 PVCWD has also received surface water from the Conejo Creek Diversion, operated by Camrosa Water District. In 2011 PVCWD received 6,657 AF of surface water from that source. Water year 2011 deliveries to the Pumping Trough and Pleasant Valley pipelines are shown in Figure 1.4-2.

1.5 GROUNDWATER ISSUES AND CONCERNS

United's core mission is to manage, conserve and protect the water resources that exist within the District boundaries. United operates Santa Felicia Dam and maintains contractual arrangements with a number of upstream agencies to store or convey surface runoff to the lower portions of the Santa Clara River watershed. United does not regulate the use of groundwater within the District, but operates a number of facilities intended to maximize the conjunctive use of surface water and

groundwater resources. Aside from United's annual State Water imports of up to 3,150 acre-feet, the lower valley of the Santa Clara River is wholly dependent on local water resources for irrigation and potable supply, an uncommon arrangement in southern California.

Despite long-term efforts to import more water to the District and optimize the use of local resources, water deficits exist in a number of areas throughout the District. In some places the depletion of groundwater reserves has simply resulted in lowered water tables. In other places significant water quality problems developed in response to conditions of overdraft. In some areas water quality problems are related to land use practices, or exist naturally.

Listed below are summaries of several of the water supply and water quality issues that exist within United's district boundaries. In some cases United's involvement includes groundwater recharge or water delivery to actively address issues related to overdraft. In other cases United has conducted or sponsored research in order to better define existing problems and help identify potential physical projects or management strategies to mitigate the problem. United management and staff are knowledgeable concerning groundwater management practices and have expertise in conducting monitoring programs and with applying various methods for evaluating basin conditions (e.g., Bachman et al, 2005).

1.5.1 OVERDRAFT CONDITIONS

Although high chloride levels in groundwater was first documented near Port Hueneme in the 1930s (California Department of Water Resources [DWR], 1954), the conditions for widespread seawater intrusion in the Upper Aquifer System (UAS) on the Oxnard Plain were initiated as early as the 1940s, when groundwater levels beneath the southern portion of the Oxnard Plain basin dropped below sea level (FCGMA, 2007). Within 5 to 10 years, chloride concentrations in wells in the Port Hueneme area started to increase rapidly. At that time, seawater had only affected a few wells in the Port Hueneme area, encompassing an area less than one square mile. Overdraft conditions were recognized in the Lower Aquifer System (LAS) in the late 1980s after the impairment of water quality in the Upper Aquifer System led to the implementation of a Fox Canyon Groundwater Management Agency (FCGMA) strategy to require new or replacement wells to be drilled into the LAS to lessen pumping on the UAS. The overdraft conditions eventually expanded into the adjacent Pleasant Valley groundwater basin and resulted in up to 2.6 feet of permanent land subsidence (Hanson et al, 2003).

Overdraft conditions in the Oxnard Plain and Forebay groundwater basins continue today with the annual overdraft amount estimated to be about 20,000 to 25,000 ac-ft/yr (UWCD, 2012)

1.5.2 SALINE WATER INTRUSION

High chloride levels were first detected on the Oxnard Plain in the vicinity of the Hueneme and Mugu submarine canyons in the early 1930s (CA DWR, 1971) and became a serious concern in the

1950s. Early monitoring programs used only existing production wells and abandoned wells as monitoring points; sampling of these wells indicated that there was a widespread area of elevated chloride concentrations in the Hueneme to Mugu areas. In 1989, the U.S. Geological Survey initiated their Regional Aquifer-System Analysis (RASA) study and cooperative studies with United Water Conservation District on the Santa Clara-Calleguas groundwater basin. As part of those studies, a series of 14 nested well sites, with three or more wells installed at each site, were drilled and completed at specific depths in the Oxnard Plain basin (Densmore, 1996).

Figure 1.5-1 shows the locations of the RASA well sites on the Oxnard Plain. Prior to the RASA study, it was believed that an area of the UAS extending from approximately Channel Islands Blvd. (2 miles north of Port Hueneme) and across to the area near Hwy 1 and Nauman Road, then south to include the area underlying Point Mugu Navy base was intruded by seawater. The installation of a dedicated monitoring network and detailed chemical analysis of water samples from the new wells and other wells yielded new interpretations on the extent of seawater intrusion on the Oxnard Plain. It is now known that some areas of the southern Oxnard Plain are not intruded by seawater, and that high chloride readings from older production wells were the result of perched water leaking down failed well casings and contaminating the aquifer (Izbicki, 1992; Stamos and others, 1992; Izbicki and others, 1995; U.S. Geological Survey, 1996). Maps presented in this report delineate the approximate extent of high-chloride water at various depths on the Oxnard Plain (Section 4.3.6).

In addition to drilling the monitoring wells, the USGS conducted geophysical surveys to determine the general extent of the high-saline areas (Stamos and others, 1992; Zohdy and others, 1993). This work indicated that the high-saline areas consisted of two distinct lobes, with relatively fresh water separating the lobes (U.S. Geological Survey, 1996). These areas were resurveyed in 2010 by United (UWCD, 2012a). The lobes originally identified by the USGS form the basis of the areas of high chloride concentration shown on the maps in this report. Additional down-hole conductivity surveys by the USGS (also resurveyed recently by United) indicate that the edges of the lobes are relatively distinct, with the first saline intrusion occurring in thin individual beds of permeable sand and gravel. As intrusion continues, more individual beds are impacted, resulting in increasing chloride levels. Thus, the interpretation of high-chloride areas shown on Figure 1.5-1 and other enclosed maps combine measured concentrations from the monitoring wells, geophysical measurements, and study results about the nature of the intrusion front.

In addition, isotope studies of samples from the nested wells indicate that the cause of the elevated chloride levels varies on the Oxnard Plain (Izbicki, 1991; Izbicki, 1992; Izbicki et al, 2005a). Four major types of chloride degradation have been documented:

Lateral Seawater Intrusion - the inland movement of seawater adjacent to the Hueneme and Mugu submarine canyons;

Cross Contamination - the introduction of poor-quality water into the fresh water supply via existing wellbores that were improperly constructed, improperly destroyed, or have been corroded by poor-quality water in the Semi-Perched zone;

Salt-Laden Marine Clays - the dewatering of marine clays, interbedded within the sand and gravel-rich aquifers, yields high concentrations of chloride-enriched water. This dewatering is the result of decreased pressure in the aquifers, caused by regional pumping stresses (also see Section 1.5.4); and

Lateral Movement of Brines from Tertiary formations - the lateral movement of saline water from older geologic formations that have been uplifted by faulting. The lateral movement occurs across a buried fault face near Pt. Mugu where Tertiary rocks are in contact with the younger aquifers (also see Section 1.5.4).

Chloride degradation from each of the processes identified above is directly related to water levels in the basin. The water balance of the Oxnard Plain and the offshore component of the aquifer units is a dynamic relationship between groundwater recharge, groundwater extraction and change in aquifer storage. The primary source of groundwater recharge for the Oxnard Plain groundwater basin is the unconfined northeastern portion of this basin, known as the Oxnard Forebay (and formerly the Montalvo Basin). High water levels in the Forebay exert a positive pressure on the confined aquifers of the Oxnard Plain, and water flows from the recharge areas toward the coast (Figure 4.3-22). While the pressure exerted by high water levels in the Forebay propagates rapidly through the aquifers, the actual movement of water is very slow, approximately 3 feet per day or less in the Forebay (Izbicki et al, 1992). The pressure (piezometric) surface of the confined aquifer are diminished by the extraction of water from the system. If pressure heads at the coast fall below sea level, the lateral intrusion of seawater will occur, resulting in aquifers being recharged with seawater due to landward pressure gradients. The dewatering of marine clays will occur if heads in the surrounding sediments remain below their historic levels for prolonged periods, allowing formerly immobile salts to enter surrounding aquifer material. The slow compaction of these clays also contributes to land subsidence.

1.5.3 DECLINING WATER LEVELS

In addition to the overdraft conditions in the coastal basins discussed in previous sections, long-term declining water levels have been observed in the Santa Paula Basin. Groundwater elevations in many of the wells (43 of 57 wells) in both the eastern and western portions of the Santa Paula basin failed to fully recover to 1998 levels after near-record precipitation in 2005. This observation is consistent with an observed long-term, gradual decline in basin groundwater elevations (Santa Paula Basin Technical Advisory Committee, 2011).

An evaluation of the spatial and temporal distribution of groundwater pumping in the basin (UWCD, 2011) concluded that no significant changes in pumping locations occurred over a 30-year study period (1980 to 2009) and that water level fluctuations observed from 1980 to 2009 in the Santa Paula Basin cannot be attributed solely to spatial or temporal variations in pumping. The Santa Paula Basin Technical Advisory Committee has initiated several specialty studies (Section 2.1.3) to provide additional data on the possible hydrologic cause(s) of the observed decline in groundwater elevations.

In 2003, a basin study titled "Investigation of Santa Paula Basin Yield" by experts from the City of Ventura, Santa Paula Basin Pumpers Association and United Water Conservation District suggested that the yield of the basin is probably near the historic average pumping amount (Santa Paula Basin Experts Group, 2003).

In March 1996, as a result of legal action relating to declining groundwater levels in the Santa Paula Basin during the 1984 to 1991 drought and the City of Ventura's stated intention to increase pumping from the basin, the Superior Court of the State of California for the County of Ventura approved a Stipulated Judgment for Santa Paula Basin (*United Water Conservation District vs. City of San Buenaventura,* original judgment March 7, 1996, amended judgment August 24, 2010). The Stipulated Judgment established pumping allocations for each basin pumper.

1.5.4 UPWELLING SALINE WATER

The upwelling of saline waters has been documented in a number of production wells in the Pleasant Valley basin. Advancements in the tools used in sampling pumping production wells has allowed for the documentation of flow and water quality profiles in long-screen production wells (Izbicki et al, 2005a, 2005b). Data from some area wells indicate that poor water quality at the wellhead results from saline water entering the well from specific aquifer zones. High chloride concentrations in the deepest portion of the well can be indicative of brines migrating from deeper zones towards a water level depression (low pressure area) created by long-term overpumping. This upwelling of brines is another form of saline intrusion, and like the compaction of marine clays, occurrence is not limited to coastal areas (Izbicki, 1992).

1.5.5 EXPORTATION OF GROUNDWATER

As agricultural land value continues to increase throughout the District, and as continued urbanization removes farmland from the valley floor, the development of the hillside lands located near a reliable supply of water is also expanding. In many cases the hillside properties will not support a productive well, and water is supplied to the property from a nearby groundwater basin or established surface water diversion. Both options result in the increased use of existing water resources. Most basins within the District lack clear policy or regulation regarding the "export" of water from the basin floor to surrounding uplands, although numerous area ranches have employed such an arrangement for many years. An export policy is currently under development for the Piru and Fillmore groundwater basins.

1.5.6 NITRATE IN FOREBAY GROUNDWATER BASIN

The Oxnard Forebay is vulnerable to nitrate contamination for some of the same reasons the basin is valued for water resource projects. The coarse alluvial sediments common to the area allow the rapid vertical transport of water from the near-surface to the water table. During wet periods, the regional water table is often only tens of feet below the land surface in the Forebay. Nitrate is

highly soluble and very mobile, making it susceptible to leaching from soils and transport to groundwater. Public supply wells in some areas of the Oxnard Forebay periodically exceed the California Department of Public Health's maximum contamination level (MCL) for nitrate, which is 45 mg/l nitrate (or 10 mg/l nitrate as N). Exceedence of this MCL can result in methemoglobinemia (or "blue baby syndrome") a condition where ingested nitrogen interferes with the blood's ability to carry oxygen. Infants less than three months of age are most sensitive to this condition (Canter, 1997). United has conducted a series of studies to determine the extent of nitrate concentrations and the possible causes of this contamination. The Santa Clara River, which provides much of the natural and artificial recharge to the Forebay, is consistently low in nitrate (averaging 7 mg/l nitrate, UWCD, 1996a). Nitrate loading to the groundwater is principally related to land uses within the Forebay, with the most significant sources being agricultural fertilizers and septic systems. United's groundwater recharge activities in the Oxnard Forebay introduce large volumes of low-nitrate water to the groundwater flow system, providing a water quality benefit to both local wells and wells located greater distances down-gradient from the recharge facilities.

Nitrate levels in the El Rio area have fluctuated widely through time, with highest nitrate levels commonly observed during and following drought periods, and relatively low nitrate levels are often recorded during wet periods (UWCD, 1998). Nitrate levels tend to stay relatively low during wet periods when low-nitrate Santa Clara River water is spread by United in the El Rio recharge basins and natural recharge to the basin is abundant. However, when there is not sufficient river water to spread at El Rio, nitrate levels in the O-H wells sometimes rise, particularly in the northeastern portion of the spreading grounds. Blending with water from other O-H wells with low nitrate concentrations keeps nitrate concentrations in delivered water within the health standard for potable supply.

During the drought of the late 1980s and early 1990s, nitrate peaks increased in intensity. Following previous droughts, nitrate concentrations in the wells generally decreased to low levels during the intervening wet years. However, following the 1980s to 1990s drought, nitrate levels in a series of wells even increased during the dry season of wet or average precipitation years when flow in the Santa Clara River was low and United was not recharging water at El Rio. The distribution of nitrate both laterally and with depth is difficult to document with certainty, but the sampling of monitoring wells installed over the past decade has shown that the highest nitrate concentrations are often recorded in the shallowest portions of the aquifer (UWCD, 2008). Whereas the large-scale groundwater flow patterns within the Upper Aquifer System (UAS) of the Forebay are believed to be fairly well understood, the individual flow paths of small volumes of water are often complex. This complexity of flow paths, unknown travel times, and an imprecise knowledge of nitrogen inputs often limits what can be concluded about nitrate provenance from the basic chemical analyses common to many routine groundwater monitoring programs.

In response to long-term concerns about water quality in the Oxnard Forebay and down-gradient areas, and a regulatory order issued by the Los Angeles Regional Water Quality Control Board, areas of high-density septic systems in the greater El Rio area have been converted to sanitary

sewers. More than 1,400 properties were connected to sewer between the years 2005 and 2011, with project costs totaling $35 million. The County of Ventura managed the eleven phases of this successful project. Ongoing programs also exist to promote efficient irrigation and fertilizer practices among area growers. These educational programs are conducted regularly by the University of California Cooperative Extension, the Ventura County Farm Bureau and various agricultural product suppliers or manufacturers.

1.6 SURFACE WATER ISSUES AND CONCERNS

Complex and variable interactions between surface water and groundwater flow systems exist within the valley of the Santa Clara River. Along the length of the Santa Clara River there are several areas where flow in the river commonly percolates entirely, resulting in dry reaches of the riverbed. Surface flow resumes some distance downstream as "rising groundwater" and discharges flow to the river, usually near a boundary of one of the groundwater basins in the valley. Flow from tributary streams sometimes reaches the confluence with the river, while at other times stream flow percolates to groundwater upstream of the main river channel.

Given the complex dynamics related to the gaining and losing reaches of the Santa Clara River and its major tributaries, management activities for both water resources and environmental protection are more complicated than might be imagined. Flows in the river are naturally variable seasonally and annually, but dry reaches are common in all but the wettest of years. These variables often complicate permitting requirements and management efforts to maintain various river habitats. In addition, water quality issues generally require consideration of the interaction of surface water and groundwater, as do efforts to convey stored surface water to points lower in the watershed via natural stream channels.

1.6.1 SANTA CLARA RIVERBED STABILIZATION

The construction of the Vern Freeman Diversion structure accomplished two primary objectives for the District: creating a diversion structure highly resistant to storm damage, and stabilizing the elevation from which surface water is diverted from the river. Following extensive mining of aggregate from the channel of the Santa Clara River in the Forebay area, riverbed elevations near Saticoy had dropped by about twenty feet by the late 1980s. Scour associated with large flow events in the river allowed the riverbed degradation to propagate ever farther upstream, and United was repeatedly required to move its Saticoy diversion location farther upstream. The completed structure has prevented further down-cutting of the river upstream of the facility as expected, and some recovery of channel elevations between Santa Paula Creek and the Freeman Diversion has been documented (Stillwater Sciences, 2007). Since completion in 1991 the elevation of the Freeman diversion point has been stable at 162 feet, and the facility has enabled the diversion of river flow soon after large storm events.

When the Freeman Diversion was constructed, the riverbed elevation upstream of the structure was elevated about ten feet, and materials excavated during construction were used to raise floodplain elevations in an area extending approximately 2,000 feet upstream of the facility. The dam structure extends about 90 feet in the subsurface and rests on a bench of low-permeability Pico Formation. While the facility was not intended to pond surface water, it does act as a dam in the subsurface. Groundwater elevations at an upstream location near the diversion structure vary little from the crest elevation of 162 feet, as groundwater moving through shallow river alluvium stages up behind the Freeman structure (Figure 1.6-1). Construction of the Freeman Diversion has benefited groundwater elevations in the Santa Paula basin as incision of the river was lowering the discharge elevation for shallow groundwater in the basin was arrested and partially restored (Santa Paula Basin Experts Group, 2003).

1.6.2 INCREASED CHLORIDE CONCENTRATION IN SANTA CLARA RIVER

The watershed of the Santa Clara River is one of the largest in southern California, draining over 1,600 square miles in Los Angeles and Ventura Counties. The Piru groundwater basin underlies the Santa Clara River just west of the LA-Ventura County line, and the nature of the river channel is such that much of the time the entire flow of the river emanating from upstream areas infiltrates to groundwater in the eastern portions of the Piru basin. Water quality in the river has suffered periodically due to land use practices in Los Angeles County, and water quality impacts have been shown to persist in the groundwater of the Piru basin for many years after corrections have been made to restore quality in surface water.

In the 1950s and 1960s brines from oil production in the greater Newhall area were discharged to the Santa Clara River, and very high chloride and TDS concentrations were recorded during this period. These practices ceased in the early 1970s after the passage of the federal Clean Water Act, but residual degradation of groundwater quality was noted when water quality objectives were formulated by the Regional Water Quality Control Board years later (UWCD, 2006). Another episode of chloride contamination has occurred more recently and is associated with wastewater discharges from the City of Santa Clarita. Beginning in 1999, rapid urban growth and the increasing popularity of self-regenerating water softeners resulted in increased flow and rising chloride concentrations in the Santa Clara River at the Los Angeles County line. A clear trend of increasing chlorides continued until late 2004, when recorded chloride concentrations in the river peaked around 150 mg/l. Wells in the eastern Piru basin responded rapidly to the changes in the quality of the recharge water to the basin, and a group of concerned growers and other Ventura County interests repeatedly requested to the Regional Board to take action to regulate the chloride discharges which exceeded regulatory limits and advisory thresholds for agricultural use (100 mg/l).

Following several years of study and a successful groundwater modeling effort to predict the impacts of various discharge scenarios on downstream areas, a compromise solution emerged that was endorsed by most area stakeholders and approved by the Regional Board in fall 2008. The approved project was to allow chloride discharges as high as 117 mg/l to the Santa Clara River,

and to construct a series of extraction wells, desalting facility and pipeline to convey blended water across the dry reach of the Piru basin. The local (Santa Clarita) board of the Sanitation Districts of Los Angeles County has refused to authorize the rate increases necessary to implement the approved project. In the meantime, the successful removal of most water softeners from Santa Clarita and lower chloride concentrations in imported State Water has resulted in wastewater chloride concentrations below the peak concentrations seen in the mid-2000s. The chloride plume associated with the worst of the past discharges continues to migrate with groundwater flow across the Piru basin, and now extends past the midpoint of the basin.

1.6.3 WATER FOR ENVIRONMENTAL INITIATIVES

Because of the Federal regulatory mandates, both Santa Felicia Dam and the Freeman Diversion have implemented bypass flows to maintain migration corridors for southern California steelhead and habitats downstream of the facilities. Santa Felicia Dam is regulated by the Federal Energy Regulatory Commission (FERC) due to a small 1.2 Mega Watt hydroelectric plant at the outlet works. The Freeman Diversion is included in a Habitat Conservation Plan (HCP) that is under development and is expected to take several years to complete.

1.6.3.1 SANTA FELICIA DAM ENVIRONMENTAL FLOWS.

The original water rights license for Santa Felicia Dam requires a minimum release of 5 cfs or natural inflow, whichever is less. Due to the conditions in the FERC license which were adopted in 2011, the bypass flows have now been changed to a minimum of 7 cfs with conditions which require higher flows to maintain downstream habitat when the monthly cumulative precipitation is above the historic average measured at County Station 160, located at the guard station entering Lake Piru. Release migration flows of 200 cfs have been implemented for fisheries migration in Piru Creek when the Santa Clara River has elevated flows due to storm runoff. The trigger to initiate migration releases occurs when the USGS gauging station on the Santa Clara River above Piru measures over 200 cfs at 8:00 am and is expected to stay above 200 cfs through the following day. Migration flows are to continue as long as flows at the county line are over 200 cfs.

Based on recommendations from NMFS, FERC has also imposed license conditions on the rate at which United may decrease flows when ending conservation releases or environmental flows. Release ramping rates are to be adjusted so that flow in Piru Creek never decreases more than two inches per hour. Ramping down the conservation release in fall 2011 took five days and a minimum of 25 adjustments to go from 300 cfs down to seven cfs.

The FERC bypass flow plan was not adopted until late May 2011. As a result of the license a habitat flow of a minimum of nine cfs was implemented on May 27, 2011 and maintained until October 1st. After October 1st minimum flows were decreased to 7 cfs until the appropriate triggers are met to change the flows.

Before the final bypass flows were accepted for the license, United proposed several plans during negotiations with NMFS. Each plan was rejected for various reasons. On October 6th 2009 NMFS recommended bypass flows that would have substantially reduced the yield of the Santa Felicia Dams operations. After further negotiations, and due to United's efforts and familiarity with the hydrology, the agencies agreed upon the above mentioned plan that is now part of the license. A yield calculation was done for the operations at Santa Felicia Dam comparing the actual operations to both the approved bypass flows in the FERC license and the recommended flow proposed by NMFS during the negotiations. In 2011 the actual storage in the lake started at 31,000 Acre-Feet in January 1st, and ended up at 75,500 Acre- Feet by June 1st. If the new FERC bypass flow plans were implemented the total storage of the lake by June 1st would have been 71,700 due to some storms that would have triggered migration releases and additional habitat flows. The recommended release schedule by NMFS required a substantially higher migration flow release from the dam which would have resulted in the final storage reaching only 56,300 AF, or a loss of storage of 19,200 Acre-Feet over the actual conditions, and 15,400 acre-feet over the proposed license (Figure 2.2-1).

After the conservation release, a short duration high impulse release of 600 cfs was done in order to perform a geomorphology study as a part of the FERC license conditions. This study took an additional 2,400 AF of water and was designed to evaluate sediment transport in various reaches within Piru Creek. The experimental release water was either diverted at the Freeman Diversion or percolated upstream. Figure 2.2-1 shows the average daily flows of the geomorphic test with the conservation release.

1.6.3.2 HABITAT CONSERVATION PLAN

The Freeman Diversion currently provides bypass flows for the upstream and downstream migration of the endangered southern California steelhead. State Water Rights Permit 18908 allows United to divert its license amounts as long as 40 cfs is provided through the fish ladder for 48 hours after the total river flow subsides below 415 cfs. These migration flow requirements are limited to storms that occur between February 15th and April 31st of each year. As part of the HCP development United remains consultation with National Marine Fisheries Service (NMFS) and is currently operating the bypass flows to better meet the needs of the species for migration between the ocean and the Freeman Diversion. In 2011, four storms provided sustained flow in the Santa Clara River and allowed for the fish ladder to be in operation nearly continuously from February 19th to June 8th, 2011. An estimated 2,400 to 3,000 AF of water was directed to fish migration flows that otherwise would have been used for groundwater recharge. However during this same year 92,600 AF were diverted from the river and Forebay water levels near the Saticoy Spreading Grounds reached maximum elevations due to groundwater mounding in this vicinity.

2 PROJECTS AND INITIATIVES

Figure 2.1-1 is a matrix introducing United's current projects underway by the Groundwater Department and the issues those projects address. The projects vary in scope and application. The groundwater and surface water projects are discussed in the following sections of this report.

2.1 GROUNDWATER

Section 2.1 introduces the groundwater projects that have been conducted by United. These consist of a wide range of projects which are discussed separately in the following sub-sections of this report. These are the same projects introduced in Figure 2.1-1.

2.1.1 UPDATE REGIONAL GROUNDWATER FLOW MODEL

The Ventura Regional Groundwater Model (VRGWM) is a numerical modeling tool developed to evaluate multifaceted conjunctive use, water recycling, and water conservation projects designed to alleviate seawater intrusion, overdraft, land subsidence, and other problems. A calibrated groundwater flow model allows the prediction of benefits or impacts associated with either specific water supply projects (such as well fields, water deliveries, recharge projects, reservoir releases, etc.) or more global changes within the model domain (changing irrigation demands, changing rainfall patterns, extended drought). Both United and the FCGMA have relied upon the existing VRGWM for planning and groundwater management activities.

The VRGWM was originally developed by the U.S. Geological Survey as part of the Regional Aquifer Systems Analysis (RASA) in the late 1980s and early 1990s. The VRGWM simulates regional groundwater flow in the Piru, Fillmore, Santa Paula, Mound, and Oxnard sub-basins of the Santa Clara River Valley Basin, and the Pleasant Valley Basin, Arroyo Santa Rosa Valley Basin, and Las Posas Valley Basin in the Calleguas Creek watershed. The MODFLOW model uses a finite difference grid consisting of 114 rows and 229 columns for a total of over 24,000 active cells with nodal spacing of approximately 900 feet throughout most of the model domain. The model presently uses 3 layers to simulate regional groundwater flow in the region's Upper Aquifer System, Lower Aquifer System, and shallow alluvial aquifers.

Since completion of the original model by the USGS in 1996, UWCD has completed several modifications to the VRGWM to improve its predictive capabilities and better address project-specific questions:

- Model Grid Size Reduction – Reduced cell size from 1/2 mile to 1/6 mile for improved accuracy;

- Model Layer Addition – Added a third model layer to simulate groundwater flow and groundwater-surface water interactions in the shallow alluvial units in the Piru, Fillmore, and Santa Paula sub-basins;
- Conceptual Model Updates – Added/modified groundwater flow barriers and hydrogeologic properties;
- Expanded Calibration Period - Added 1994 to 2000 hydrology;
- Model Recalibration – Recalibrated the Oxnard Basin to 1998 to better reflect the new conjunctive use projects built after USGS originally calibrated the model; and
- Improved Predictive Simulations – Expanded the forward model (predictive tool) period to a full 55 years that reflect the climate and hydrology of the years 1944 through 1998.

While the existing VRGWM has been successfully used in this capacity for more than a decade, the model must be updated in order to answer the increasingly complex and detailed questions water managers are now faced with. As environmental stewardship, climate change, drought preparedness, and recycled water have become integral aspects of groundwater management, the level of analysis required to support planning has become increasingly more detailed in both time and space, as compared to the early 1990s when the model was developed. In its current form, the VRGWM is not fully capable of evaluating the complex issues Ventura County water managers are faced with today or expect to confront in future years.

Grant funds were used to start the VRGWM update process. The VRGWM update is divided into two geographic areas that will be completed in two separate, but linked project phases. The first phase includes the Oxnard Forebay and Oxnard Plain. The second phase will include other basins such as Mound, Piru, Fillmore, Santa Paula, and Pleasant Valley. Each project phase has three tasks: (1) Develop Basin Conceptual Model; (2) Develop Groundwater Flow Model; and (3) Calibrate Groundwater Flow Model. The grant funding is to facilitate completion of Tasks 1 and 2 of the first project phase, which will be completed within the two year grant period (estimated: fall 2013). The remaining VRGWM update tasks are funded via other sources.

The basin conceptual model provides the basis for developing the numerical groundwater flow model. The goal of Task 1 is to update the basin conceptual model for the Oxnard Forebay and Plain with improved geologic understanding so a more detailed groundwater flow model can be constructed. Currently, the VRGWM is based on a conceptual model that uses an aquifer system framework where multiple aquifers are grouped into upper and lower systems. This approach ignores difference in water levels and properties between the aquifers in each system, which are significant in most areas. As groundwater management issues become more complex, the need for aquifer-specific answers increases. Thus, a key objective of Task 1 is to expand the basin conceptual model to include aquifer-specific data.

Updating the basin conceptual model is a two-step process – data collection and data analysis. Data collection includes identifying and compiling available geological data. United has focused on

subsurface data contained in water, oil, and gas well logs. District staff have identified available geophysical logs and prioritized the logs for digitization. The digitized logs were georeferenced and input into GIS for analysis. United's hydrogeologists thereafter identified and correlated regional hydrogeologic units (aquifers and aquitards); constructed geologic cross-sections; and identified regional facies changes that affect the occurrence and movement of groundwater within the hydrogeologic units. Geologic maps and studies were also reviewed to identify geologic structures (faults and folds) that are barriers or partial barriers to groundwater flow. Ultimately, the goal is to use this work to build a 3-dimensional (3-D) geologic model of the basins for use in developing the numerical groundwater flow model (Task 2).

The goal of Task 2 is to develop the numerical model architecture and initial inputs that will be used for calibration. The model will be constructed using USGS's Modular Three-Dimensional Ground Water Flow Model code (MODFLOW) and the commercial pre-processing package Groundwater Vistas offered by Environmental Simulations, Inc. Groundwater model development is a three-step process that includes: (1) grid design, (2) establishing boundary conditions, and (3) assigning initial parameter values. As part of the model construction process, data will be georeferenced and input into GIS.

Grid Design

United's groundwater staff will construct a finite-difference grid for the model domain based on the 3-D geologic model prepared in Task 1. Model layers will be used to represent the different hydrogeologic units, where possible. The grid node spacing will be determined by evaluating the impact of cell size on model calculation run times. The goal will be to minimize the nodal spacing while not creating excessive run times. This will depend on the number of layers and the geographic extent of the model domain. If necessary, the numerical model will be broken into separate (but linked) models for different sets of basins to achieve an acceptable level of detail and run times.

Boundary Conditions

Boundary conditions are used to represent flow barriers (no-flow boundary), recharge and discharge processes (i.e. stream percolation, pumping, etc.), and inflow/outflows to/from other basins and the ocean. The geologic model will dictate the location of no-flow barriers representing low permeability bedrock units and fault barriers. Recharge estimates will be derived from prior studies and agency records of artificial recharge, as updated by new data collected by UWCD and others since the early 1990s. The primary discharge mechanism is pumping. Pumping locations and rates are available from UWCD and FCGMA pumping records. Other Inflows and outflows to the model domain will be implemented as either specified-flux boundaries or as head-dependent flow boundaries. These include flow in and out of adjacent basins and the ocean.

Initial Parameter Values

Once the model grid has been constructed, initial aquifer parameter values (hydraulic conductivity storage coefficient, etc.) will be assigned to each active cell in the model grid. These values will be estimated using available aquifer test data and the texture descriptions from the geologic model. Partial flow barriers and estimates of their hydraulic properties (conductance) will also be input during this step. Where possible, UWCD will seek opportunities to perform aquifer tests or collect other data that will help quantify the hydraulic properties of the different aquifers and flow barriers.

Following the successful construction and calibration of the groundwater flow model, the model can be utilized to evaluate specific water supply projects or broader pumping or precipitation changes within the watershed. The evaluation of individual projects requires the construction of model input files that define changes in pumping or recharge associated with the project under consideration. Model scenarios that include the new water project are typically compared to a "base case" scenario that characterizes how the basin or basins operate without the new project. United anticipates that the calibrated VRGWM will be used to assist cities or management agencies such as the FCGMA in evaluating large and/or complex water supply or water management proposals.

2.1.2 AB3030 GROUNDWATER MANAGEMENT PLAN UPDATE

The AB3030 Groundwater Management Plan (GMP), which is currently in draft form, is a cooperative effort of United Water, the City of Fillmore, and water companies/pumpers in the Piru and Fillmore Groundwater basins (Piru/Fillmore Groundwater Management Council, 2011). The original 1996 GMP was formulated with input gained from public information meetings and hearings. This 2011 GMP is an update of the original 1996 Plan (Piru/Fillmore Groundwater Planning Council, 1996).

The GMP uses the groundwater management plan authority contained in California Water Code Section 10750 et seq. initially enacted in 1992 through Assembly Bill 3030. An initial 1995 Memorandum of Understanding (MOU) between United, the City of Fillmore, and the water companies/pumpers, was incorporated in the plan and established the GMP as a cooperative groundwater management plan for the basins. The MOU outlines the roles of the various parties in implementing the Plan (M.O.U., 1995). The Piru and Fillmore basins are considered part of the Ventura Central Basin which is subject to critical conditions of overdraft (California Department of Water Resources, 1980).

United, as the lead agency, has formally adopted the GMP, which was formulated to ensure local control of groundwater management. It is the intent of the GMP to foster local control in as many aspects of the management of the basins as possible. The draft 2011 GMP update includes numeric Basin Management Objectives (BMO) for groundwater levels, groundwater quality, and surface water quality. Water Code Section 10753.7 now requires the inclusion of BMOs in a GMP for any local agency seeking state funds administered by the California Department of Water Resources for the construction of groundwater projects or groundwater quality projects. In addition

the update includes a formal groundwater export policy which was a requirement of the original GMP.

2.1.3 SANTA PAULA BASIN SPECIALTY STUDIES

In March 1996, the Superior Court of the State of California for the County of Ventura approved a stipulated Judgment for the Santa Paula Basin. (*United Water Conservation District vs. City of San Buenaventura etc, Ventura County Superior Court Case No. CIV115611,* Judgement entered March 7, 1996, and amended August 24, 2010) [hereinafter "Judgment"]). The Judgment recognized that all of the parties have an interest in the Santa Paula Basin, and in the proper management and protection of both the quantity and quality of this important groundwater supply. The basin is a significant water resource in the County of Ventura. Members of the Santa Paula Basin Pumpers Association and the City of San Buenaventura exercise rights to pump water from the basin for reasonable and beneficial uses. The United Water Conservation District does not produce water from the basin, but the basin is located within its boundaries and the District is authorized to engage in groundwater management activities and to commence actions to protect the water supplies which are of common benefit to the lands within the District or its inhabitants.

In 2010 the Judgment was amended to join various groundwater pumpers that were not previously joined as parties to the adjudication, and to clarify certain provisions pertaining to shortage conditions, the responsibilities of the Santa Paula Basin Pumpers Association and groundwater production by its members, and water rights transfer procedures.

The Judgment provides for the creation of a Technical Advisory Committee (TAC). The committee is charged with establishing a program to monitor conditions in the basin, including, but not necessarily limited to, verification of future pumping amounts; measurements of groundwater levels; estimates of inflow to and outflow from the basin; increases and decreases in groundwater storage; analyses of groundwater quality; studies relative to the basin; development of programs for its conjunctive use and operation; and other information useful in developing a management plan for the basin. The Judgment also authorizes the TAC to consider and attempt to agree on the safe yield of the basin.

The Judgment among other things requires the TAC to monitor and annually report individual and cumulative groundwater production from the basin. The Judgment further specifically provides that *"United Water Conservation District shall have the primary responsibility for collecting, collating, and verifying the data required under the monitoring program, and shall present the results thereof in annual reports to the Technical Advisory Committee*." The United Water Conservation District submits draft annual reports to the Santa Paula Basin TAC members for review, comment, and approval.

The 2008 Annual Report, filed with the Court in 2010, noted that the TAC has observed a long-term, but gradual, decline in basin groundwater elevations. The Annual Report stated that the TAC would over the following 12-24 months seek to determine the cause of the long-term gradual decline in the

groundwater elevations, and formulate remedial actions to reverse the problem should it persist (United Water Conservation District, 2009).

In 2011 the Santa Paula Basin TAC created a Santa Paula Basin Working Group to investigate the cause of the long-term gradual decline in groundwater elevations. The Working Group consists of technical experts from the United Water Conservation District, the Santa Paula Basin Pumpers Association and the City of San Buenaventura. The Working Group has initiated a series of studies that will address the cause of the long-term gradual decline in groundwater elevations.

In August 2011, the TAC issued a list of ten work items which were evaluations and studies to be completed for the Santa Paula Basin. These items are listed below:

- Investigation of Hydrologic Base Period.
- Investigation of groundwater and surface water inflow at Fillmore-Santa Paula Basins boundary.
- Evaluate groundwater confinement and differentiate measured wells by aquifer.
- Evaluate water level trends in both confined and unconfined parts of the Santa Paula Basin.
- Identify crop change over time.
- Investigation of groundwater storage change.
- Evaluate historical changes to the Santa Paula Creek channel and potential effects on basin recharge.
- Refine and finalize spatial and temporal Pumping Trends Report.
- Compilation of Santa Clara River infiltration data.
- Compilation of Santa Paula Creek infiltration data.

The technical evaluation of the spatial and temporal pumping trends within the basin has been completed (UWCD, 2011b), and the Technical Working Group of the TAC concluded that the long-term gradual decline of water levels in the basin are not due to shifts in pumping locations or magnitude over time.

2.1.4 DISTRICT-WIDE GROUNDWATER LEVEL MONITORING

United monitors groundwater elevations in all or portions of eight groundwater basins within the District boundaries. The regular monitoring of a large number of wells in the multiple aquifers throughout the District is necessary to adequately define the regional influences of groundwater extractions as well as natural and artificial groundwater recharge to the basins. Measurements are collected from both active production wells and dedicated monitoring wells. “Nests” of monitoring wells exist in some locations, allowing determination of heads in various aquifer units, and vertical gradients between aquifer zones at these locations.

In excess of 2,400 water level measurements were collected by District staff in 2011, on either a monthly, bimonthly, quarterly or semi-annual basis. The semi-annual runs are the most extensive runs and are scheduled to document annual high groundwater conditions in the spring and annual low groundwater conditions in the fall. The locations of wells measured by United at various frequencies are shown by basin in Figure 2.1-2. The locations of wells with groundwater elevation measurements are represented in various figures in Section 4 of this report.

In the Santa Paula basin, a more extensive groundwater elevation monitoring effort was initiated in 1998 and is continuing. The monthly, bimonthly and semi-annual monitoring of wells is conducted to assist technical work in progress to determine the perennial yield of the basin, and related to a March 1996 Court Settlement regarding pumping in the basin.

Beginning in the spring of 1999 the number of Upper and Lower Aquifer System wells monitored in the Oxnard Forebay, Oxnard Plain, Pleasant Valley and Mound basins was increased substantially. The increased frequency and distribution of groundwater elevation data in the coastal basins is intended to better define areas of groundwater abundance and deficit, and how these conditions relate to groundwater recharge and extraction in the basins, and geologic features within and between the basins. The implementation of an extensive semi-annual (spring and fall) water level measurement program in these basins is also intended to define the extremes of water levels throughout the year.

Beginning in 2009, United has increased its efforts to instrument additional wells in each groundwater basin with pressure transducers ("transducers"). These units consist of a compact pressure transducer and data logger, and are commonly suspended in a well by a special cable that allows records to be retrieved without removing the device from the well. The transducers are programmed to record water levels at frequent time intervals, allowing the acquisition of data sets that would be impossible or impractical to collect by hand. The automated collection of head measurements are very useful in evaluating transient events, such as tidal influences, the area of influence surrounding pumping wells, and water table responses to both natural and artificial recharge events. As of fall 2011, approximately 65 pressure transducers were deployed throughout the District (Figure 2.1-2).

A number of other Ventura County agencies routinely measure and record groundwater elevations in their wells, most commonly on a monthly or quarterly basis. Most cities and the larger mutual water companies measure water levels in their wells, often under both static and pumping conditions. Water levels are also routinely measured in monitoring wells at a number of environmental sites, such as landfills, large scale contaminant sites, or wastewater percolation ponds. United obtains water level records from these various sources and archives the records in a central database.

The Groundwater Section of the Water and Environmental Resources Division of the Ventura County Watershed Protection District also maintains a long-term groundwater elevation monitoring program (VCWPD, 2012). As with United's monitoring program, the lengthy water levels records

now associated with many of the wells in the County's program are valuable records for assessing long-term changes in water levels within area basins. United and the County of Ventura regularly exchange groundwater elevation records. The County of Ventura in turn reports groundwater elevation records to the California Department of Water Resources (DWR) as part of the California Statewide Groundwater Elevation Monitoring (CASGEM) program. This reporting program was authorized by the Legislature in 2009 as part of bill SBX7 6, and encourages local agencies to develop monitoring programs that adequately characterize groundwater conditions in their areas and regularly report the records to DWR for archiving and improved public accessibility.

2.1.5 DISTRICT-WIDE WATER QUALITY SAMPLING

United's water quality monitoring program integrates the District's sampling with sampling conducted by a variety of other organizations. Together, this monitoring serves the following varied purposes:

- For purveyors' wells, monitoring of a variety of regulated constituents ensures that groundwater is safe for potable use, and ensures taste and odor are within established guidelines.
- The saltwater intrusion monitoring network tracks the migration of saline water by direct seawater intrusion and the movement of chloride from clay layers between the aquifers. The network monitors the full series of aquifers from the Oxnard to the Grimes Canyon aquifer.
- Monitoring of wells allows documentation of both abrupt and long-term changes in water quality.

United staff samples numerous monitoring and production wells on a regular basis in order to evaluate the quality of groundwater within the District. Monitoring programs sometimes focus on specific areas within the District, typically for a specific type of degradation or improvement of water quality. In addition to United's regular sampling programs, water quality data are routinely acquired from other sources, most notably the California Department of Public Health (DPH) and the County of Ventura's Groundwater Section. Other sources of information include the California Department of Water Resources, cities, consultant reports and technical studies, landfill operators and individual well owners.

United routinely samples production wells and dedicated monitoring wells throughout the District, but monitoring is performed with increased frequency and density in two critical areas. One such area is the Oxnard Forebay basin, where United operates its main groundwater recharge facilities and the well field supplying the Oxnard-Hueneme potable water system. The monitoring serves to document both typical conditions and the variability of groundwater quality in areas of groundwater recharge and areas of groundwater production near specific land uses. Another area of frequent monitoring is the coastal area near and between the Hueneme and Mugu submarine canyons. Elevated chloride levels from the intrusion of saline waters continue to be a concern in this area,

especially in the area surrounding the naval base at Point Mugu. In recent years there has been interest in documenting increasing chloride conditions in the Piru basin. Water quality monitoring has increased in that basin, with much of the increased sampling being performed by the Groundwater Section of the Ventura County Watershed Protection District.

When water is delivered to the public, the California Department of Public Health enforces minimum monitoring requirements to assure that delivered water is free of chemical and biological contaminants. Testing requirements vary depending on the number of people served by the system and a system's vulnerability to contamination, as determined by the DPH. United regularly collects samples from the wells supplying the O-H potable water system, with sampling frequency exceeding the minimum DPH requirements. Water purveyors throughout California are required to report results of all water analyses to the DPH, and United regularly obtains these water quality records from the DPH for integration into United's water quality database.

United's groundwater staff regularly collects water quality samples from approximately 150 monitoring wells located throughout the District. Nearly all of these wells are PVC wells with a diameter of two inches. A portable submersible sampling pump is lowered into the well in order to purge the well prior to collecting a sample. Alternatively, an air compressor and long air line are used to purge other wells, where compressed air is released in the well below the water surface and water is "air lifted" to the surface by the air exiting the well. Most of the monitoring wells have a short screened interval, allowing the collection of water from a limited section of the aquifer. Many monitoring wells were installed as a nest or cluster of wells in a single borehole, allowing the collection of piezometric head and water quality samples from multiple depths at the same location. United measures field parameters during sampling, but all water quality analyses are performed by a commercial laboratory.

United also monitors a number of private domestic and irrigation wells throughout the District as part of its regional monitoring programs. The sampling of production wells spares the expense of drilling new monitoring wells, and provides examples of water quality pumped by groundwater users. However, the long screen intervals common to most production wells often draws water from multiple water-bearing zones, which can mask poor quality water that may source from specific aquifer zones. The Groundwater Section of the Ventura County Watershed Protection District also conducts annual sampling of a number of production wells in Ventura County, commonly in the fall of the year. The County sampled over 200 wells in 2011, and this sampling significantly contributed to the water quality sample coverage for several basins within United's district boundary.

The distribution of wells sampled by United is shown in Figure 2.1-3. As shown in the map, the Oxnard Forebay and the coastal areas of the southern Oxnard Plain have the highest density of monitoring wells. Production wells belonging to private parties and monitored by United are concentrated around the Oxnard Forebay and in the basins of the Santa Clara River Valley. The figure includes a table showing the number of wells monitored in each basin.

Special water quality studies are occasionally conducted within Ventura County. One significant recent study was the Groundwater Ambient Monitoring and Assessment (GAMA) program, conducted by the United States Geological Survey (USGS) in cooperation with the CA State Water Resources Control Board. This project sampled a number of "representative" wells throughout the Santa Clara River valley and the Oxnard Plain in order to assess the quality of local groundwaters commonly used for public supply. Many wells were sampled in spring 2007 for a broad suite of compounds at very low concentrations in order to document both the character of natural waters and the nature of contamination where it exists. While the identities of the wells sampled remain confidential, results from this sampling effort allowed characterization of groundwater in the study area. Contamination related to human activities was found to be relatively uncommon, and associated with shallow wells screens and younger waters when present. Older and deeper groundwater in some areas has somewhat elevated mineral content, and may have elevated iron and manganese concentrations related to reducing groundwater conditions (Burton el al, 2011). The geologic setting and nature of the area's aquifers are largely responsible for the high mineral content in the water, resulting in some aesthetic issues but not health concerns.

2.1.6 SALINE WATER INTRUSION MAPPING

The intrusion of saline waters remains the principal water quality threat to the groundwater resources of the Oxnard Plain and the Pleasant Valley basin. As described in Section 1.5.2, the movement of brines into fresh aquifer units remains a concern as long-term overdraft conditions persist in these basins, and chloride impacts are no longer limited to the coastal areas adjacent the Hueneme and Mugu submarine canyons. Water with elevated chloride concentration is not suitable for either potable use or for irrigation water. In recent years United has conducted several investigations to better define the extent of saline water in the coastal basins. Some of the subprojects of this effort include:

- Seismic reflection survey on south Oxnard Plain – this subproject focused on meso-scale geologic structures/features that were postulated to impact groundwater movement on the south Oxnard Plain;
- Time domain electromagnetic survey in the Port Hueneme and Point Mugu areas – this subproject was designed to reassess the areal extent of saline water intrusion and compare it to the USGS data from the early 1990s;
- Borehole electrical conductivity surveys in existing piezometers in the Port Hueneme and Point Mugu areas - conductivity profiling in existing wells/piezometers was performed to determine if the saline waters have begun to impact strata other than the screened intervals; and
- Collection of flow profile data and discrete-depth water quality samples - conduct flow profiling, depth-specific sampling with water quality analyses, and mass balance calculations are proposed on existing production wells to identify salinity changes for Mugu and Hueneme saline water impact areas that may be masked in a high capacity well.

To date, two of these subprojects have been completed and brief summaries of the project results are presented below.

2.1.6.1 SEISMIC REFLECTION SURVEY ON SOUTH OXNARD PLAIN

In 2010 United conducted an approximate 6 mile high-resolution seismic reflection survey in the southern Oxnard Plain that was supported by a California Department of Water Resources Grant (UWCD, 2011a). The overall purpose of the seismic reflection survey was to resolve the structural geology in the area east of Port Hueneme to provide additional subsurface data to assist with the design of the western portion of the proposed Seawater Intrusion Injection Barrier. A primary goal of the project was to better understand the structural geology and stratigraphy associated with the aquifers in the area. The seismic reflection data was obtained along four lines totaling about 6 miles in length. In spite of the semi-urban environment and the challenging site conditions, the seismic reflection survey successfully provided high-resolution images of the Plio-Pleistocene stratigraphy in the study area at depths ranging from as shallow as 60 feet to over 2,000 feet below ground surface. By correlating the stacked migrated reflection sections and data from nearby oil and water wells, United Water was able to establish an interpretation that approximates the depth, thickness, and configuration of the two major aquifer systems in the area; the Upper Aquifer System (UAS) and the Lower Aquifer System (LAS).

The base of the LAS is reported to represent the bottom of the sediments containing fresh water underlying the Oxnard Plain. United's interpretation also identified reflecting horizons within these systems that could represent the boundaries of their component aquifers such as the Oxnard and Mugu aquifers in the UAS and the Fox Canyon and Grimes Canyon aquifers in the LAS. In addition, the interpretation identified three unconformities associated with the aquifers, including a strong continuous reflector that correlates with the unconformity that forms the boundary between the UAS and LAS.

One of the objectives of the seismic reflection survey was to confirm or deny the existence of an igneous "dome" structure in the central portion of the field area (extending between the UAS and LAS). A sedimentary mound type structure was also considered to possibly occur at that location instead of the igneous dome. The existence of the structure(s) was based on conflicting data. The study concluded that no igneous dome was interpreted to exist and the subsurface materials were deemed to be sedimentary. United's interpretation of the seismic reflection data does confirm the existence of a mound of stratigraphic origin.

One significant localized thick section of low-permeability material was resolved in the data and interpretation. The body of low-permeability material is located northeast of Port Hueneme. The thick part of the body is approximately 1.8 miles (northeast-southwest direction) by 1.3 miles (northwest-southeast direction) in lateral extent and is approximately 600 feet thick. It is directly in line with the submarine canyon at Port Hueneme and is described in literature as "clay deposits Old Hueneme Canyon" (Hanson et al, 2003). It likely represents the landward extension of the submarine canyon by Port Hueneme during a transgression of the sea.

This body of low-permeability material will have an effect on the placement and design of a proposed LAS injection barrier well field to prevent further saline intrusion on the southern Oxnard

Plain. It is located directly adjacent to the saline water "plume" on the northeast side. Wells will need to avoid that area at the depths of the low-permeability material in order to be successful at injecting water. The lateral limits and thickness/depth of the materials is defined well enough for the design of the barrier injection wells. In addition the low-permeability body can be strategically used for saline water blockage in part of the injection barrier system.

2.1.6.2 TIME DOMAIN ELECTROMAGNETIC SURVEY IN THE PORT HUENEME AND POINT MUGU AREAS

United Water performed a Time Domain Electromagnetic (TDEM) geophysical survey on the southern Oxnard Plain to assess the lateral limits of saline water intrusion in the Upper Aquifer System (UAS) and Lower Aquifer System (LAS) at four different depth ranges (UWCD, 2012a). The survey was designed to replicate a study performed by the USGS in the early 1990s that provided information about the vertical and horizontal extent of saline water intrusion (Zohdy et al, 1993). The field survey area was approximately 35 square miles and extended along the coast between Port Hueneme and Point Mugu (approximately 7 miles) and inland for approximately 5 miles. One hundred twenty five (125) soundings (data points) were obtained in agricultural fields, open private land, open preservation land, game preserve land, and in open areas on the Mugu Naval Air Station. The data were forward and inverse modeled for each sounding. The model data were used to construct resistivity maps, at four depth ranges typical of the UAS and LAS.

The investigation was successful at delineating earth resistivity values that are typical of saline and brackish water in both aquifer systems. Resistivities typical of saline water occurred along the coast and extended farther inland near Point Mugu with brackish water inferred at various locations inland. The resistivity maps also exhibited configurations that are typical of geologic features which may be groundwater pathways for the migration of saline waters.

2.1.6.3 BOREHOLE ELECTRICAL CONDUCTIVITY SURVEYS IN EXISTING PIEZOMETERS IN PORT HUENEME AND POINT MUGU AREAS

United Water performed conductivity profiling in existing piezometers along the South Oxnard Plain in summer and fall 2011 to determine if the saline waters have begun to impact strata other than the screened intervals. United Water routinely records water levels and collects and analyzes water quality samples from several piezometer nests in the south Oxnard Plain. These piezometers provide much of the information about how chloride and TDS values have changed over time. The chloride concentrations are not constant with time or depth. These piezometer nests provide the opportunity to evaluate the vertical change in TDS over time. When the piezometer nests were initially constructed, borehole geophysical logs were performed in each borehole. Changes in the conductivity over time can be used to infer changes in the water chemistry. This technology works in PVC-cased piezometers (i.e., the conductivity tool can collect readings through the casing). By relogging these piezometers, the changes in the conductivity in the formation outside of the blank casing intervals can be assessed. Conductivity profiling of the piezometers, coupled with the production profiles from existing wells, will greatly increase our ability to evaluate how the vertical

distribution varies in the study area. Data from the conductivity profiling is currently being evaluated and findings have yet to be published.

2.1.6.4 COLLECTION OF FLOW PROFILE DATA AND DISCRETE-DEPTH WATER QUALITY SAMPLES

This proposed subproject includes conducting flow profiling, depth-specific sampling with water quality analyses, and mass balance calculations on production wells to identify salinity changes for Mugu and Hueneme saline water impact areas that may be masked in a high capacity well. United Water proposes to field verify the TDEM geophysical results by performing production profiles and discrete-depth water quality sampling from existing production wells located near the leading edge of the saline zones identified by the TDEM survey. Production profiles (also called flowmeter surveys) are performed on wells to determine the distribution of water entering the perforated intervals. The results of a production profile are often presented as gallons/minute (gpm) per ft of perforated interval or percentage of the total flow per perforated interval.

Inflow rates to a production well can be measured and typically the flow rates are not equal along the length of the perforations. By identifying the proportional flow rates, discrete-depth water samples can be collected from each flow interval and mass balance calculations can be used to determine the water chemistry in the aquifer surrounding the inflow zones. These techniques are in use by many water districts and the USGS to better understand the impact well hydraulics have on water quality sampling and evaluate variations in groundwater geochemistry with depth. For our study, we propose to use this technique to look for production intervals within existing wells that have elevated chloride values and determine the depths at which the well has been impacted by saline waters. Funding for this subproject has been included in United's draft budget for the 2012-13 fiscal year.

In 2002 United sponsored a similar study for a number of high-capacity production wells in the Pleasant Valley Basin. Researchers from the USGS performed flow profiling and collected water quality samples at specific depths within the screened interval of the wells under pumping conditions. The work demonstrated that deeper portions of these wells generally produced little water but tended to have higher chloride concentrations (Izbicki et al, 2005a and Izbicki et al, 2005b). This study was proposed by United and funded by DWR through an AB303 local groundwater assistance grant.

2.1.7 FOREBAY AQUIFER DELINEATION/MAPPING USING SURFACE GEOPHYSICS

Reconnaissance-level time domain surveys performed by UWCD in 2010 identified previously unrecognized geologic conditions (e.g., faults, thick clay sequences) underlying several of the District's recharge basins. Previous investigations (e.g., Daniel B. Stephens & Associates, 2008) depict the presence of clay units (aquitards) in the Oxnard Forebay, but the lateral continuity and presence/absence of faulting were not addressed. The Oxnard Forebay is a critical component of

the region's water supply system and is envisioned as a location for expansion of future groundwater pumping and the potential introduction of recycled water for aquifer recharge. As the groundwater resource utilization in the Forebay intensifies, a more refined understanding of the hydrogeologic conditions is needed to facilitate optimization of this resource.

The Fox Canyon Groundwater Management Agency (FCGMA) is assisting financially with a Forebay Basin surface geophysical survey being performed by United Water with a grant from their *Groundwater Supply Enhancement Assistance Program (GSEAP)*. This is an ongoing project with 50+ time domain electromagnetic (TDEM) geophysical soundings collected to date. Additional field work is planned in 2012. United Water field crews have enjoyed extensive cooperation from land owners who have readily provided access to their property.

2.1.8 PIEZOMETER INSTALLATION ALONG SANTA CLARA RIVER

In fall 2011 United contracted for the installation of eleven new monitoring wells in the Oxnard Forebay. Nine of the wells are located along either bank of the Santa Clara River, from the Saticoy area to the area near the RiverPark pits. Two wells were installed adjacent United's Noble Pit recharge basins. The boreholes were drilled by a hollow stem auger rig and most of the wells were screened from approximately 60 to 100 feet below the land surface. These new wells were installed in order to better characterize groundwater recharge sourcing from flows in the Forebay reach of the Santa Clara River, and to evaluate how recharge from United's recharge operations in areas near the river interact with groundwater mounding associated with natural recharge within the river channel. Matching funds of 50% were supplied by the Fox Canyon GMA as part of their Groundwater Supply Enhancement and Assessment Program (GSEAP). The locations of the eleven new wells are shown on Figure 2.1-2.

2.2 SURFACE WATER

The interaction of surface water and groundwater is complex and dynamic in the valley of the Santa Clara River. Surface water flows are often highly variable both between years and seasonally within single years. The water quality of stream flow also commonly varies throughout the year, with mineral content typically increasing as flows decrease. United's interest in surface water flows has historically centered on the Santa Clara River near Saticoy, where water is diverted from the river and routed to various facilities for either groundwater recharge or direct use as irrigation water. Because of various regulatory requirements imposed upon the District by the federal government, United has recently devoted more effort to the study and characterization of flow in the river and its major tributaries in order to better understand aquatic habitat within the lower watershed of the Santa Clara River. Of particular interest are seasonal migration opportunities for the endangered southern California steelhead and how United's activities affect flows in Piru Creek and the Santa Clara River.

2.2.1 STREAM FLOW

Flows in the Santa Clara Watershed are recorded by United, United States Geological Survey (USGS) and the Ventura County Watershed Protection District (VCWPD). Flows in the main stem of the Santa Clara River are recorded by the USGS at the Los Angeles/ Ventura County line (funded by United) and by the VCWPD downstream at Victoria Bridge near Oxnard. United also records continuous flows diverted at the Freeman Diversion. All of the major tributaries are monitored coming into the Ventura County portion of the watershed. United Water funds the USGS to monitor the flows above and below Lake Piru. The VCWPD funds the USGS to record Sespe and Santa Paula Creek while the VCWPD records Hopper and Pole Creek.

Additionally in 2011, over 150 manual discharge measurements were made in locations that are not at a continuous gauging location. These data provides the information needed to estimate benefits to each basin during the conservation/State Water release, discharge/percolation rates of each basin, and adjustment of environmental flows.

2.2.2 WATER QUALITY

United maintains a water quality monitoring program and samples from a number of locations (Figure 4.2-4) either seasonally, monthly or every two weeks. Sampling sites are generally located near groundwater basin boundaries or on major tributaries near their confluence with the Santa Clara River. Sampling of tributaries and the upstream reaches of the Santa Clara River assure that waters are acceptable for natural groundwater recharge. Sampling is conducted on a quarterly basis and consists of either a full general mineral suite or several key constituents. Water temperature and pH is documented at the time of sample collection. Sampling is conducted more frequently along the Santa Clara River near the Los Angeles County line (monthly) and at the Freeman Diversion (every two weeks).

Beginning in January 1999, United has sampled the Santa Clara River at Blue Cut near the Los Angeles County line each month. This monitoring is intended to improve understanding of how urbanization and community water supply decisions in the Santa Clarita area affect the quality and quantity of water flowing into Ventura County. From the late 1990s through 2003 discharges from the Valencia Water Reclamation Plant increased steadily in both volume and chloride concentration, with chloride concentrations exceeding 200 mg/l at the end of this period. Discharge rates continued to increase for several more years before diminishing slightly. Chloride concentrations in the discharges have fallen to levels common to the early 1990s (Figure 4.3-6), the result of lower chloride levels in State Water Project imports and a successful ban of self-regenerating water softeners in area homes.

Water quality monitoring of the river water diverted at the Freeman Diversion is performed every two weeks to confirm that the water is acceptable for use in both aquifer recharge and for irrigation deliveries. The mineral content of water in the river at this location exhibits a strong negative

correlation with flow, where higher flows are less mineralized. Nitrate concentrations are routinely low in the river and do not show a strong correlation with flow. The County of Ventura maintains and operates composite sampling device at the Freeman, and samples storm flow and dry weather base flows several times per year. These samples are analyzed for a broad suite of organic contaminants and metals as part of a storm water quality program required by the Los Angeles Regional Water Quality Control Board.

In recent years both the City of Fillmore and the City of Santa Paula have eliminated discharges of treated wastewater to the Santa Clara River upstream of the Freeman Diversion. Santa Paula's new treatment plant came on-line in 2010 and utilizes percolation basins for wastewater disposal. Fillmore completed a new plant in 2009 and now distributes reclaimed water to both percolation basins near the plant site and a network of subsurface irrigation systems constructed in parks and school fields throughout the city.

2.2.3 SANTA FELICIA DAM CONSERVATION RELEASES

United's conservation releases are designed to replenish the Piru, Fillmore and Santa Paula Basins by direct percolation from the Santa Clara River. The remaining portion of the release is diverted at the Freeman Diversion and is either spread for percolation into the Forebay, or is sent to the Oxnard Plain or Pleasant Valley Basins via the surface water delivery system. The conservation release can be adjusted in quantity (duration and magnitude) and timing to optimize benefits within the district. The quantity in most years is limited by the supply from the wet season runoff and the amount of State Water purchased. Lake Piru maintains a minimum pool of 20,000 AF of storage that is designed to keep the sediment deposits in the lake away from the outlet works. Releases beyond this point are only done when State Water released from Pyramid Lake is expected to fill the lake back to the minimum pool shortly after the conservation release.

In 2011 there was 56,400 AF of stored water available for the conservation release. The following factors were considered when deciding on how much of the stored water was to be released:

- Provide enough storage capacity in Lake Piru to minimize the chances of spilling in 2012;
- Meet the needs of the downstream basins;
- Meet the needs of the surface water deliveries to Pleasant Valley and the PTP system; and
- Hold over enough water in the lake in case 2012 was a dry year.

The analysis found that the optimal volume to be released was 31,700 AF leaving 46,100 AF (with minimum pool) in the lake for the following year in case it was dry. Figure 2.2-1 shows the basic hydrology of inflows and outflows of Lake Piru.

Because the water levels were relatively high in the Piru and Fillmore basins due to the wet year and a 11,000 AF release from Castaic Lake, the release was designed to concentrate more on the lower basins. A higher release rate normally accomplishes this goal. The release started at 400 cfs in order to cut a channel across the Piru Basin so that a higher percentage of the release would end up downstream in Santa Paula basin and the Coastal basins (the Oxnard Forebay, Oxnard Plain, Mound, West Las Posas and Pleasant Valley basins). Once the channel was cut, the release was tapered back so that the duration of the release could be extended using the same volume of water. This type of release is now called a tapered release and has been done several times in the past few years.

The timing of the release was designed to coincide with the maximum demand for the surface water deliveries out in the Oxnard Plain. Peak demand occurs with the planting of the strawberries that take place from mid September to the end of October. Heavy groundwater pumping at the end of the dry season would otherwise meet this demand. The release started on September 12 and ended on November 6. Consideration was also given to allow enough time to dry out and prepare the percolation ponds so that they are ready for the 2012 wet season.

Of the 31,700 AF released from Santa Felicia Dam in 2011, approximately 15,700 AF (50%) of the water directly percolated into the Piru and Fillmore basins (Upper basins). The remaining 16,000 AF either percolated into the Santa Paula basin or was diverted at the Freeman Diversion for groundwater recharge or surface water deliveries. Below is a table showing the estimates of the distribution of percolated flows in each basin during the conservation releases since 1999 with 2011 being near the 12 year average of the releases in terms of total quantity of the release and the direct benefit to each basin. Figure 2.2-2 shows the conservation release and the associated direct benefit to each basin. Discharge measurements were made near the Piru and Fillmore basin boundary to calculate the amount of water that percolated into the Piru Basin, and measurements were also made at Willard Rd. for the Fillmore Santa Paula basin boundary to calculate what percolated in the Fillmore Basin. The remaining discharge measured at Willard Rd. is assumed to either benefit the Santa Paula Basin or diverted at the Freeman Diversion ("Lower Basins" in following tables).

Table 2-1 Benefits of the SFD Conservation Release due to direct percolation

Year	Total Released from SFD AF	Direct Deliveries in AF. of SFD Release to:			
		Piru Basin	Fillmore Basin	Lower Basins (groundwater recharge)	Surface water Deliveries PTP and PV
1999	22,800	5,700	3,500	11,200	2,400
2000	47,200	13,800	6,100	24,150	3,150
2001	47,400	14,000	2,900	28,300	2,200
2002	20,200	8,000	5,100	6,530	570
2003	29,000	21,000	3,500	3,600	900
2004	12,200	8,000	2,150	1,600	550
2005	9,100	na	na	4,500**	0
2005	23,400	na	na	17,200**	150
2006	30,900	na	na	17,200**	1,600
2007	40,700	15,900	6,300	12,200	6,400
2008	44,400	15,400	5,700	17,400	5,800
2009	26,700	13,200	4,700	5,200	3,000
2010	33,000	14,500	4,800	10,700	3,200
2011	**31,700**	**12,400**	**3,300**	**14,100**	**1,600**
Average	29,907	12,900	4,368	12,420	2,251
13 yr. Total	448,607	154,800	52,418	186,300	33,771

*2005 had two conservation releases. Portion of the release includes spill water when the lake was full

** measured at the Freeman Diversion

2.2.4 IMPORTATION OF STATE WATER

Ventura County has a 20,000 AF allocation of State Water. United Water's share of the allocation is 5,000 AF. Port Hueneme Water agency uses 1,850 AF of the original 5,000 AF and takes delivery through Metropolitan Water District. The remaining 3,150 AF of water is permitted to be released from Pyramid Lake and sent to Lake Piru through the natural water course of Piru Creek. United may receive this water from November 1st through the end of February of each year. Typically the conservation release will end before the State Water has arrived in Lake Piru. In order to release the state water that year, United will continue the release below the lake's minimum pool to the volume of State Water that was purchased, knowing that state water will fill it back to the minimum pool by the end of November. The State Water allows the conservation release to be extended a

few extra days due to the extra volume of water. The volume of water that percolates into each basin on the extended days of the release was considered to be the direct benefit to each basin.

In 2011 the State Water Project made available 80% of water allocations held by subscribers to the system. United received its 80% or 2,520 AF by a release from Pyramid Lake in November and December of 2011. Due to the wetter than normal conditions United chose to store the State Water until 2012 when it can be delivered at the end of the conservation release, along with any other additional State Water purchased for 2012.

The table below is a summary of all the state water purchased by United Water along with the direct benefits to each basin from percolation. Detailed stream flow measurements are taken near the basin boundaries throughout the releases to determine where the state water is percolating.

Table 2-2 Summary of State Water Release from Santa Felicia Dam

	Summary of State Water Released From Santa Felicia Dam in 1991-2011 (Values in AF)				
Year State Water Purchased	From Santa Felicia Dam	Release to Upper Basins (Fillmore and Piru)	Releases to the Lower Basins (Santa Paula and Coastal Basins)	Delivered to PV. And PTP	Recharge To Lower Basins
1991	4,836	3,603	1,233	0	1,233
1992	988	84	904	0	904
2000	2,200	406	1,794	69	1,725
2002	3,150	1,455	1,695	192	1,503
2003	3,150	2,041	1,109	70	1,039
2004	4,047.5	3,348	700	228	472
2007	1890	844	1046	116	930
2008	1980	673	1307	306	1001
2009	3150	1045	2105	724	1381
2010	3150	917	2233	559	1674
2011	**2520***				
Total	28,542	14,416	14,126	2,264	11,862

* To be released in 2012 conservation release

The benefit of the conservation release along with the State Water released can be seen in Figure 2.2-3. Since November of 2007 a transducer has been monitoring water levels in a monitoring well near the river in the Piru Basin. The graph shows the immediate rise in water levels in a well during the releases (shown in red). Because the well is approximately 600 feet from the flow in the river, a mound will build rapidly when the release starts and dissipate a little more slowly at the end of the release. Water levels are always considerably higher following the release, compared to the projection of water levels trends before the release.

2.2.5 PIRU DIVERSION EVALUATION

The Piru Diversion has been historically operated to divert surface water into United's nearby spreading grounds for groundwater recharge however this facility has not been operated since September of 2008. The diversion is located on the western bank of lower Piru Creek just south of the old Center Street Bridge in the town of Piru. Part of the diversion dam is built under the two roadway bridges crossing lower Piru Creek at Center Street.

The existing diversion consists of an earthen berm that extends out across the river channel, a sluice channel that can accommodate approximately 200 cfs, and a diversion structure with a trash rack and four 24-inch inlets leading to a 48-inch diversion pipe that conveys diverted water to the 44- acre spreading grounds.

The structure is not in compliance with National Marine Fisheries Service standards for diverting water in a stream that is considered by NMFS to constitute anadromous waters for Southern California steelhead. Therefore the facilities have been included as parts of United's Habitat Conservation Plan (HCP) so that the facility will be covered for incidental take. The diversion will not be put back into operation until the take permit has been issued and the facility has been retrofitted.

2.2.6 SANTA CLARA RIVER FLOW DIVERSIONS

The Freeman Diversion diverted 92,600 AF in 2011. This represents about 150% of the historical average diversions since 1955. In wet years such as 2011 various operational strategies were implemented to assure maximum yield at the diversion. Such strategies included limiting turbidity turn-outs, shifting the locations to spread water to reduce mounding near the river, alternating ponds to insure the maximum possible percolation rates, and implementing new SCADA controls to optimize canal levels. Some of these strategies are discussed below.

High flows in the river are normally associated with high turbidity. During times when the river is at its peak, diversions stop so that the sediment-laden water is not diverted. A recently implemented more aggressive schedule to divert more turbid water allowed the facility to divert 2,000 to 3,000 acre feet more than it would have in prior years. This more aggressive turn in procedure increases the use of the desilting basin, resulting in the need for more frequent cleanouts.

United's aggressive wet season spreading at Saticoy and the Noble Basin increased water levels in the surrounding area to a point where groundwater from spreading in the Saticoy and Noble basins was discharging back to the river near the Highway 118 Bridge. Rising groundwater in this area reached around 50 cfs of discharge in the river in the month of April. The spreading ponds further away from the river were used to limit the amount of discharge back to the river. The discharging water is in large part due to the degradation in the riverbed near the Highway 118 Bridge. The riverbed is currently about 20 feet lower than it was in the early 1950's allowing for a larger elevation differential between the pond and the river. A portion of the discharging water will

percolate downstream of the discharging point. With the balance of the discharging river that breached the Forebay to become part of the environmental flows that were needed to maintain downstream passage for the Southern California steelhead.

Nearly 72,000 AF were spread for groundwater recharge at United's three recharge facilities. El Rio recharged nearly half of the water, with Saticoy and the Noble Basins making up the other half (Figure 2.2-4). The remaining 20,600 AF went to surface water deliveries discussed in Section 1.4.6.

2.2.6.1 EL RIO RECHARGE BASIN

Recharge to El Rio exceeded the 56 year average in all months except for August. The total volume recharged was approximately 160% of normal. El Rio became the preferred facility to recharge due to the mounding of water and discharge back to the river at the other facilities. Due to the active O-H well field surrounding the facility, the groundwater mounding does not reach the surface thereby reducing percolation rates.

Table 2-3 Recharge to El Rio for 2011 calendar year

Recharge to El Rio AF		
	2011 Year	average since 1955
Jan	3,776	2,691
Feb	3,617	3,123
Mar	5,283	3,473
Apr	6,070	2,709
May	2,188	2,035
Jun	2,594	1,053
Jul	1,459	871
Aug	224	1,144
Sep	2,283	1,604
Oct	4,370	1,705
Nov	3,520	1,548
Dec	2,461	2,138
Totals	37,845	24,096

2.2.6.2 NOBLE RECHARGE BASIN

The Noble Basin is normally the last of United's Forebay facilities to be used for groundwater recharge. It is difficult to maintain the ponds during the wet season due to greater water depths and proximity to groundwater. During 2011, water was spread into the basin for a portion of four months

during the natural runoff period, and two months during the conservation release. The average spreading at this facility was nearly double the average since it was built in 1994.

Table 2-4 Recharge to the Noble Basin for calendar year 2011

Recharge to Noble Basin AF		
	2011	average since 1994
Jan	766	275
Feb	2,507	808
Mar	2,259	1,279
Apr	4,305	1,385
May	0	614
Jun	0	435
Jul	0	210
Aug	0	108
Sep	0	150
Oct	137	153
Nov	705	160
Dec	0	175
Totals	10,679	5,754

2.2.6.3 SATICOY RECHARGE BASINS

The Saticoy facilities recharged 23,400 AF in 2011, which is about average for the 55-year period since construction of Lake Piru. As mentioned above, mounding was occurring under the ponds and recharged water was flowing back out to the river. Priority was given to the El Rio facility at this time to attempt to decrease the amount of rising groundwater going back to the river. Regardless of the mounding, United was able to divert its instantaneous surface water diversion license limits with consideration to the environmental bypass flows for the entire year.

Table 2-5 Recharge to Saticoy for calendar year 2011

Recharge to Saticoy AF		
	2011	average since 1955
Jan	7,608	2,229
Feb	1,946	2,504
Mar	2,208	3,361
Apr	4,478	3,074
May	265	2,377
Jun	164	1,461
Jul	0	1,233
Aug	0	1,076
Sep	816	1,453
Oct	5,041	1,927
Nov	909	1,270
Dec	0	1,662
Totals	23,435	23,627

2.2.7 SATICOY WELL FIELD USAGE AND CREDIT SYSTEM BALANCE

In conjunction with the conservation releases from Santa Felicia Dam, United temporarily stores surface water beneath the Saticoy Spreading Ground for later delivery to the overdrafted areas of the Pleasant Valley and Oxnard Plain basins. United constructed the Saticoy well field in 2004, allowing the pumping of mounded groundwater for delivery to the PV and PTP systems. The Fox Canyon Groundwater Management Agency adopted a resolution that created a pump- back storage program of the Saticoy spreading system and its well field usage. Recharged water from the conservation release at the Saticoy Facility to the surface water delivery system can be pumped back for a period of two years. At the end of the two years the storage credits expire. Below is a table showing the history of the credit/ balance of this system. To date an additional 24,900 AF have been stored during the conservation releases at Saticoy, with a total of 9,550 AF extracted for surface water deliveries. The credit system does not include the State Water that is part of the conservation release or the well field pumping when the water levels have “mounded”.

Table 2-6 Credit system for the Saticoy Well Field

	Total Available at the Start of year	Saticoy Well Field S.W. deliveries	Unused allocation	Recharged to Saticoy at end of year less state water
2006	0	0		7,846
2007	7,846	1,753	6,093	3,247
2008	9,340	3,845	5,495	5,695
2009	8,942	2,455	6,487	1,045
2010	6,740	759	5,981	1,821
2011	2,866	737	2,129	5,237

2.2.8 CASTAIC LAKE FLOODFLOW RELEASE

United is the lead member of a water conservation agreement between the California Department of Water Resources and the Downsteam Water Users (DWU). The DWUs consist of United, Los Angeles County, Newhall Land and Farming, and Valencia Water District. The program is designed to hold back flood flows in Castaic Lake and release them at a later date in a manner that allows the flows to percolate in the basins downstream of the dam, benefiting the DWU's. United takes the lead role for the DWUs in requesting the storage and releases, and by monitoring of the associated release to make sure that the flows are benefiting the basins. In 2011 approximately 11,000 AF of captured flood flows were released. Most of the released water percolated into the Piru Basin with some of it making it to the Fillmore Basin. Figure 2.2-5 shows the water level increase in a key well in Piru Basin during the associated release. Figure 2.2-6 shows the inflows/outflows from Castaic Lake in 2011.

2.2.9 BOUQUET RESERVOIR RELEASES

United has an agreement with the Los Angeles Department of Water and Power (LADWP) that provides for the release of flows from Bouquet Reservoir to recharge the aquifers of the Santa Clara River Valley to the extent that they were recharged from Bouquet Canyon outflows prior to construction of the reservoir. The agreement stipulates that LADWP release between 2,100 and 2,194 acre feet per year. This quantity is based on historical annual inflows to the reservoir. The agreement requires a continual release of 5 cfs between April 1st and September 30th; and 1 cfs between October 1st and March 31st of each year.

The prescribed flows were interrupted following an extreme weather event in 2005 that resulted in raising the streambed and pushing it toward Bouquet Canyon Road. In several locations the stream is higher than the road and on occasion stream flows have entered the road posing a threat to public safety. When water is observed on the road, flows from Bouquet Reservoir are reduced.

To complicate matters, this area of Bouquet Creek is designated critical habitat for unarmored three-spined stickleback, and flow changes require special consideration for this species. United has been participating in the stakeholders meetings to ensure that the deficit of water will eventually be released. By 2008 the deficit was approximately 4,400 AF. Since releases have at times been more than the required release, the overall deficit has been reduced to 3,328 AF.

3 HYDROGEOLOGY OF DISTRICT

United Water Conservation District overlies all or portions of eight groundwater basins in central and southern Ventura County. The geologic setting of the basins, the regional aquifers, and some characteristics of each basin are discussed in this section. Discussion related to 2011 conditions in the basins are included in Chapter 4 of this report.

3.1 GEOLOGIC SETTING

The United Water groundwater basins are part of the Transverse Ranges geologic province where the mountain ranges and basins are oriented east-west rather than the typical northwest-southeast trend of much of California. The geology associated with the Transverse Ranges is primarily east to west trending folds and faulting (fold axes trend east-west). This configuration creates the elongate mountains and valleys that dominate Santa Barbara County and Ventura County.

The boundaries of United Water Conservation District are located within the more regional Ventura Basin, which is an elongate east to west trending structurally complex syncline within the Transverse Range province (Yeats, et. al., 1981). The seven basins that underlie the District are the Piru, Fillmore, Santa Paula, Mound, Oxnard Forebay, Oxnard Plain, and Pleasant Valley basins (Figure 1-1). The western portion of the West Las Posas Basin also falls within the District boundary.

The Santa Clara River Valley occupies the Ventura Basin, which is one of the major sedimentary basins in the geomorphic province. The total stratigraphic thickness of upper Cretaceous, Tertiary, and Quaternary strata exceeds 55,000 feet (Sylvester and Brown, 1988).

Active thrust/reverse faults border the basins of the Santa Clara River Valley, contributing to the uplift of the adjacent mountains and down-dropping of the basins. The Piru, Fillmore, and Santa Paula basins are bounded by the Oak Ridge fault to the south and the San Cayetano fault system to the north. The Oxnard Plain and Mound basins extend across the offshore marine shelf to the shelf/slope break (the edge of the shelf).

The basins are filled with substantial amounts of Tertiary and Quaternary sediments that were deposited in both marine and terrestrial settings. The basins on the coast, including the Mound

basin, are filled with recent sediments deposited on a wide delta complex that formed at the terminus of the Santa Clara River. Figure 3.1-1 shows the local formations which form the mountain ranges, surface/subsurface geology, and the major faulting in relation to the United Water basins.

3.2 AQUIFERS

Most of the coastal basins within United Water Conservation District have a shallow perched aquifer zone, and the aquifers of all the basins can be classified as part of an Upper Aquifer System (UAS) and Lower Aquifer System (LAS) (e.g., Turner, 1975; Mukae and Turner, 1975). The UAS consists of the Oxnard and Mugu aquifers. The LAS consists of the Hueneme, Fox Canyon and Grimes Canyon aquifers. The aquifers contain gravel and sand deposited along the ancestral Santa Clara River, from alluvial fans along the flanks of the mountains, from a coastal plain/delta complex at the terminus of the Santa Clara River, and marine deposits from transgressional seas. The aquifers are recharged by infiltration of streamflow (primarily the Santa Clara River), artificial recharge of diverted streamflow, mountain-front recharge along the exterior boundary of the basins, direct infiltration of precipitation on the valley floors of the basins and on bedrock outcrops in adjacent mountain fronts, and irrigation return flow in some agricultural areas.

Figure 3.2-1 is a schematic of the UAS and LAS showing their subsurface sequence. The figure also shows general depths in feet. However, more recent work with geophysical logs has suggested that some of the aquifers are actually deeper than originally thought and indicated on this schematic. Also note that the clay layers (aquicludes) shown in the UAS are inter-fingering and in some places discontinuous.

3.2.1 PERCHED/SEMI-PERCHED

On the Oxnard Plain, the uppermost silt and clay deposits of the Oxnard aquifer are overlain by sand layers of the “semi-perched zone,” which generally contains poor-quality water. This zone extends from the surface to no more than 100 ft in depth. The confining clay of the upper Oxnard aquifer generally protects the underlying aquifers from contamination from surface land uses. Deep percolation of rainfall and irrigation return flows are the major components of recharge to the semi-perched zone. The semi-perched zone is rarely used for water supply on the Oxnard Plain.

3.2.2 UPPER SYSTEM

The Upper Aquifer System (UAS) consists of the Oxnard and Mugu aquifers. These aquifers are characterized by recent alluvium (Oxnard aquifer) of Holocene age and older alluvium (Mugu aquifer) of late Pleistocene age. The Oxnard aquifer rests unconformably on the Mugu aquifer. A clay layer occurs between the aquifers.

Recent river channel deposits comprise the uppermost water-bearing units along portions of the Santa Clara River basins. These deposits are generally up to 100 ft in thickness. In the Santa Paula basin, nested monitoring wells indicate that this upper alluvial aquifer is somewhat isolated from the underlying aquifers of the San Pedro formation. The alluvial unit, from which there is considerable water production in the Santa Clara River basins, may be time-equivalent to portions of the UAS on the Oxnard Plain, but has not been assigned to the UAS in the literature.

3.2.2.1 OXNARD

The Oxnard aquifer materials generally consist of lagoonal, beach, river, floodplain and alluvial fan deposits (Turner, 1975). The Oxnard aquifer is present throughout the Oxnard Plain and other basins. The Oxnard aquifer is the primary aquifer used for groundwater supply on the Oxnard Plain. This highly-permeable assemblage of sand and gravel is generally found at a depth of approximately 100 ft to 250 ft below land surface elevation.

3.2.2.2 MUGU

The Mugu aquifer materials generally consist of lagoonal, beach, river, floodplain, alluvial fan terrace and marine terrace deposits. The Mugu aquifer rests unconformably on the LAS. Basal conglomerates occur in many areas (Hanson et al, 2003). In the Oxnard Plain, these coarse-grained basal deposits comprise the Mugu aquifer (Turner, 1975). The Mugu aquifer is generally penetrated at a depth of 255 ft to 500 ft below land surface.

3.2.3 LOWER SYSTEM

The Lower Aquifer System (LAS) consists of the Grimes Canyon, Fox Canyon, and Hueneme aquifers (Figure 3.2-1). The LAS is part of the Santa Barbara, San Pedro, and Saugus formations of Plio-Pleistocene age (Mukae and Turner, 1975).

In any of the basins, the aquifers of the LAS may be isolated from each other vertically by low-permeability units and horizontally by regional fault systems. The LAS is folded and tilted in many areas, and has been eroded along an unconformity that separates the upper and lower aquifer systems.

3.2.3.1 HUENEME

The Hueneme aquifer is considered to underlie the Oxnard Plain basin (Hanson et al, 2003). The Hueneme aquifer materials generally consist of terrestrial fluvial sediments, and marine clays and sands. In the basins along the Santa Clara River, the deeper aquifer system is generally considered to be the San Pedro Formation (Mann, 1959) or the time-equivalent Saugus Formation, although the U.S. Geological Survey considers this deeper aquifer to be equivalent to the Hueneme aquifer (Hanson et al, 2003).

3.2.3.2 FOX CANYON

The Fox Canyon aquifer underlies the Las Posas, Pleasant Valley, Oxnard Forebay and Oxnard Plain basins. The Fox Canyon aquifer materials generally consist of marine shallow regressive sands and some clays. The Fox Canyon aquifer is the lower unit in the San Pedro formation. This same unit also extends north into the Mound basin, but the character of the sediments change to more finely-bedded deposits (UWCD, 2012).

3.2.3.3 GRIMES

The lowest water-bearing unit of the East Las Posas and Pleasant Valley basins is commonly referred to as the Grimes Canyon aquifer (CA DWR, 1954; Turner, 1975). The Grimes Canyon aquifer materials generally consist of marine shallow regressive sands.

3.3 GROUNDWATER BASINS

The groundwater basins within the District vary in their water production and ability to be recharged rapidly. The groundwater basins detailed here are really sub-basins of the larger basin of the Santa Clara River Valley (CA DWR, 2003). Hydraulic connection exists between all basins within the District boundaries. The Fillmore basin receives recharge as underflow from the Piru basin, and the Santa Paula basin receives significant recharge from the Fillmore basin. The Mound basin receives recharge from the Santa Paula basin and from the Oxnard Plain and Oxnard Forebay basins, although head differentials across the western Santa Paula basin boundary are greater than those between the other sub-basins of the Santa Clara River valley. The Oxnard Forebay basin is widely recognized as the primary recharge area for aquifers in the Oxnard Plain. Many of the confining clays present in the aquifer systems of the Oxnard Plain are absent or discontinuous in the Oxnard Forebay basin, creating a window for recharge to other down-gradient aquifers. High groundwater elevations in and near the Oxnard Forebay promote groundwater flow to the nearby Mound and West Las Posas basins. The Pleasant Valley basin is more distant from the Oxnard Forebay and receives less direct benefit from United's recharge operations, but pipelines have been constructed to convey irrigation water directly to water users in Pleasant Valley and on the southern Oxnard Plain.

3.3.1 PIRU

The Piru basin consists of recent and older alluvium underlain by San Pedro (Saugus) Formation. The recent and older alluvium is made up of coarse sand and gravel that are present to a depth of approximately 60 to 80 feet throughout the basin. The San Pedro Formation consists of permeable sand and gravel and extends to a depth of approximately 8,000 feet. Two faults bound the Piru basin, the Oak Ridge fault to the south and the San Cayetano fault to the north (UWCD, 1996b).

Groundwater flow in the alluvium of the Piru basin tends to be westerly, parallel to the river channel. Similarly, the flow gradient in the San Pedro Formation is westerly with a small north/south component as the groundwater moves parallel to the axis of the syncline that forms the basin. The basin is considered to be an unconfined groundwater basin. The Santa Clara River and Piru Creek are major sources of recharge to the Piru basin, with minor sources from smaller streams, from outcrops to the north of the basin, and from percolation of rainfall. United occasionally operates the Piru Spreading Grounds, a 44-acre recharge basin which diverts water from Piru Creek for groundwater recharge. The Piru basin readily accepts large volumes of recharge as surface water percolates to groundwater in the channel of the river. During United's conservation releases from Lake Piru a significant percentage of flow infiltrates through the river channel and serves to recharge the Piru basin.

Under low-flow conditions (up to approximately 100 cfs), all of the surface flow of the Santa Clara River coming from Los Angeles County commonly infiltrates into the Piru basin above the confluence of Piru Creek, so that there is no continuity of river flow across the basin. Continuous surface flow may extend the length of the basin following large winter storms, during large releases from Castaic Lake, and in the winter and early spring of exceptionally wet years. A lengthy "dry gap" of approximately five miles commonly exists in the central portion of the Piru basin, extending from the point of complete percolation of surface water east of Piru Creek to areas near the downstream end of the basin. During United's conservation releases flows ranging from 100-200 cfs are often required to establish surface flow between Piru Creek and the west end of the basin. In the area west of Hopper Creek groundwater flow is constricted as the basin narrows and shallow groundwater intersects the river channel. This "rising groundwater" contributes or restores surface flow in the river near the west end of the basin. When groundwater levels in the Piru basin are high, the area of rising groundwater extends farther east than in drier times, and the total flow of the discharge to surface water is greater. At the lower end of the Piru basin, a significant amount of groundwater flows into the Fillmore basin as underflow (Mann, 1959).

The channel of the Santa Clara River stays along the basin's southern edge over the length of the basin, likely secured in that position by the alluvial fans of Piru and Hopper Creeks entering the basin from the north. Chloride impacts associated with wastewater discharges sourcing from Los Angeles County over the past decade are now observed in wells along the northern portions of the middle of the basin. The northerly extent of these chloride impacts suggests the primary groundwater flow paths down the basin are north of the modern river channel. Groundwater flow paths are likely influenced by both geologic structure within the basin and the extraction of groundwater in the northern portions of the basin.

3.3.2 FILLMORE

The Fillmore basin consists of varying alluvial deposits resting on the San Pedro Formation. The younger alluvial deposits comprise recent sands and gravels of the Santa Clara River and Sespe Creek in the southern and eastern parts of the basin. Southward-sloping alluvial fan material forms

the Sespe uplands in the north-central portion of the basin, and alluvial fan material of the Pole Creek Fan underlies the City of Fillmore (UWCD, 1996b). Alluvial thickness varies from 60 to 120 ft. The San Pedro Formation, folded into an east-west syncline, underlies most of the Fillmore basin. Along the main axis of the syncline, the San Pedro Formation reaches a depth of 8,430 feet. At the western basin boundary, the San Pedro Formation extends to a depth of 5,000 to 6,000 feet.

The groundwater flow gradient in the Fillmore basin generally creates an east to west movement of groundwater through the alluvium. Groundwater that infiltrates from Sespe Creek generally flows towards the southwest. In the San Pedro Formation, the movement of groundwater is believed to be southerly beneath the Sespe fan, changing to westerly near the axis of the syncline. The basin is considered an unconfined groundwater basin. The Santa Clara River and Sespe Creek are two major sources of recharge to the Fillmore basin, as is underflow from Piru basin. As with the Piru basin to the east, the Fillmore basin readily recharges in years of abundant rainfall and streamflow.

The Fillmore basin narrows at the downstream end, resulting in an extensive area of rising groundwater and gaining flow in the Santa Clara River. Extensive wetlands exist in this area, and are easily visible on aerial photographs. Groundwater underflow into the Santa Paula basin is likely significant, although some suggest surface flow related to rising groundwater comprises a larger component of the discharge from the basin (Mann, 1959).

3.3.3 SANTA PAULA

The Santa Paula Basin is located along the Santa Clara River, extending from approximately Kimball Road and the town of Saticoy in the west to Santa Paula Creek in the east. The basin is bounded by the Sulphur Mountain foothills on the north and South Mountain on the south. The basin is elongated in a northeast-southwest direction, about 10 miles long and as much as 3.5 miles wide. The surface area of the basin is approximately 13,000 acres, and ranges in elevation from 130 feet above sea level near Saticoy to 270 feet above sea level near the City of Santa Paula. Ongoing uplift along the Oak Ridge and other faults has created a deep basin, with Plio-Pleistocene deposits exceeding 10,000 feet in thickness.

The principal fresh water-bearing strata of the Santa Paula Basin are the Pleistocene San Pedro Formation, Pleistocene river deposits of the ancient Santa Clara River, alluvial fan deposits shed from the uplifted mountain blocks, and recent river and stream sediments deposited locally along the Santa Clara River and its tributaries. These water-bearing sediments are underlain by relatively impermeable Pliocene and older units. The sediments of the basin have been warped into a syncline that is oriented in a northeast-southwest direction along the center of the basin. To the east, the Santa Paula Basin is considered to be in hydraulic connection with the Fillmore Basin. To the south, the Oak Ridge fault forms a partial barrier to groundwater movement. On the north, the portion of the aquifer represented by the San Pedro Formation is exposed in an outcrop along the Sulphur Mountain foothills. The Santa Paula basin borders the Oxnard Forebay and Mound basins on the west. The western boundary of the Santa Paula Basin is more complex, with local uplift and

faults mapped by some investigators. Although there is general agreement that there is some hydraulic connection between Santa Paula Basin and the Mound Basin, the degree of connection is uncertain.

Long-term records of groundwater elevations within the Santa Paula basin demonstrate that the basin has a more muted recharge response to wet years than the Piru and Fillmore basins to the east. Much of the recharge likely occurs in the eastern portion of the basin (Santa Paula Basin Experts Group, 2003). Groundwater levels in many wells in the central and western portions of the basin show significant seasonal variability, suggesting some degree of confinement. During high rainfall years, monitor wells in the southern portion of the basin near the Freeman Diversion, and historically some other wells near Saticoy, have shown artesian flow. The complex subsurface geology in the western portion of the basin complicates interpretations of groundwater flow in this area.

3.3.4 MOUND

The principal fresh water-bearing strata of the Mound basin are the upper units of the San Pedro Formation and overlying Pleistocene deposits that are interpreted to be correlative with the Mugu aquifer of the Oxnard Plain basin. There is an upper confining layer of Pleistocene clay approximately 300 feet in thickness. The basin extends several miles into the offshore.

The sediments of the basin have been warped into a syncline that is oriented in an east-west direction that roughly follows Highway 126. Structural disruption along the Oak Ridge fault in the southern portion of the basin has resulted in considerable uplift and erosion of the San Pedro and younger sediments. This disruption is the cause of the topographic “mounds” near the intersection of Victoria Avenue and U.S. 101, for which the basin is named. The Montalvo anticline has traditionally been used to define the southern extent of the basin. These structural features generally offset only the deeper LAS units of the adjacent Oxnard Plain. The deposits of the Upper Aquifer System overlie the faults and folds along the southern margins of the basin, but the character of the deposits change as they extend to the north, becoming more finely bedded and fine-grained (UWCD, 2012b).

The limited number of wells in the Mound basin, especially in the northern half of the basin, complicates efforts to ascertain the primary sources of recharge to the basin. There likely is some component of recharge from precipitation falling on aquifer units that outcrop in the hills along the northern margin of the Mound basin (Figure 3.1-1), but no wells exist to provide evidence of this occurrence. There is general agreement that the basin benefits from recharge from the Oxnard Forebay and Oxnard Plain to the south, especially during periods of high water level on the Plain (GTC, 1972; Fugro, 1996; UWCD 2012b). The hydrogeologic boundaries of the Mound basin are not coincident with the structural boundaries of the basin, so there is hydrologic connection between the Mound basin and adjoining groundwater basins (UWCD, 2012b). The amount of recharge from the Santa Paula basin to the east is also unclear, but high heads in some wells in the eastern

Mound basin suggests some degree of connection and recharge. Mann (1959) suggested that there is little underflow from the Santa Paula basin to the Mound basin, although more recent studies suggest it may be significant (Fugro, 1996; UWCD, 2012b).

Groundwater flow in the Mound basin is generally to the west and southwest with modest to weak gradients, especially in times of drought. The poor distribution and limited number of wells with water level records complicates efforts to contour groundwater elevations in the basin. During periods of drought and increased pumping, a pumping trough forms along the southern portion of the basin that significantly modifies groundwater gradients.

3.3.5 OXNARD FOREBAY

Both UAS and LAS aquifers are present in the Oxnard Forebay and Oxnard Plain basins. The Oxnard Forebay maintains direct hydraulic connection with confined aquifers of the Oxnard Plain basin, which extends several miles offshore beneath the marine shelf where outer edges of the aquifer are in direct contact with seawater. In areas near Port Hueneme and Pt. Mugu where submarine canyons extend nearly to the coastline, the fresh-water aquifers may be in direct contact with seawater a short distance offshore.

The Forebay is the main source of recharge to the Oxnard Plain basin. Recharge to the Forebay benefits other coastal basins (Mound, West Las Posas, Pleasant Valley) but a majority of the water recharged to the Forebay flows downgradient to the confined aquifers of the Oxnard Plain. The shallow sediments of the basin are dominated by coarse alluvial deposits of the ancestral Santa Clara River. The absence of low-permeability confining layers between surface recharge sources and the underlying aquifers in the Forebay allow rapid groundwater recharge in the Forebay. The recharge to the Forebay comes from percolation of Santa Clara River flows, artificial recharge from United's spreading basins, irrigation return flows, percolation of rainfall, and likely lesser amounts of underflow from the Santa Paula basin and mountain-front recharge from the nose of South Mountain. In the area of the Forebay between the El Rio and Saticoy spreading grounds, the LAS has been uplifted and truncated along its contact with the UAS. In this area recharge from surface sources may enter both the UAS and the underlying LAS. The U.S. Geological Survey estimates that about 20% of the water recharged to this area reaches the LAS, with the remainder recharging the UAS. In some areas of the Forebay significant clays are present among the deposits of the LAS.

3.3.6 OXNARD PLAIN

The Oxnard Forebay is hydraulically connected with the aquifers of the Oxnard Plain basin, which is overlain by an extensive confining clay layer. Thus, the primary recharge to the Oxnard Plain basin is from underflow from the Forebay rather than the deep percolation of water from surface sources on the Plain. Natural and artificial recharge to the Forebay serves to raise groundwater elevations in this up-gradient area of the groundwater flow system for the Oxnard Plain. High water levels in

the Forebay increase the hydrostatic pressure in the confined aquifers extending from the margins of the Forebay to the coastal and offshore portions of these continuous aquifer units. While the physical movement of groundwater out of the Forebay is fairly slow, the pressure response in the confined aquifers distant from the Forebay responds more rapidly to significant recharge events in the Forebay. When groundwater levels are below sea level along the coastline, there may also be significant recharge by seawater flowing into the aquifers.

Vertical gradients also commonly exist between aquifer units on the Oxnard Plain, resulting in some degree of water movement through low-permeability units that occur between most of the major aquifers. When LAS water levels are substantially lower than UAS water levels (creating a downward gradient), there may be substantial leakage of UAS water into the LAS through the confining clays. Likewise, a downward pressure gradient can exist between the Semi-perched aquifer and the Oxnard aquifer when heads in the shallow confined Oxnard aquifer are lowered (either regionally by drought conditions or locally by pumping wells). The movement of poor quality water from the semi-perched zone to the Oxnard aquifer has been documented in some locations, with abandoned or improperly constructed wells being a notable pathway for this downward flow (Izbicki, 1992; Stamos et al, 1992).

The highly-permeable deposits of the UAS are relatively flat lying across approximately the upper 400 feet of the Oxnard Plain. In the northern Oxnard Plain heads are often similar in the Oxnard and Mugu aquifers, but heads in the Mugu are considerably deeper in the greater area surrounding Mugu Lagoon. Deposits of the LAS are generally finer-grained and have been deformed by folding and faulting in many areas. An uneven distribution of pumping, along with structural and stratigraphic changes within the deposits of the LAS result in varied heads among the deep wells across the Oxnard Plain and Pleasant Valley.

3.3.7 PLEASANT VALLEY

Pleasant Valley is bounded to the south by the Santa Monica Mountains, to the north by the Camarillo Hills, and to the west by the Oxnard Plain. The Bailey fault runs along the base of the Santa Monica Mountains, and the Camarillo fault along the Camarillo Hills to the north.

The Pleasant Valley basin is differentiated from the Oxnard Plain basin by a general lack of UAS aquifers (Turner, 1975). The UAS is composed of alluvial deposits about 400 feet thick. In Pleasant Valley much of the UAS is fine grained and not extensively pumped for water supply (Turner, 1975; Hanson et al, 2003). Although where coarse-grained deposits are present, wells in the UAS underlying Pleasant Valley can yield large quantities of water to wells.

The LAS is composed of the Hueneme, Fox Canyon, and Grimes Canyon aquifers to a depth of about 1,400 feet. The Hueneme aquifer is composed of alternating layers of sand and finer grained deposits. The Fox Canyon and Grimes Canyon aquifers are composed of thick sequences of relatively uniform marine sand. The Fox Canyon aquifer is the major water-bearing unit in the basin.

In Pleasant Valley the LAS is surrounded and underlain by partly consolidated marine deposits and volcanic rocks. Marine deposits are present in the Camarillo Hills and in the western edge of the Santa Monica Mountains near the coast. As a result of faulting and uplift of the underlying marine deposits near Mugu Lagoon the LAS is not hydraulically connected to the Pacific Ocean in this area (Izbicki, 1996a; Hanson et al., 2003). Volcanic rocks consisting of basalts, submarine volcanic flows, and debris flows are present in the Santa Monica Mountains along the southern edge of the valley (Weber et al., 1976). The underlying marine deposits and volcanic rocks both contain high-chloride water.

Under predevelopment conditions groundwater movement in the UAS and LAS was likely from recharge areas in the eastern part of Pleasant Valley toward the Oxnard Plain to the southwest. The LAS in Pleasant Valley appears to be fairly isolated from sources of recharge, and the time since recharge of the ground water ranges from 3,000 to more than 6,000 years before present (Izbicki, 1996b). Groundwater age increases with depth and water within deeper aquifers has contacted aquifer material longer, reacting to a greater extent with these materials than water in overlying aquifers. Over the past two decades water levels in two wells in northern Pleasant Valley have recovered more than 250 feet. The re-establishment of surface flow in Arroyo Las Posas that subsequently percolates at the northern margin of the basin is now recognized as a source of recharge to the basin.

High-chloride concentrations are present in water from wells throughout Pleasant Valley, especially along the southern edge of the valley near the Bailey Fault. Wells yielding high-chloride water in this area may have been drilled too deep and directly penetrated deposits having high-chloride water, or high-chloride water may have invaded deeper freshwater aquifers from surrounding and underlying deposits as a result of pumping. However, despite their isolation from sources of ground water recharge, chloride concentrations in water from deep wells in Pleasant Valley increase during dry periods when ground-water pumping increases. Conversely, chloride concentrations decrease during wetter periods when alternative sources of irrigation water are available from surface supplies and groundwater pumping decreases. Regardless of the source, changing hydraulic pressure as water levels within the lower aquifer system decline as a result of pumping wells, especially during dry periods, may increase chloride concentrations in water produced from deeper wells if the proportion of high-chloride water yielded to the well from underlying deposits increases (Izbicki et al., 2005a). In addition to water from surrounding and underlying rocks, irrigation return also may contribute to high chloride concentrations in deep wells that are partly screened in the upper aquifer system. More recently, groundwater recharge from Arroyo Las Posas in the northern portion of the basin has been recognized as an additional source of salt in the basin.

3.3.8 LAS POSAS

The West Las Posas basin lies adjacent the northeast Oxnard Plain in the area south of South Mountain and north of the Camarillo Hills. The basins generally consists of a broad alluvial plain sloping to the south, and is drained by Beardsley Wash which flows west around the Camarillo Hills.

Only the western portion of the West Las Posas basin lies within United's District boundary. Tree crops are the dominant land use in this agricultural area. Much of this area is served by groundwater imports from the Oxnard Plain, but some agricultural pumping is reported from deep wells near Beardsley Wash and the South Mountain foothills.

Most groundwater production in the West Las Posas basin is from deposits of the San Pedro Formation. Beneath most of the Las Posas Valley, the upper San Pedro Formation consists of low permeability sediments with lenses of permeable sediments which are age-equivalent to Hueneme Aquifer on Oxnard Plain (DWR, 1975). The permeable lenses form isolated, yet, locally important water sources. The water-bearing zones in the upper San Pedro Formation are not well connected. Some recharge to the deeper Fox Canyon aquifer may source from downward leakage from the upper San Pedro Formation. Many wells in the Las Posas Basin are perforated in the Fox Canyon aquifer, making it the principal water-bearing unit (Mukae, 1988). The FCA is exposed almost continuously along the southern flank of South Mountain. South of the outcrop, beds of the Fox Canyon aquifer dip below the valley and are folded into a series of anticlines and synclines. Groundwater in the Fox Canyon aquifer exists under confined conditions beneath the valley and unconfined conditions at the valley margins where the aquifer is folded upward and exposed at the surface. Much of the groundwater recharge to the western portion of the West Las Posas basin is believed to source from the Oxnard Plain. Minor amounts of recharge are derived likely from infiltration of precipitation and runoff in the outcrop areas.

4 ANNUAL HYDROLOGIC CONDITIONS

This section details the range of hydrologic conditions observed throughout United's district boundaries in the year 2011. While the emphasis is placed on surface water and groundwater conditions over the past year, some discussion is devoted to the comparison of recent conditions to conditions documented in the historical record. Recorded rainfall totals were commonly several inches greater than average, but significant storm events occurring in December 2010 and March 2011 resulted in high base flows in the Santa Clara River and its major tributaries. The groundwater response to the above-average flow in stream channels, increased surface water deliveries and reduced pumping associated with the wet conditions was favorable.

4.1 PRECIPITATION AND EVAPOTRANSPIRATION

United participates in data collection in partnership with the Ventura County Watershed Protection District's three rainfall gauges, two of which are also evaporation stations. The VCWPD maintains approximately 125 gauges around the county (Figure 4.1-1). United's gauges are located at the field offices in Saticoy, El Rio, and at the guard station at the Lake Piru. United also maintains records from the gauge at the office in Santa Paula for its own use. United's monitoring stations showed that precipitation was about 136% of normal for the water year, with December and March

accounting for 65% of the rainfall. Lake Piru recorded 28.48 inches of rainfall, approximately 8.6 inches more that the average received at that location, and in the top 20% in terms of rainfall totals for this station.

Table 4-1 Monthly Precipitation for water year 2011

Monthly Precipitation Data - 2010-11 Water Year													
Gauge Location	**Gauge no.**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
El Rio	**231**	1.87	1.01	8.43	0.53	2.34	4.58	0.00	0.55	0.10	0.00	0.00	0.00
Lake Piru	**160**	2.04	1.54	11.92	0.62	5.27	6.22	0.06	0.80	0.01	0.00	0.00	0.00
Santa Paula	**245**	2.11	1.07	9.61	0.30	3.64	6.03	0.00	0.89	0.14	0.00	0.00	0.00

4.2 SURFACE WATER

The Santa Clara River Watershed is extensively monitored by multiple agencies for rainfall, daily stream discharge and flood flows. Data for many of the monitoring sites goes back to the early 1900s giving a long period of record for comparison purposes. The year 2011 overall would fall in the normal to wet category in terms of both precipitation and run-off. Below is a brief discussion of how 2011 compares to the historical record. Daily and monthly data for all the sites discussed can be obtained on-line at websites maintained by the USGS and VCWPD.

4.2.1 SANTA CLARA RIVER SYSTEM

The Santa Clara River is the largest river system in southern California remaining in a relatively natural state. The headwaters start on the northern slopes of the San Gabriel Mountains and the river flows approximately 84 miles to an estuary and river mouth at the Pacific Ocean near Ventura Harbor on the northern Oxnard Plain. The major tributaries include Castaic Creek and San Francisquito Creek in Los Angeles County, and Sespe, Piru and Santa Paula creeks in Ventura County. While the Los Angeles portion of the watershed accounts for 40% of the total area, it only produces about 20% of the total river flow, with dry-season base flows sustained by discharges from wastewater treatment plants and rising groundwater from the Eastern groundwater basin. As mentioned in other sections of this report, even though 2011 was wetter than most years, large sections of the main stem of the Santa Clara River remained dry for most of the year.

4.2.1.1 FLOW IN THE SANTA CLARA RIVER WATERSHED

Surface water flows in the Santa Clara River system were well above normal for the 2011 calendar year. The season started out wet with an early storm in December 2010, before the reporting period for this report. Figure 4.2-1 shows monthly flows in each of the tributaries. The storm peaked Sespe flows over 3,000 cfs a couple of times before runoff subsided in late February. Two

smaller storms were then followed by a large March storm where the Sespe's peak flow exceeded 35,000 cfs. Flows in the Sespe were over 1,000 cfs for the next 10 days. Figure 4.2-2 shows the monthly flows in the Sespe compared to the monthly average flows. The response to the March storm was much different in the Piru watershed due to the elevation difference between the two watersheds. The higher elevations in the Piru watershed accumulated several feet of snow. The storm resulted in flows peaking at about 600 cfs in Piru Creek at Pyramid Lake. The runoff then subsided to less than 200 cfs over the next couple of days. A warm period then melted the snow, creating diurnal fluctuations in runoff of up to 600 cfs in Piru Creek (Figure 4.2-3).

The USGS station 111090000, Santa Clara River near Piru, measures the entire contribution from Los Angeles County's portion of the watershed that flows into Ventura County. This station recorded a peak flow of nearly 9,000 cfs in the March storm. Flows subsided to a little over 300 cfs within a couple of days after the peak. A large release from Castaic Lake in the month of April brought the average flow up to 11,000 AF that month.

Table 4-2 Total Discharge for various stream flow stations

USGS/VCWPD Stream flow Stations	Total Discharge for 2011
	AF
Santa Clara River Near Piru USGS Sta. 11109000	61,824
Piru Creek Above Santa Felicia Dam USGS Sta. 11109600	61,787
Piru Creek Below Santa Felicia Dam USGS Sta. 1110900	36,175
Sespe Near Fillmore USGS Sta. 1111300	124,500
Santa Paula Creek VCWPD 709	29,700
Santa Clara River at Victoria VCWPD 723	121,052

The natural runoff in most of the tributary watersheds was about 130% to 140% of average. The main exceptions were flows coming from Los Angeles County which were 156% of the average, and flows below Santa Felicia Dam which were near normal. Los Angeles County's flows may have been proportionally higher than the other watersheds for two reasons. Wastewater discharge to the river has been gradually increasing since the late 1970s, and the DWR did not appropriate any storm inflow into Castaic Lake in 2011 because all stored inflows could be beneficially used downstream in April and May. See Section 2.2.8 for discussion concerning the Castaic flood flow release.

4.2.1.2 WATER QUALITY

United maintains a surface water quality monitoring program and collects samples from a number locations at frequencies ranging from quarterly to every two weeks. Sampling sites are generally located on the Santa Clara River near groundwater basin boundaries and at the major tributaries near the confluence with the river. Additional water quality sampling sites include the Santa Clara River at the Freeman Diversion and the weir where surface water arrives at United's El Rio

recharge basins. Sample analysis commonly consists of either a full inorganic general mineral suite or several key constituents such as TDS, chloride and nitrate. This surface water quality monitoring provides documentation of variations in surface water quality and information on the quality of water that is recharging the groundwater basins of the District. Sampling is conducted every three month at most of the sites, but more frequently at some key locations (Santa Clara River: every month near County Line and every two weeks at Freeman Diversion).

Water quality at the various sampling sites throughout the District tends to vary seasonally, with the lowest annual mineral concentrations commonly recorded in the winter and spring when flow is higher. Results from United's 2011 surface water sampling are shown on Figures 4.2-4 and 4.2-5, where the annual recorded maximum concentrations of chloride and TDS, respectively, are displayed over the annual minimum values. The range in values is from four seasonal samples at most locations, so the true range in quality in the water bodies is likely greater than what is documented.

Water quality in Piru Creek is influenced by Pyramid Lake located higher in the Piru Creek watershed, which receives large volumes of water from the State Water Project. Water in middle Piru Creek is a blend of State Water and local runoff from the upper Piru Creek watershed. When chloride concentrations in State Water are high, the chloride in middle Piru Creek and Lake Piru can be much higher than what would occur naturally. In 2011 the maximum-recorded chloride above Lake Piru was 57 mg/l, a value lower than many recent years due to lower State Water chloride concentrations and above-average precipitation in the watershed.

Chloride concentrations in the Santa Clara River near the Los Angeles County line are also influenced by chloride in imported State Water, as Castaic Lake Water Agency delivers State Water to water retailers in the greater Santa Clarita area. Nearly 50% of the chloride load in wastewater discharges is from the chloride load in delivered water (LACSD, 2008). Additional chloride loading occurs during beneficial use of the delivered water, but loading has been significantly reduced in recent years as the Los Angeles County Sanitation District has managed a successful campaign to remove thousands of self-regenerating water softeners from the community. The Sanitation Districts are trying to satisfy regulatory requirements for the quality of their effluent, but the approach to be taken is not yet clear as community residents have resisted funding a chloride TMDL proposed by the Sanitation Districts and approved by the Los Angeles Regional Water Quality Control Board in December 2008.

Over the past decade chloride concentrations in the Santa Clara River have varied considerably near the Los Angeles County line as water quality at this location is heavily influenced by discharges from the Valencia Water Reclamation Plant. From the late 1990s through 2003 the discharges from the Valencia plant increased steadily in both volume and chloride, with chloride concentrations exceeding 200 mg/l near the end of this period. Since 2003 chloride concentrations in the discharges have fallen somewhat: however, chloride in the river commonly exceeds the 100 mg/l surface water objective during months without significant rainfall (Figure 4.2-6). The lower chloride concentrations in the Santa Clara River in recent years are largely related to lower chloride

in wastewater discharges from the Valencia WRP (Figure 4.3-6). This is likely the result of lower chloride levels in State Water Project imports and a successful ban of self-regenerating water softeners in City of Santa Clarita area homes. Prior to 1970 the discharge of oilfield brines significantly impaired water quality in the river at this location, but flows associated with this poor water quality were likely minor.

Beginning in January 1999, United has sampled the Santa Clara River near the Los Angeles County line each month for chloride and other analytes. Sampling in 2011 documented chloride concentrations ranging from 79 to 132 mg/l. Chloride concentrations in the water released from Lake Piru ranged from 47 to 59 mg/l over the same time period (Figure 4.2-4). All surface water sample locations recorded lower-than-average chloride in 2011 following the abundant rainfall in the winter and spring.

In recent years both the City of Fillmore and the City of Santa Paula have eliminated discharges of treated wastewater to the Santa Clara River. Santa Paula's new treatment plant came on line in 2010 and now utilizes percolation basins for wastewater disposal. Fillmore completed a new plant in 2009 and now distributes reclaimed water to both percolation basins near the plant site and a network of subsurface irrigation systems constructed in parks and school fields throughout the City. The City of Fillmore has banned installation of self-regenerating water softeners as part of its efforts to reduce chloride loading to the watershed. There are now no Ventura County water reclamation plants discharging flow to the Santa Clara River. Continuous river flow from Los Angeles County to the Freeman Diversion is uncommon, but when there is connection flows are usually high in the lower watershed and the recycled water component sourcing from Los Angeles County is very minor. The maximum-recorded chloride concentration in the Santa Clara River at Freeman Diversion in 2011 was 69 mg/l (Figure 4.2-4).

United frequently monitors water quality in the Santa Clara River at the Freeman Diversion, the point where water is diverted from the river for either direct deliveries to agricultural users or groundwater recharge in the Oxnard Forebay. Samples are collected at the Freeman Diversion approximately every two weeks to confirm that the water is acceptable for use in both aquifer recharge and for irrigation deliveries. The TDS and chloride content of water in the river at this location exhibits a strong negative correlation with flow, with higher flows being less mineralized (Figure 4.2-7 and Figure 4.2-8). Under dry conditions groundwater discharge from the Fillmore basin comprises a large portion of the river flow at the Freeman Diversion. Under wetter conditions tributary flow, most notably from Sespe and Santa Paula Creeks, contribute flow to the lower river and improves water quality compared to low-flow conditions. High river flows resulting from the direct runoff of precipitation commonly has the lowest dissolved mineral content, as does the recession limb of hydrographs from large flow events (Figure 4.2-7). United commonly diverts large volumes of water from the river for groundwater recharge during these periods of high flow and good water quality. Recorded TDS concentrations at the Freeman Diversion ranged from 570 to 1150 mg/l in 2011 (Figure 4.2-5).

Nitrate concentrations in the Santa Clara River at Freeman Diversion show some negative correlation with flow but concentrations are routinely low in the river during both high and low flows (Figure 4.2-9). A weak seasonal signature has been observed, with nitrate concentrations rising slightly in the fall (UWCD, 2008). For the 26 samples collected at Freeman Diversion in 2011 the maximum-recorded nitrate concentration was 8.4 mg/l, well below the CA DPH health standard of 45 mg/l.

The County of Ventura maintains and operates composite sampling device at the Freeman Diversion, and samples storm flow and dry weather base flows several times per year. These samples are analyzed for a broad suite of organic contaminants and metals as part of a storm water quality program required by the Los Angeles Regional Water Quality Control Board. Detections of organic contaminants such as pesticides are uncommon and generally of low concentration (VCWPD, 2010)

4.2.2 CALLEGUAS CREEK

United does not actively gauge or sample surface water in the Calleguas Creek watershed. Much of the monitoring activity in the Calleguas Creek watershed is currently associated with the Salts TMDL under development for the watershed.

4.3 GROUNDWATER

Groundwater is utilized extensively for municipal and agricultural use throughout the boundaries of United Water Conservation District, as imported water supplies are unavailable over much of this area. United has a responsibility to monitor conditions in the basins throughout the District so that the basins are understood and managed as needed. Many small water supply projects are completed without United's direct involvement, but proponents of most large water projects engage United's support in some way (e.g., data sets, technical support, financial assistance, etc.).

The following sections detail 2011 basin conditions within the eight groundwater basins which fall wholly or partially within United's District boundaries. Following the favorable recharge conditions in the watershed in the winter and spring of the year, and large releases from Lake Piru and Castaic Lake, groundwater conditions were generally good compared to other recent years. Some discussion in the following section is devoted to comparing current conditions to past periods of drought, or periods pre-dating some major water supply projects within the District.

4.3.1 PIRU BASIN

The Piru basin has the capacity to rapidly accept water from the channel of the Santa Clara River and tributary streams. Some component of the water stored in the basin is slowly discharged to the downstream Fillmore basin, so that in some ways the Piru basin acts as a "forebay" to downstream groundwater basins in the Santa Clara River Valley. Surface water discharge of rising groundwater

at the west end of the basin is greater when water levels are higher in the downstream portions of the basin. Groundwater elevations tend to remain well above historic lows, but over the past decade chloride impacts sourcing from Los Angeles County have migrated down past the midpoint of the basin.

4.3.1.1 WATER LEVELS

Historical groundwater elevations for United's Piru basin key well, located northwest of the confluence of Piru Creek and the Santa Clara River are shown on the hydrograph in Figure 4.3-1. The historical record for this well shows that groundwater elevations in the Piru basin fluctuate dramatically, and that the basin is capable of rapid recovery of water levels following drought periods. Water level recovery at this location is largely related to channel recharge associated with high and prolonged flow in the Santa Clara River and in Piru Creek, such as that which occurs during reservoir releases or large winter storms.

The basin fills in wet years such as 1998 and 2005, as shown by the flat-topping of groundwater elevations at 620 feet. Although 2011 was a moderately wet year the basin did not fill to historical highs. The 2011 recorded high groundwater elevation at United's key well is approximately 12 feet lower than recorded high groundwater elevations. The groundwater elevation recorded in this well in 1991 was 510 feet above sea level, at the end of a period of drought.

Piru basin groundwater levels have benefited from the recharge of recycled water discharged to the Santa Clara River by water reclamation plants in Los Angeles County. Historically the Santa Clara River has maintained perennial flow in the vicinity of Blue Cut and the County line, with the flow sustained by groundwater discharge from the Eastern groundwater basin. The City of Santa Clarita began importing State Water in 1980, and steady growth in that community resulted in steady increases in wastewater discharges until recent years, when discharge has diminished slightly. United's fall conservation releases from Lake Piru provide an additional source of recharge to the basin. Release volumes vary year-to-year, and variable channel conditions affect the percentage of the released water that percolates in the Piru basin. Recharge through the channel of Hopper Creek is likely another source of significant recharge during wet years like 2011.

Groundwater elevation contours were interpreted from measured groundwater elevation highs from the spring of 2011 and groundwater elevation lows from the fall of 2011, and are shown in Figures 4.3-2 and 4.3-3 respectively. Groundwater flow is consistently from east to west, roughly following the land surface gradient of the river channel. Depths to water are greater along the northern portions of the basin where alluvial fan deposits elevate the land surface. Groundwater elevations were similar in the spring and fall of 2011, in part due to a large fall release from Lake Piru and a late spring release of stored runoff from Castaic Lake.

The tight contours shown in the eastern Piru Basin, just west of United's District boundary, indicate that this eastern portion of the basin is an area of significant recharge. This is the area where surface water sourcing from Los Angeles County infiltrates to groundwater and the river often goes

dry. Spring 2011 groundwater elevations are approximately 20 feet higher than in fall 2011 in this area.

Groundwater rises near the constriction at the downstream west end of the basin, contributing flow to the Santa Clara River. Groundwater elevations near the constriction at the west end of the basin are historically more stable than those in the central and eastern portions of the basin. Recorded groundwater elevations are approximately the same in this area in the spring and fall of 2011. The contours also show groundwater flow to the Fillmore basin to the west.

4.3.1.2 GROUNDWATER EXTRACTIONS

Reported groundwater extractions from 101 active wells in the Piru Basin totaled 11,700 acre-feet for the 2011 calendar year. This is 720 acre-feet less than the historical average for the period 1980 to 2011, the period of available records. A portion of the Piru basin extends east of United's District boundary and any pumping from this portion of the basin is not reported to United. The historical annual extractions for the Piru basin are shown in the histogram in Figure 4.3-4. Only a small percentage of groundwater pumping in the Piru basin is for municipal and industrial use, consistent with agriculture being the dominant land use within the basin.

Figure 4.3-5 is a map showing reported groundwater extractions from individual wells in the Piru Basin for the 2011 calendar year. Pumping magnitude is indicated by dot size and color. Agriculture is the predominant land use within the Piru basin, and pumping is shown to be distributed throughout the basin. Few active wells exist along the southeastern margin of the basin, and some crops here are irrigated with water piped in from other areas. Two private mutual water companies operate within the basin. The Piru Mutual Water Company diverts water from Piru Creek for agricultural use in the north-central portion of the basin, and Warring Water Company pumps water primarily for domestic use in the town of Piru.

In some canyon and upland areas, orchards are irrigated with groundwater pumped from lower areas of the basin and piped to higher elevations. In recent years a large number of orange orchards have been removed and replaced by row crops or box tree nurseries.

The primary losses of groundwater from the Piru basin are the result of discharge of groundwater to the Santa Clara River at the western boundary of the basin, the subsurface outflow of groundwater at the western boundary of the basin and extraction of groundwater by wells.

4.3.1.3 WATER QUALITY

Over the past decade the main water quality concern in the Piru basin has been impacts associated with high chloride concentrations in the Santa Clara River flows sourcing from Los Angeles County. Discharge from the Valencia Water Reclamation Plant located next to the river at Interstate 5 significantly influences the flow and water quality of this reach of the river, which normally percolates completely in the eastern Piru basin (UWCD, 2006; CH2M Hill, 2006). The chloride

concentration of plant discharges began to increase in the late 1990s and peaked at over 210 mg/l in 2003 (Figure 4.3-6). The chloride plume associated with these discharges has made a steady advance with groundwater flow down the Piru basin. The extent of chloride impacts is now approaching Hopper Creek in the western third of the basin (Figure 4.3-7). Irrigation of salt-sensitive crops such as strawberries and avocado with water over 100 mg/l chloride is generally not recommended, and growers in Ventura County remain concerned about the westward progression of these impacts. More recently, chloride concentrations in Los Angeles County wastewater discharges are improving, the result of a successful campaign to remove self-regenerating water softeners from Santa Clarita residences and lower chloride concentrations in imported State Water Project deliveries. In the western portion of the basin chloride concentrations are generally less than 70 mg/l, indicative of background levels within the basin (DWR, 1989).

The Piru basin generally does not have problems with nitrate contamination, and samples collected in 2011 show only one well exceeding the MCL of 45 mg/l (VCWPD, 2012). Many wells record TDS concentrations of 1,200 mg/l or less, but some wells record TDS concentration twice this value (VCWPD, 2012). Water quality of the Piru basin is characterized more thoroughly in the revised Groundwater Management Plan for the Piru and Fillmore basins (Piru/Fillmore Groundwater Management Council, 2011).

4.3.2 FILLMORE BASIN

The City of Fillmore overlies the northeast portion of the Fillmore basin, and relies entirely on groundwater for water supply. Sespe Creek is the largest tributary to the Santa Clara River and enters the basin from the north. Sespe Creek is an important source of recharge to the basin, providing high-quality water from a largely undeveloped watershed draining the southern slopes of the Pine Mountain complex in the Los Padres National Forest. Groundwater supports extensive acreage of agriculture in the basin, ranging from row crops and nursery stock near the valley floor to citrus and avocado plantings at both low and high elevations. Discharge to the downstream Santa Paula basin is thought to be significant, especially during high groundwater conditions such as those observed in 2011.

4.3.2.1 WATER LEVELS

Many water levels in the Fillmore basin behave in a manner similar to the Piru basin. Water levels from a key well in the Bardsdale area shows that water levels rise to a threshold elevation in significant wet years, as evidenced by the flat topping of groundwater elevations in 1998 and 2005 (Figure 4.3-8). In this vicinity south of the confluence of Sespe Creek and the Santa Clara River, groundwater elevations do not fluctuate as dramatically as those in the Piru basin.

Groundwater elevations at United's key well for the basin show that in 2011, a moderately wet year, the basin did not fill completely. The 2011 recorded high groundwater elevation at United's key well is approximately 3.1 feet lower that the 1998 recorded high groundwater elevation, and

approximately 26 feet higher than the recorded low groundwater elevation during the 1987 to 1991 drought.

Fillmore basin groundwater levels likely benefit from increased discharge from the Piru basin as that basin has sustained fairly high water levels in recent decades. The Fillmore basin also benefits from United's fall conservation release from Lake Piru which helps stabilize groundwater elevations. The Fillmore basin receives most of its recharge from the Santa Clara River and Sespe Creek.

Groundwater elevation contours are shown for spring and fall 2011 in Figures 4.3-2 and 4.3-3. Groundwater flow is predominantly east to west in the area of the Santa Clara River alluvium. In the Pole Creek fan area underlying the City of Fillmore, groundwater flow is generally westerly, but few wells exist here, which constrains interpretations of groundwater flow. Well control in the Sespe Upland area is also poor, but groundwater flow here is thought to be predominantly north to south. Along the valley floor groundwater gradients are quite uniform and are similar for the spring and fall of 2011. The contours merge at the west end of the basin where the groundwater flow is east to west. Groundwater elevations in wells located in the Sespe Upland area and in the Pole Creek fan area of the basin generally exhibit more variability than well wells along the valley floor.

The relatively tight contours shown in the eastern Fillmore Basin near the basin boundary show a steeper gradient as groundwater moves from the constriction of the Piru narrows and moves into the basin. In this area surface water commonly infiltrates to groundwater, resulting in diminished surface flow and a greater component of flow as groundwater. As in Piru basin, groundwater is forced to the surface near the downstream end of the Fillmore basin as geologic structure constricts the main aquifer units of the Fillmore basin. In this area groundwater elevations are more stable than elsewhere in the basin. At this discharge area of the basin contouring shows that spring and fall 2011 groundwater elevations are approximately the same (Figures 4.3-2 and 4.3-3). Extensive wetlands in this area are clearly visible on aerial imagery.

4.3.2.2 GROUNDWATER EXTRACTIONS

Reported groundwater extractions from 266 wells in the Fillmore Basin totaled approximately 40,855 acre-feet for the 2011 calendar year. This is 3,337 acre-feet less than the historical average from 1980 to 2011. The historical annual extractions for the Fillmore basin are shown in the histogram in Figure 4.3-9. Recently and historically, agriculture has been the predominant user of groundwater in the basin.

Figure 4.3-5 is a map depicting reported groundwater extractions from individual wells in the Fillmore Basin for the 2011 calendar year. This graphic shows that: 1) the City of Fillmore pumps from three wells located in the north Pole Creek fan area near Sespe Creek and no longer pumps from wells located near the Santa Clara River; 2) there are numerous wells in the Bardsdale area pumping small volumes of water, as there is no mutual water company distributing potable water in this area; 3) few active wells in the Sespe Upland area and most active wells are located at lower elevations; and 4) Groundwater extractions from wells at the Fillmore Fish Hatchery located at the

eastern boundary of the basin accounts for a significant portion of the groundwater extractions of the basin. In 2011 Fillmore Fish Hatchery wells reported pumping of 9,146 acre-feet (22% of the total groundwater extractions from the basin).

Twelve mutual water companies operate in the Fillmore Basin, serving water primarily for irrigated agriculture. Fillmore Irrigation operates a surface water diversion on Sespe Creek, supplying water to nearby agricultural lands. Several water companies operate wells near the valley floor and pump water to higher elevation where groundwater is not as plentiful. Plantings in Timber Canyon and many areas of the Sespe Uplands are served by such arrangements. In recent years many orange orchards at lower elevations have been removed and replaced by row crops or box tree nurseries. Plantings of citrus and avocado remain the primary agricultural land use at higher elevations.

Discharge of groundwater to the Santa Clara River at the western boundary of the basin, subsurface outflow of groundwater to the Santa Paula Basin and extraction of groundwater by wells are the three primary losses of groundwater from the basin. The extensive wetlands and stands of *Arundo donax* (an invasive giant cane) at the west end of basin likely transpire large volumes of water. By some estimates *Arundo donax* may transpire up to six times the amount of water as native vegetation (CA Invasive Plant Council, 2011)

4.3.2.3 WATER QUALITY

The Fillmore basin is not known for having any pervasive water quality problems. TDS concentrations can be somewhat elevated in some locations, as in other groundwater basins along the Santa Clara River Valley. The City of Fillmore no longer uses wells near the Santa Clara River, favoring locations near Sespe Creek where TDS tends to be lower. Deeper aquifer units may have elevated concentrations of iron and manganese, a common occurrence throughout Ventura County.

Chloride concentrations from samples collected in 2011 are shown on Figure 4.3-7. Recorded concentrations exceeding 70 mg/l are uncommon, and limited to the area located south of the Santa Clara River. Concentrations in the 40s and 50s in the downstream/discharge portion of the basin are likely indicative of background chloride concentrations in the basin.

4.3.3 SANTA PAULA BASIN

Groundwater storage in the Santa Paula basin is generally less dynamic than in surrounding basins. Pumping in the Santa Paula basin is managed by a stipulated Judgment which assigns pumping allocations to each basin pumper that restricts the amount or groundwater each pumper can extract (within a seven-year rolling average). The City of Santa Paula occupies the eastern portion of the basin and relies entirely on groundwater for its water supply. Extensive water delivery systems have long existed in the basin, delivering water to areas with poor water quality or areas of the basin that are not readily recharged.

4.3.3.1 WATER LEVELS

Long-term records of groundwater elevations in the Santa Paula Basin indicate that water levels do not recover as readily as in the Piru and Fillmore basins. The channel of the Santa Clara River is located south of the Oakridge fault in the central portion of the basin, and overlies sediments of low permeability. The basin likely receives significant recharge as underflow from the Fillmore basin. Recent gauging of Santa Paula Creek and the Santa Clara River suggests the amount of recharge the basin receives from these sources, at least during low-flow conditions, is limited. An extensive flood control project on lower Santa Paula Creek, completed in the late 1990s, may have negatively affected the amount of recharge derived from this source.

Historical groundwater elevations dating from 1923 to present are shown in a hydrograph for United's key well for the basin (Figure 4.3-10). The well is located near Peck Road and Highway 126 in the eastern portion of the basin. The hydrograph shows that groundwater elevations in spring 2011, a moderately wet year, were higher than in spring 2010, a year of nearly average precipitation. The hydrograph also shows that the recorded high groundwater elevation for 2011 was approximately 8 feet lower than the recorded high groundwater elevation in 1998, and approximately 30 feet higher than the recorded low groundwater elevation during the 1987 to 1991 drought.

Evaluation of the key well hydrograph and other the hydrographs for other wells located throughout the basin show that water levels in many of the wells (43 of 57 wells) in both the eastern and western portions of the Santa Paula basin failed to fully recover to 1998 levels after near-record precipitation in 2005. This lack of complete recovery is consistent with an observed long-term, gradual decline in basin groundwater elevations (UWCD, 2009; Santa Paula Basin Technical Advisory Committee, 2011).

Figure 4.3-11 and Figure 4.3-12 show groundwater elevation contours in the Santa Paula Basin for spring and fall 2011, respectively. The spring contours represent the annual basin high groundwater elevations and the fall contours represent the annual basin low groundwater elevations. The difference between the spring high groundwater elevations and the fall low groundwater elevations is approximately 10 feet throughout the basin.

The contours show a general east to west flow direction with groundwater underflow from the Fillmore basin to the Santa Paula Basin and groundwater underflow from the Santa Paula Basin to the Mound basin. The relatively tight contours just west of the Santa Paula-Fillmore boundary show an area of recharge to the basin. The complex subsurface geology related to extensive faulting in the most western portion of the basin complicates the interpretation of groundwater flow in this area.

4.3.3.2 GROUNDWATER EXTRACTIONS

A histogram of reported basin pumping from 1980 to 2011 is shown in Figure 4.3-13. In recent years municipal pumping has accounted for more than 20% of the total pumping from the basin. The total reported groundwater extractions from 124 active wells in the Santa Paula Basin totaled 24,265 acre-feet for the 2011 calendar year. This is 1,432 acre-feet below the long-term average of 25,697 acre-feet. A 2003 basin study titled "Investigation of Santa Paula Basin Yield" was conducted by experts from the City of Ventura, Santa Paula Basin Pumpers Association and United. The study suggested that the yield of Santa Paula basin is probably near the historic average pumping of about 26,000 acre-feet per year.

Figure 4.3-14 is a map showing groundwater extractions by wells in the Santa Paula Basin in year 2011. The map shows significant pumping within the Santa Paula city limits and near the Fillmore basin boundary. Numerous wells report pumping in agricultural areas in the central portion of the basin. Few active wells exist north, west and south of this vicinity. In the western third of the basin, significant pumping is reported south of Highway 126 and west of Ellsworth Barranca, and in the area north of Highway 126 and west of Brown Barranca.

Several private irrigation companies are active in the Santa Paula basin, operating wells and delivery pipelines that distribute large quantities of water around the basin. Farmers Irrigation Company pumps groundwater primarily from the eastern portion of the basin and distributes the water by pipeline for agricultural use in areas of the central and western basin. Also affiliated with Farmers Irrigation Company are Canyon Irrigation Company and Thermal Belt Mutual Water Company. Canyon Irrigation operates the Harvey Diversion on Santa Paula Creek, and some wells in the eastern basin, delivering water to agriculture in the area of Santa Paula Canyon. Thermal Belt Mutual pumps groundwater from the east basin for pipeline distribution for agriculture in the Foothill Road area and upland area of the north central basin. Alta Mutual Water Company extracts water from the Saticoy area in the west basin, and delivers water primarily to agricultural areas north of Telegraph Road. These extensive water delivery systems were largely established to deliver water to areas of the Santa Paula basin having poor quality groundwater. In the canyons and foothills along the northern flank of the basin, both well production and water quality are generally poor.

Farmers Irrigation Company, Thermal Belt Mutual Water Company and Canyon Irrigation Company pumped a combined total of 9,125 acre-feet in 2011. This pumping totaled approximately 38% of all groundwater extracted from the basin in 2011.

4.3.3.3 WATER QUALITY

Water quality is fairly variable throughout the Santa Paula basin, but water quality is generally worse in the western portion of the basin. The maximum recorded TDS concentrations for Santa Paula basin wells in calendar year 2011 are shown in Figure 4.3-15, with the highest concentrations recorded in the west. In these wells sulfate is commonly a large contributor to TDS. Deeper wells

in the basin tend to have elevated iron and manganese concentrations, and both the City of Santa Paula and City of Ventura operate treatment facilities to reduce these constituents in delivered municipal water. Recorded nitrate concentrations from wells within the basin are generally low, with one well measuring nitrate over the MCL of 45 mg/l in 2011.

United conducts groundwater quality monitoring at the two nested monitoring well sites in the Santa Paula Basin, and in several production wells in the basin. Mineral concentrations are observed to vary with groundwater elevation in some wells. More thorough characterizations of groundwater quality in the Santa Paula basin can be found in other publications (DWR, 1989; Santa Paula Basin TAC, 2011).

4.3.4 MOUND BASIN

The Mound Basin is located in the westerly portion of the District and has experienced over time a progression of groundwater use that was historically dominated by agriculture, followed by a period of time when municipal and industrial pumping was dominant, and most recently a return to greater pumping by agriculture than by municipal and industrial users.

4.3.4.1 WATER LEVELS

Historical groundwater levels for a key monitoring well in the Mound Basin are shown in Figure 4.3-16. Measured water levels have varied over about a 90-foot range over the period of record for this well, located in the eastern portion of the basin near Kimball Road. An extended period of low water levels was recorded in the late 1980s and early 1990s when water levels declined to below sea level. Water levels recovered in the 1990s and generally have remained more than 15 feet above sea level over the past decade, except when falling below sea level in 2004.

Recharge of the aquifers in this basin comes from multiple sources such as direct precipitation, mountain-front recharge, and subsurface flow from adjoining basins (e.g., Santa Paula, Oxnard Forebay, and Oxnard Plain). Recharge from the Oxnard Forebay and Oxnard Plain is thought to be significant, most notably during periods of high water levels in these adjacent basins (GTC, 1972; UWCD, 2012b).

Groundwater elevation records exist for nearly 60 active and historic wells located within the Mound Basin. A number of important wells have water levels dating to the late 1920s, allowing an evaluation of long-term water level trends within the basin. However, the distribution of wells is heavily skewed towards the southern half of the basin, with relatively few wells existing north of Telephone Road. In the western portion of the basin wells are concentrated along Olivas Park Drive and near the railroad tracks south of Highway 101. This poor distribution of active and historic wells complicates the assessment of potential mountain-front recharge to the basin from the north. The southern and eastern boundaries of the basin are defined by structural features, and water level records from adjacent areas help assess the nature of the basin boundaries in these

areas. Water level trends for many wells within the basin are similar, with evidence of recharge from adjacent basins to the east and south (UWCD, 2012b). The main groundwater flow pattern is down the axis of the basin from east to west. The slope of the potentiometric surface within the basin is quite flat during dry periods and the gradient increases somewhat following periods of above-average rainfall. During dry periods, groundwater elevations in many wells fall below sea level.

The contouring of past water level conditions is complicated at times by sparse data. Available groundwater elevation data for the spring and fall of 2011 are presented in Figures 4.3-17 and 4.3-18. Increased collection of water level records is recommended in this basin to better define groundwater gradients between this basin and adjacent basins. The recent installation of monitoring wells north of the Santa Clara River near the northwestern margin of the Forebay should be helpful in better defining the flow of groundwater from the Oxnard Forebay to areas north of the Montalvo anticline (see Section 2.1.8). Relatively few wells, however, exist along the southeastern portion of the Mound basin, an area of sparse well records and known structural complexity.

4.3.4.2 GROUNDWATER EXTRACTIONS

The City of Ventura is the major municipal and industrial groundwater pumper in the Mound basin, with its wells concentrated in the area near the Ventura County Government Center. Agricultural pumping was historically the majority use of groundwater in the Mound Basin, but municipal and industrial use exceeded or approximately equaled agricultural use for the period 1999 through about 2006 (Figure 4.3-19). Municipal pumping peaked in 2003 and has declined fairly steadily in recent years, with agricultural use predominating since 2007. Since the mid-1980s agricultural pumping has averaged nearly 4,200 acre-feet per year with a peak annual production of 5,850 acre-feet recorded in 1990. In 2011 reported agricultural pumping totaled 3,120 acre-feet with municipal and industrial pumping reaching 1,525 acre-feet.

4.3.4.3 WATER QUALITY

While the quality of the groundwater produced by most wells within the Mound Basin is suitable for municipal and agricultural uses, the basin is not known for the high quality of its groundwater. Water quality is variable between wells, and many records indicate somewhat elevated concentrations of TDS, sulfate, hardness and other analytes. Water quality appears to be relatively stable among many of the Mound basin wells having long-term water quality records, although some municipal production wells (e.g., Victoria 1 and 2) in the central portion of the basin have been experiencing declining water quality (i.e., increasing TDS values) that currently reach about 1,800 mg/L. Available records from wells nearest the coast do not show evidence of saline intrusion.

A map showing recorded TDS concentrations in Mound basin wells from 2011 is shown as Figure 4.3-20. The map plots TDS (by summation) from production well samples collected by the

Groundwater Section of the Ventura County Watershed Protection District, as well as TDS (by residue) as sampled by United Water and the City of Ventura. Without the sampling by the County's Groundwater Section, coverage in the basin would be very poor. The distribution of sampled wells within the basin for 2011 is better than in most prior years. TDS in the production wells ranged from 1,150 to over 2,200 mg/l. Sulfate commonly contributes roughly half the TDS in these samples, and water quality results are often variable among nearby wells.

4.3.5 OXNARD FOREBAY

The Oxnard Forebay basin is an area of critical importance to the water resources of the Oxnard Plain. This is the unconfined portion of the Oxnard Plain where units of low permeability are generally absent or discontinuous, allowing water to percolate deep into the ground and recharge the underlying aquifers. The basin readily accepts large volumes of recharge water under wet hydrologic conditions. A time series of estimated changes in available groundwater storage within the Forebay is shown in Figure 4.3-21. The graphic shows that storage in the basin can change rapidly, especially when the basin is filling.

Coarse gravel deposits deposited by high flows of the ancestral Santa Clara River are common in the Oxnard Forebay. These gravels have historically been extensively mined, both within the river channel and in nearby upland areas. The high permeability of these coarse alluvial deposits also comprise an ideal substrate for groundwater recharge. Groundwater recharge occurs naturally where water percolates through the bed of the Santa Clara River, and in upland areas near the river where United distributes diverted river water to a series of recharge basins. United's recharge activities are sometimes termed "artificial recharge" because the activities augment the recharge that would naturally occur in this area. The term "managed aquifer recharge" has become more popular in recent years.

Groundwater recharge to the Forebay serves to raise groundwater elevations in this upgradient area of the groundwater flow system for the Oxnard Plain. High water levels in the Forebay increase the hydrostatic pressure in the confined aquifers extending from the margins of the Forebay to the coastal and offshore portions of these continuous aquifer units. While the physical movement of groundwater out of the Forebay is fairly slow, the pressure response in the confined aquifers distant from the Forebay responds more rapidly to significant recharge events in the Forebay. During wet climatic years the Forebay has the ability to quickly accept large volumes of water, allowing storage of surface water that otherwise would be lost from the system. Water stored in the Forebay slowly bleeds out to the outlying areas, flowing naturally from areas of high elevation to areas of lower elevation on the Oxnard Plain and near the coast, and serves to raise or sustain groundwater elevations in wells in downgradient areas. Groundwater extraction by wells, both in the Forebay and in the confined aquifers of the Oxnard Plain, hastens the decline of Forebay water levels as water is removed from the system. Under drought conditions, groundwater elevations in the Forebay may approach sea level, resulting in flattened groundwater gradients and only minor groundwater flow out of the Forebay. Ventura County has not experienced a prolonged

drought since completion of the Freeman Diversion in 1991, and estimates of available storage show the basin has filled to historic highs in subsequent years with above-average precipitation (Figure 4.3-21). Storage estimates suggest little available storage existed in the basin in spring 2011.

4.3.5.1 WATER LEVELS

Groundwater elevation contours for the Upper Aquifer System (UAS) in the spring of 2011 are shown in Figure 4.3-22. An area of closely-spaced contours is shown beneath the Saticoy and Noble recharge basins in the up-gradient portion of the basin. This is an area of groundwater mounding due to United's recharge activities. A fairly uniform groundwater gradient is interpreted to exist beneath the channel of the Santa Clara River. The groundwater elevation contours deflect around the El Rio Spreading Grounds, where in the spring the volume of water recharged at this location greatly exceeded that pumped and delivered to the southern Oxnard Plain. Overall, natural and artificial recharge to the Forebay was abundant in winter and spring 2011, largely related to two large storm events and other lesser storms that resulted in sustained high flows in the Santa Clara River.

Figure 4.3-23 displays UAS groundwater elevation contours for the Oxnard Plain in fall 2011. Groundwater mounding is again apparent beneath the Saticoy Spreading Grounds, as a portion of the water from the fall conservation release from Lake Piru is routed here for groundwater recharge. Southwest of this location groundwater elevation contours show greater spacing than in the spring of the year, and are more consistent with the regional gradient across the Oxnard Plain to the south. Adjacent to the Forebay in the northeast Oxnard Plain groundwater elevations are similar or slightly higher than elevations were in the spring. Water stored in the winter mounding of groundwater within the basin is now flowing to down-gradient areas, and in this year counters the effects of groundwater extractions which normally result in annual water level lows in the fall when pumping exceeds local recharge. The general direction of groundwater flow in the basin remains similar throughout the year. Water level records show a slight pumping depression in the fall beneath the El Rio Spreading Grounds.

Historical water level hydrographs from selected wells in the Forebay are shown in Figure 4.3-24. UAS water levels in the Forebay fluctuate by as much as 100 feet, with groundwater elevations dropping below sea level in drought periods and recovering during wet periods. Historic highs were recorded in a number of wells in recent years, following a number of consecutive wet years and the expansion of United's recharge facilities.

4.3.5.2 GROUNDWATER EXTRACTIONS

Reported 2011 groundwater extractions from the Forebay totaled nearly 18,500 acre-feet. Figure 4.3-25 shows reported extractions for the basin since 1980. Pumping in the Forebay has decreased for five consecutive years, with pumping totals from the past two years being below the

average annual extraction rate of 25,000 AF. Pumping from the Forebay is often more variable than in other basins within the District, caused by the variable amount of groundwater pumping for delivery to the Oxnard Plain and Pleasant Valley basins. Agricultural pumping in 2011 was similar to that in 2010, but the big change from the prior year was a reduction in municipal pumping at the O-H well field at United's El Rio Spreading Grounds. O-H customers used nearly 5,000 AF less water in 2011 compared to the prior year. The reduction in use was partially related to a large construction project which required a realignment of the O-H supply pipeline.

In the 2011 calendar year some 37,800 AF of water were spread for groundwater recharge at the El Rio Spreading grounds. Over this same period 10,740 AF was pumped from UAS wells at El Rio for deliveries to the O-H system.

The distribution of UAS pumping for calendar year 2011 is shown in Figure 4.3-26. Significant pumping is apparent surrounding the El Rio Spreading Grounds, where municipal pumping in the basin is centered. The majority of the pumping in the up-gradient areas of the Forebay is for irrigation purposes, including the pumping on the south side of United's Saticoy Spreading Grounds. Wells screened in units of the Lower Aquifer System are uncommon in the Forebay, and 2011 pumping from LAS wells is shown in Figure 4.3-27.

4.3.5.3 WATER QUALITY

Water quality records from Forebay basin wells near the Santa Clara River and United's recharge facilities show that groundwater quality in these areas is similar to that of the Santa Clara River. The most recharge from the river takes place when flows are high, which is generally when water quality in the river is best. Some characterization of Santa Clara River water quality is included in Section 4.2 of this report. During the dry season when river flows are lower and mineral content is generally higher, much of the diverted surface water is blended with well water and used for irrigation in areas served by the PTP and Pleasant Valley pipelines.

Occasional high nitrate concentrations in UAS wells has historically been the water quality issue causing concern in the Forebay. A definitive evaluation of sources of nitrate and flow paths to area wells has proven difficult, but septic systems and fertilizer from irrigated agriculture are commonly believed to be major contributors of nitrate to the groundwater flow system (UWCD, 1998). The highest nitrate concentrations are often observed during drought periods, when nitrogen inputs continue but the diluting influence of natural and artificial recharge is reduced. High nitrate has also been documented in wells as water levels rise following periods of drought, as nitrogen stored in the vadose zones is mobilized as sediments become saturated by a rising water table. Installation of additional monitoring wells in the Forebay has contributed to the understanding that the highest nitrate concentrations are often observed in the shallowest wells (UWCD, 2008). Once high-nitrate water enters the groundwater flow system its movement is likely very complex. An incomplete understanding of nitrate inputs to the Forebay basin and the complexity of water movement in the unsaturated and saturated zones of the subsurface make predictions of future nitrate impacts to area wells impractical.

Maximum-recorded nitrate concentrations from wells in the Forebay and northern Oxnard Plain in 2011 are shown in Figure 4.3-28. Few samples exceed 23 mg/l, a value half the nitrate MCL of 45 mg/l. A single Forebay well recorded very high nitrate, a shallow monitoring well in the south-central portion of the basin. Near United's Saticoy Spreading Grounds UAS nitrate concentrations ranged from three to eight mg/l, values that match the range of nitrate concentrations recorded for diverted Santa Clara River water spread nearby. The public supply wells in the El Rio community and at the El Rio Spreading Grounds also recorded relatively low nitrate concentrations in 2011.

A major effort to sewer the El Rio community was recently completed, significantly reducing nitrate loading in this areas of shallow unconfined groundwater. Residents and regulators are hopeful that significant nitrate impacts will be avoided in future droughts, but a cautionary statement from a recent UC Davis report on nitrate contamination is repeated here as a reminder that flow paths to production wells are often not well understood, and may be longer and more complex than many might imagine: "Travel times of nitrate from source to wells range from a few years to decades in domestic wells, and from years to many decades and even centuries in deeper production wells. This means that nitrate source reduction actions made today may not affect sources of drinking water for years to many decades" (Harter and Lund, 2012).

4.3.6 OXNARD PLAIN BASIN

Early newspaper accounts suggest that the confined aquifers of the Oxnard Plain were first drilled for water supply wells in the early 1870s. Artesian conditions existed on the Oxnard Plain at this time, and the well installations that received press coverage were wells providing impressive flow at the land surface without a pump in the well. Artesian conditions are believed to have persisted through the late 1800s. The town of Oxnard was established in 1897, and in 1899 a large sugar beet processing facility began operations. The large water demands associated with irrigation of beets and other crops on the Oxnard Plain, along with the growing population and industrial uses, lowered the pressure in the Oxnard aquifer. By the turn of the century widespread artesian conditions were generally absent, requiring wells to be fitted with pumps to lift water from elevations below the land surface (Freeman, 1968).

Over the approximately 110 years since the initial depressuring of the Oxnard Aquifer in the late 1800s, artesian conditions have periodically returned to the Oxnard Plain during wet climatic cycles. Documentation of water levels in the aquifers of the Oxnard Plain are sparse until the early 1930s, but artesian conditions were documented in Oxnard City well #9 in the winters of 1917, 1919, 1922 and 1923 (CA Division of Water Rights, 1928). The early 1940s was a wet period, and widespread artesian conditions likely existed at that time. The year 1945 marked the beginning of a long dry period during which water levels fell across the plain and problems with saline intrusion intensified in coastal areas. These alarming developments at a time of urban and economic growth in Ventura County prompted significant investments in water resource projects, including the O-H well field at El Rio and a pipeline delivery system to urban areas on the coastal plain. In subsequent years pumping patterns continued to change as the City of Oxnard grew. The city once had water supply

wells distributed throughout its service area, but now pumping is centralized in two primary well fields. As farmland around the city margins has converted to urban areas, pumping has generally been transferred to the City of Oxnard's main well field in the northern Oxnard Plain. Much of the population growth in the cities of Oxnard and Port Hueneme has been supported by State Water Project supplies, imported and delivered by Calleguas Municipal Water District.

Widespread artesian conditions were again present on the Oxnard Plain in the late 1990s following the completion of the Freeman Diversion and high precipitation totals in 1993, 1995 and 1998. More recently, artesian conditions periodically existed in coastal areas surrounding Port Hueneme, and are more common in UAS wells than in wells with deeper screened intervals.

Following a period of drought in the 1970s and expansion of the areas impacted by saline intrusion, the Fox Canyon Groundwater Management Agency (FCGMA) was established in 1982 as a local agency with regulatory authority to bring overdraft conditions under control in southern Ventura County. The agency has successfully implemented a number of mandatory cutbacks for production from public supply wells, and agricultural pumpers are required to demonstrate the use of efficient irrigation practices. One early strategy was a shift of pumping from the Upper Aquifer System to the Lower Aquifer System on the Oxnard Plain. This shift in pumping resulted in improved conditions in the UAS but considerable overdraft of deeper aquifers. An update to the FCGMA's management plan was completed in 2007, and describes a number of projects and strategies that might be employed to bring pumping in the Oxnard Plain, Pleasant Valley and Las Posas basins into balance with recharge to the aquifers of these highly-developed basins (FCGMA, 2007).

The primary water quality concern on the Oxnard Plain is degradation associated with the intrusion of saline waters. The direct lateral intrusion of seawater remains the primary threat in coastal areas, with the near-shore submarine canyons at Port Hueneme and Point Mugu exposing aquifer beds to the sea. The vertical movement of deep brines and shallow water of poor quality has also been documented. This movement of poor-quality groundwater is also related to overdraft conditions, but is not limited to coastal areas. Nitrate problems have been documented periodically in specific Oxnard Plain wells. In some cases this degradation is related to the downward movement of poor-quality water, in other locations it may be related to nitrate contamination sourcing from the Oxnard Forebay (UWCD, 2008).

4.3.6.1 WATER LEVELS

As discussed in the groundwater basin descriptions of the Oxnard Forebay and Oxnard Plain, large volumes of groundwater flow from the Oxnard Forebay to the Oxnard Plain. Contouring of recorded UAS water levels from wells shows that groundwater flows radially from recharge areas in the Forebay to surrounding areas (Figures 4.3-22 and 4.3-23). Recharge from the Forebay serves to raise or sustain water levels in wells on the Oxnard Plain, countering the decline in groundwater elevations resulting from groundwater extractions. When water levels are high across the basin groundwater may flow past the coastline to the offshore extension of the aquifers of the plain, or exit the system at near-shore canyons as discharge to the sea.

Precipitation totals in 2011 were higher than average, and a large storm event in March helped sustain above-average flows in the Santa Clara River through the spring of the year. Significant natural and artificial recharge occurred in the Forebay, and mounded groundwater conditions are evident in Figure 4.3-22. A sizable storm hit the area in December 2010, allowing an early start to wet-season recharge to the basins. Artesian conditions existed in coastal areas of the north and central Oxnard Plain by March and April 2011, the period when water levels were collected for contouring spring conditions.

In fall 2011 UAS groundwater elevations in most areas of the Oxnard Plain were similar to what they were in the spring, suggesting that between spring and fall the amount of groundwater pumped on the Plain was similar to the amount of water moving from the Forebay to the Plain. It is more typical for water levels in the confined aquifers of the Oxnard Plain to exhibit a distinct annual signature, with increased pumping stresses and reduced recharge in the summer and fall resulting in water level declines of ten feet or more (Figure 4.3-29). In the southern Oxnard Plain the sea level (0 feet) contour is mapped more than two miles inland from the coast in fall 2011. In this area south of Hueneme Road, piezometric heads in the Mugu aquifer of the UAS are commonly at least 20 feet lower than in the Oxnard aquifer. The selected hydrographs shown in Figure 4.3-29 show spring 2011 heads were often about ten feet below historic highs, but in some cases 60 feet higher than historic lows.

LAS heads are contoured for the spring and fall of 2011 for the Oxnard Forebay, Oxnard Plain and Pleasant Valley basins (Figures 4.3-30 and 4.3-31). These contours show a new interpretation for LAS groundwater flow. Evaluation of well construction, interpretation of geophysical well logs and construction of stratigraphic cross-sections for the area indicate that a number of wells in the Oxnard Forebay and north Oxnard Plain, utilized in the past construction of LAS contours, and previously classified as LAS wells, are likely influenced by heads in the UAS. Some of these wells may be screened in both the LAS and UAS. South of a certain point these “shallow LAS” wells are absent, and wells are screened much deeper due to structural and stratigraphic changes in the subsurface.

A better understanding of UAS and LAS stratigraphy and the structural deformation of the LAS has allowed United staff to better interpret water levels recorded in the Oxnard Forebay. Groundwater elevations recorded in the deep monitoring wells at the El Rio Spreading Grounds, utilized in this new interpretation, better conform to groundwater elevations of LAS wells in the central and south Oxnard Plain.

The inclusion of the “shallow LAS” wells in earlier contouring resulted in a steep break in groundwater elevations that was thought to be indicative of a structural barrier to groundwater flow. This revised interpretation of LAS groundwater elevations functionally expands the pumping depression seen along the eastern Oxnard Plain and western portions of the Pleasant Valley Basin north into the Forebay. Above sea level LAS groundwater elevations near the Saticoy Spreading Grounds, however, indicates that the LAS pumping depression does not extend north to this area of the Forebay. Water level records and associated contouring shows that in the aquifers of the LAS,

groundwater flows from the Oxnard Forebay to the large pumping depression in the eastern Oxnard Plain and the Pleasant Valley basin.

Also notable in this interpretation (of deeper LAS wells) is higher LAS heads along the coast in the western Oxnard Plain than in most other areas of the basin. Maps showing LAS pumping locations within the basin (next section) are consistent with the contouring. The LAS contouring presented here is somewhat preliminary and subject to modification in the future as work on the hydrogeology in this area is ongoing.

In the northwestern Oxnard Plain, LAS groundwater flow is likely from the Oxnard Forebay towards the coast. Few LAS wells exist in this area (Figure 4.3-27), as recharge to the Oxnard Forebay is very effective in sustaining groundwater elevations in this area (UWCD, 2010). LAS wells near Victoria Avenue and the northern boundary of the Oxnard Plain record groundwater elevations similar to nearby UAS wells (UWCD, 2010), and artesian conditions were observed in a LAS monitoring well near the coast in spring 2011 (Figure 4.3-30.). The exclusion of "shallow LAS" groundwater elevations from Figures 4.3-30 and 4.3-31 provides an incomplete representation of LAS heads in the northwestern Oxnard Plain.

Historical water level records from selected LAS wells on the Oxnard Plain are shown on Figure 4.3-32. Periods of drought are clearly evident in some of the wells, with measured water level declines exceeding 100 feet in some wells. Annual water level fluctuations of greater than thirty feet are common in the confined conditions of the LAS. Water levels in wells near the coast are more muted, as recharge by seawater prevents heads from falling as low as they do in inland areas.

4.3.6.2 GROUNDWATER EXTRACTIONS

The groundwater resources of the Oxnard Plain are heavily utilized to support overlying land uses. The area is famous for its highly productive agriculture, supporting year-round production of a wide variety of agricultural products. Groundwater supports much of the agriculture on the Plain, but surface water is available in some areas. The area also supports an extensive urban population. The Cities of Oxnard and Ventura maintain active wells on the Oxnard Plain, but also rely on other sources of water. The City of Port Hueneme and other coastal communities generally maintain wells in reserve status and import water from inland areas given their location near the coast and vulnerabilities with respect to seawater intrusion.

The distribution of reported UAS pumping shown in Figure 4.3-26 is typical of pumping patterns in recent years. The City of Oxnard operates several wells at its main well field near Third Street and Oxnard Blvd., and at a smaller facility some distance to the northeast. Aside from these locations UAS pumping is uncommon in the urban areas of the Oxnard Plain. Agricultural interests pump extensively from the UAS in the northwest Oxnard Plain, as well as in the northeastern portion of the basin near the Oxnard Forebay. Additional pumping is scattered across the central Plain east

of the City of Oxnard, where a number of wells reporting minor pumping are small domestic wells. Few UAS wells are active south of Hueneme Road on the southern Oxnard Plain.

The distribution of LAS pumping on the Oxnard Plain is concentrated in the eastern half of the basin, as shown in Figure 4.3-27. Near the basin boundary in the northwestern Oxnard Plain the City of Ventura operates two wells at the Ventura Municipal Golf Course, and exports water for municipal use in the Mound basin. LAS extractions are common for irrigation in the northeastern Oxnard Plain, as they are in the east-central portion of the basin. South of Hueneme Road LAS aquifers are pumped extensively for irrigation, in contrast to the UAS which is pumped very little in this area. Also notable is the near-absence of LAS pumping in the northwest portion of the basin.

A histogram of historical extractions from the Oxnard Plain and the portions of the Pleasant Valley and West Las Posas basins within United's District boundary are shown in Figure 4.3-33. Pumping in the portions of the West Las Posas and Pleasant Valley basins within United's district boundary are included with the Oxnard Plain due to the way records are processed within United's Finance Department. Reported pumping for both agricultural and municipal uses were slightly higher in 2011 than in 2010. Despite 2011 rainfall totals being slightly higher than 2010, the timing and rainfall totals for 2010 storms may have been more favorable for avoiding pumping for irrigation on the Oxnard Plain and surrounding areas.

The 60,300 acre-feet of pumping reported for the Oxnard Plain in 2011 was considerably less than reported pumping in 1990, when a record 105,000 acre-feet of pumping was reported. The Freeman Diversion was completed the following year, which improved the quantity and reliability of surface water delivered to the Oxnard Plain. Completion of the Conejo Creek Diversion in 2002 brought additional surface water to the Pleasant Valley area. Municipal and Industrial (M&I) pumping has been subject to cutbacks mandated by the FCGMA, beginning with 5% in 1992 and currently at 25%. Municipal pumping has not actually been reduced by this amount: pumping allocations have been transferred to the Cities of Oxnard and Camarillo, as these cities have expanded into agricultural areas. As noted in earlier sections, large volumes of potable water are imported from both the Oxnard Forebay and from northern California, so the extraction totals represented in Figure 4.3-33 are less than the total demand for agricultural and M&I water in the area.

4.3.6.3 WATER QUALITY

Seawater intrusion was first recognized on the Oxnard Plain in the 1930s and since that time this issue has dominated water quality concerns in southern Ventura County (CA DWR, 1971; FCGMA, 2007). In areas not impacted by saline intrusion, groundwater quality is somewhat variable among wells but generally is adequate for most agricultural and municipal/industrial uses. Water in the confined aquifers of the Oxnard Plain tends to be somewhat mineralized due the marine deposition of many of the aquifers (TDS, sulfate, iron, manganese), but contamination by organic contaminants is uncommon (Burton et al, 2011). Nuisance concentrations of iron and manganese are most commonly associated with LAS wells where reducing conditions are present.

In the northern portion of the Oxnard Plain samples for some wells in 2011 show elevated concentrations of nitrate. The provenance of the high nitrate detected in these wells is generally difficult to determine, but high and variable concentrations are likely related to the downward leakage of near-surface waters (Izbicki, 1992, Zohdy et al, 1993). On the southern Oxnard Plain nitrate concentrations in wells are not commonly detected, and the rare detects are related to damaged or improperly constructed wells.

Recorded chloride concentrations across the central Oxnard Plain were consistently low in 2011, as shown in Figure 3.4-34. These values are similar to native chloride concentrations in the basins of the Santa Clara River Valley. South of Hueneme Road some wells record chloride concentrations of greater than 16,000 mg/l, concentrations similar to seawater.

4.3.6.3.1 SALINE INTRUSION

Since the 1930s the southern Oxnard Plain in Ventura County has been subject to seawater intrusion. The Oxnard, Mugu, Fox Canyon, and Grimes Canyon aquifers are believed to be geologically vulnerable, to varying degrees, to seawater intrusion by their exposure in offshore submarine outcrop in the walls of submarine canyons and along the broader offshore shelf. Concerns related to the expansion of intruded areas in the 1970s and 1980s helped motivate the funding of cooperative studies with the U.S. Geological Survey.

In 1989 the U.S. Geological Survey initiated the Regional Aquifer-System Analysis (RASA) study in the Santa Clara-Calleguas groundwater basin. As part of this project a series of fourteen nested monitoring well sites were installed in coastal areas. Extensive sampling was conducted, and a number of advanced analytical techniques were used to provide a much better understanding of the nature and extent of saline intrusion on the Oxnard Plain. The USGS studies concluded that some areas classified as seawater intrusion in the past were in fact subject to increased chloride concentrations from connate saline water squeezed from fine-grained sediments within and separating the aquifers (Izbicki, 1992). The USGS mapped areas of high salinity in the major aquifer units of the southern Oxnard Plain, and classified sources of salinity as either seawater intrusion or saline intrusion from local sediments. A major product of the RASA study for the Santa Clara-Calleguas study area was a calibrated groundwater flow model. A solute transport component of the model was proposed in the scoping of the study, but this component was later abandoned after initial efforts proved unsuccessful.

United continues to sample the network of monitoring wells on the southern Oxnard Plain. In all of the recent samples from the southern Oxnard Plain, calcium or sodium are the dominant cations. Among samples not affected by high salinity, sulfate and bicarbonate are the dominant anions. For most samples impacted by saline waters, sodium and chloride are the dominant ions (UWCD, 2007). Major ion analysis is helpful in determining chemical conditions and changes over time, but not necessarily the source of brine causing water quality degradation. Researchers from the USGS have advanced methods for determining whether high chloride is sourcing from direct seawater intrusion or rather from deep or stranded brines (Izbicki, 1992 and Izbicki et al, 2005a). The minor

ions iodide and bromide, along with the trace elements boron and barium, are useful indicators for delineating the source of brines impacting fresh aquifers. Analysis of minor ion concentrations and trace element ratios from coastal monitoring wells suggest that some wells are impacted by the recent intrusion of seawater via the near-shore submarine canyons at Port Hueneme and Point Mugu. Other wells are likely impacted by inland brines, such as those expelled from buried fine-grained marine deposits. Clays within these deposits compact over time in response to regional pumping stresses, allowing the brines to enter adjacent permeable beds within the aquifer system (UWCD, 2007).

Over the past decade the sampling of coastal monitoring wells has indicated that near Port Hueneme chloride conditions have generally improved as heads in most aquifers have remained near or above sea level. United's sampling of wells and contouring of groundwater elevations in this area suggest the chloride plumes associated with past periods of drought are now migrating southeast towards the Mugu area, most notably in the UAS (UWCD, 2004). Figure 4.3-35 displays chloride records for selected UAS monitoring wells in coastal areas of the southern Oxnard Plain. The figure shows well A1-195 located north of Port Hueneme has totally recovered from chloride impacts in the early 1990s. The chloride plume shown east of Hueneme Harbor likely extended north from Hueneme Canyon during the drought (chloride spike in well A1-195), and since that time the plume has slowly shifted towards the southeast (groundwater flow is perpendicular to the groundwater elevation contours shown on Figure 4.3-23). Within the plume of displaced seawater, samples from well CM4-275 remain above 6,000 mg/l, and chloride continues to rise in well CM7-190 some 20 years after the drought ended. In the Mugu area, however, saline groundwater would likely flow out from the groundwater basin if a significant seaward groundwater gradient could be maintained, but such conditions have not existed for many years. In inland areas surrounding Mugu Lagoon aquifers of the UAS remain impaired by high chloride. One well in the western portion of this area has shown some improvement in recent years, but chloride is still over 2,000 mg/l (Figure 4.3-35). Other UAS wells show continued degradation by either brines or direct intrusion of seawater (UWCD, 2007).

Selected chloride time series for Lower Aquifer System monitoring wells on the southern Oxnard Plain are shown in Figure 4.3-36. Near Hueneme Canyon few wells show chloride impacts, but well CM2-760 shows increasing chloride at concentrations greater than 10,000 mg/l. In the greater Mugu area chloride degradation is severe in a number of wells, and chloride is trending upwards in many wells. Degradation by brines continues unabated in LAS monitoring wells at the Q2 well site, located about two miles north of Mugu Canyon. Degradation in these wells is related to chronically depressed water levels in the area, allowing brines to migrate into the aquifers from surrounding sediments or deeper zones hosting poor-quality groundwater (UWCD, 2007).

Given the chronic groundwater depression existing north and northeast of the Mugu area, basin managers wish to better understand the extent of existing chloride impacts and the potential for further degradation. While additional monitoring wells allow the ability to sample discrete zones within an aquifer and identify vertical head gradients, expansion of the network of monitoring wells

is an expensive endeavor. United received California DWR grant funding in 2006 for an additional nested monitoring well installation located about a mile north of and between the existing DP and Q2 well sites, and samples from these new wells do not have high chloride concentrations (UWCD, 2007). A better understanding of the extent of saline water impacts and the rate of change in recent years will help both pumpers and water managers plan and prepare for water quality changes that may make groundwater unsuitable for beneficial uses in specific areas.

United has recently sponsored geophysical studies on the southern Oxnard Plain to assess conditions over a broad area in this productive agricultural region (see Section 2.1.6). One such project was a Time Domain Electromagnetic (TDEM) geophysical survey on the southern Oxnard Plain to assess the lateral extent of saline water intrusion over four different depth ranges (UWCD, 2012a). The survey was designed to replicate a study performed by the USGS in the early 1990s, conducted as part of the RASA project (Zohdy et al, 1993). United's field survey area was approximately 35 square miles and extended along the coast between Port Hueneme and Point Mugu (approximately 7 miles) and inland for approximately 5 miles. One hundred twenty five soundings were collected throughout the study area and the data were forward and inverse modeled for each sounding. The model data were used to construct resistivity maps, at four depth ranges typical of the UAS and LAS.

United's TDEM investigation was successful at delineating earth resistivity values that are typical of saline and brackish water in both the Upper and Lower Aquifer Systems. Resistivities typical of saline water occurred along the coast and extended farther inland near Point Mugu with brackish water inferred at various locations inland. An image of contoured resistivity values at depths approximating the lower portions of the UAS are shown in Figure 4.3-37. A second image of contoured resistivity values for the shallower portions of the LAS are shown in Figure 4.3-38. Groundwater salinity estimates from the TDEM surveys generally correlated well samples from areas monitoring wells. The work suggested that geologic features such as paleochannels may affect groundwater flow and the migration of chloride, particularly in deposits of the UAS (UWCD, 2012a).

Local water managers share a common desire to better understand the extent of saline water impacts on the southern Oxnard Plain and how rapidly it might be migrating toward the more large scale pumping to the north. There exists relative few monitoring wells in the coastal areas of the southern Oxnard Plain and the extent of saline impacts is not precisely known, but it is well understood that elimination of groundwater overdraft conditions will largely mitigate the worsening of chloride impacts on the southern Oxnard Plain. Prevention of additional water quality degradation is a common goal for all stakeholders as degraded aquifers can negatively affect land values. Restoration of degraded aquifers is a difficult prospect, especially in areas already suffering from groundwater overdraft.

4.3.7 PLEASANT VALLEY BASIN

The Pleasant Valley basin lies adjacent and east of the Oxnard Plain, occupying the area south of the Camarillo Hills. Aquifers of the Upper Aquifer System are poorly developed in this basin and dominated by fine-grained deposits. This change in UAS deposits forms the basis for the basin boundary with the Oxnard Plain. Aquifers of the Lower Aquifer System are continuous with areas to the west on the Oxnard Plain. The City of Camarillo occupies the northern portion of the basin. Agriculture is the predominant land use in the remainder of the basin, where the Pleasant Valley County Water District operates an extensive water delivery system. The entire area of the basin falls within the Calleguas Creek watershed.

4.3.7.1 WATER LEVELS

Most wells in the Pleasant Valley basin area are completed in units of the Lower Aquifer System. Some wells are perforated in coarse basal units of the UAS, but pumping and water level measurements from UAS wells are uncommon as the UAS in the Pleasant Valley basin is predominantly comprised of fine-grained sediments (UWCD, 2003). United does not attempt to contour UAS water levels in the Pleasant Valley basin.

Groundwater elevation hydrographs for selected LAS wells are shown in Figure 4.3-39. The LAS well located in the northeast corner of the Pleasant Valley basin near Las Posas Road and Lewis Road recorded groundwater elevations approximately 140 feet below sea level in the early 1990s. Since the early 1990s water levels in this well have increased dramatically, reaching levels of nearly 120 feet above sea-level in 2011. This recovery is related to increased surface water flow in Arroyo Las Posas and the associated groundwater recharge in the northern portion of the basin. Since the 1990s flow in the Arroyo Las Posas has increased dramatically, largely due to population growth in upstream areas and related water imports and wastewater discharges (LPUG, 2011). This recharge in recent years has lead to the recognition that the basin is unconfined in this area and may be considered a forebay area for the Pleasant Valley basin (Hopkins, 2008). Some recovery in this well is likely related to the relatively wet period the area has experienced since the drought period ending in 1991. The degree to which this recharge has influenced water levels in the central portion of the basin is a topic of current study.

The groundwater elevation hydrograph for the LAS well located at the intersection of Las Posas Road and Pleasant Valley Road shows a clear response to drought conditions in the late 1980s, with water levels reaching approximately 180 feet below sea level in 1991. Since that time, with the onset of a relatively wet period, groundwater elevations have increased steadily except for a slight decline during a dry period from 2002 to 2004. Since 2004, however, groundwater elevations have increased considerably above the water levels recorded in the late 1980s and early 1990s. This recent recovery is most likely related to the utilization of surface water diverted from Conejo Creek and delivered to agricultural users in the basin. Camrosa Water District constructed the Conejo Creek Diversion in 2002 and has negotiated agreements to provide water to Pleasant Valley County

Water District (PVCWD), a major supplier of agricultural water in the Pleasant Valley basin. From 2004 to 2011, diversions from Conejo Creek have averaged approximately 5,600 acre-feet per year. Use of this water for irrigation has reduced pumping demands in the basin. Despite the water level recovery in this well over the past twenty years, recent records show levels remain 26 feet below sea level.

The groundwater elevation hydrograph for a well in the southern Pleasant Valley area, located along Laguna Road, shows a 1991 drought groundwater elevation of 174 feet below sea level. Since 1993, groundwater levels have returned to pre-drought levels and annual high water levels have remained fairly stable. Annual variability in groundwater elevation appears to be greater following the drought, which could be the influence of a nearby well. Unlike some wells in the northern portion of the basin, spring high water levels recorded in this well are not appreciably higher than they were in the 1980s. The highest recorded groundwater elevation for this well is approximately twenty feet below sea level.

Groundwater elevation contours for LAS wells measured in spring and fall 2011 are shown in Figures 4.3-30 and 4.3-31. The LAS contours on the maps show the significant pumping depression that exists in west Pleasant Valley and the eastern Oxnard Plain, where groundwater elevations are well below sea level over a broad area. The fall maps show groundwater elevations in the pumping depression in excess of sixty feet below sea level, and approximately twenty feet lower than water levels recorded in the spring of 2011. The contours for both spring and fall indicate groundwater flow from the west Oxnard Plain and from the Oxnard Forebay to the north. A better understanding of the stratigraphy in the area between the Oxnard Forebay and the Pleasant Valley pumping depression has resulted in a change in the way water levels are contoured in this area (see discussion in Section 4.3.6.1). A steep groundwater gradient likely exists between the pumping depression and the recharge area along Calleguas Creek in the northern part of the basin, but this area is not contoured due to sparse well control and the unknown influence of faulting in the northern basin.

4.3.7.2 GROUNDWATER EXTRACTIONS

Maps showing reported groundwater pumping from LAS wells in the Pleasant Valley basin and on the Oxnard Plain are shown in Figure 4.3-27. The northern and eastern portions of the basin fall outside of United's district boundary, and pumping in those areas is not shown on figures in this report. Pumping from the LAS is concentrated along the western portion of the basin, and aligns with the areas where water levels are deepest in the basin. Pumping of the UAS is limited, and skewed towards the eastern portion of the basin that lies within United's boundary (Figure 4.3-26). A majority of the UAS wells report minor pumping and are likely used for domestic supply.

A majority of the pumping in the Pleasant Valley Basin occurs within United's boundaries. In 2011 5,684 acre-feet of groundwater was pumped from LAS wells, and 881 acre-feet of water was pumped from UAS wells in the Pleasant Valley Basin within United's boundary.

4.3.7.3 WATER QUALITY

The map showing the maximum groundwater chloride concentrations recorded in 2011 is shown as Figure 4.3-34. Samples from wells in the Pleasant Valley basin are distinctly higher than those from the Oxnard Plain to the west. Many wells in the Pleasant Valley Basin had chloride concentrations well over 100 mg/l, a common advisory chloride level for sensitive agricultural crops. A number of the samples are from wells operated by Pleasant Valley County Water District, which blends well water with surface water diverted from Conejo Creek and the Santa Clara River before delivery to areas growers.

During the RASA study in the early 1990s USGS investigators recognized high chloride in some Pleasant Valley basin wells. Innovative techniques were employed to profile flow and chloride concentrations in deep production wells. It was recognized that the highest chloride and TDS was commonly sourcing from the deepest portions of these deep LAS wells, but these zones contributed little water to the well. In 2001 United sought and was awarded an AB303 grant from the California Department of Water Resources to study the nature of the inland saline intrusion problem in the Pleasant Valley basin (UWCD, 2003). A major part of this study was depth dependent sampling and flow profiling of eight deep production wells in the basin. The USGS was contracted to perform this work, which included chemical analysis of major ions and trace elements as well as specific isotopes and chemical tracers. United staff characterized overdraft in the basin and performed groundwater modeling to assess how much additional water might be needed to bring the basin into balance. Geochemical analysis by the USGS was not complete before the project due date, and United's report titled *"Inland Saline Intrusion Assessment Project*" was submitted without the geochemical analysis. The report concluded that chloride increased with pumping during past period of drought, and that increased delivery of surface water to the area of the Pleasant Valley Basin pumping depression would help groundwater levels recover and likely decrease chloride concentrations in water produced from deep wells in the basin.

In 2005 the USGS published technical papers detailing the results of their sampling of Pleasant Valley wells, which included depth-dependent groundwater sampling, flow profiling, and analysis of isotopic and chemical tracers (Izbicki et al, 2005a; Izbicki et al, 2005b). The results detailed by the USGS included that: 1) high chlorides were entering wells from various sources at different depths; 2) concentrations of chlorides in the upper portion of some wells influenced by irrigation return flow were as high as 220 mg/L; 3) concentrations of chlorides in wells with depths greater than 1400 feet were as high as 500 mg/L and had the chemical and isotopic composition trending toward oil field production water in the area; 4) higher chloride concentrations occurred in deep wells near faults that bound the valley such as the Camarillo fault in the north basin and the Bailey Fault on the south side of the basin; and 5) chlorides increase with increased pumping during droughts.

A recommendation by the USGS was that the sealing of the low-yield and poor-quality lower portions of some deep wells would act to improve water quality in many production wells without sacrificing appreciable yield. The 2011 chloride concentrations shown in Figure 4.3-34 suggests that a majority of the wells in the basin are impacted by elevated chloride concentrations. These

impacts are likely to continue as chronic overdraft conditions persist in the basin and deep brines migrate upward in response to the hydraulic gradients produced by over-pumping. Figure 4.3-40 displays maximum chloride concentrations from calendar year 1990, a year when extensive sampling was conducted by the USGS as part of the RASA study. In this drought year few wells recorded chloride less than 100 mg/l. Comparison of chloride records from 1990 to 2011 reveals that recent samples from a number of wells record higher chloride now than they did in a past period of drought.

Recharge water sourcing from Arroyo Las Posas in the northern portion of the Pleasant Valley basin is another significant chloride input to the basin. Chloride loading associated with this recharge is currently under evaluation as part of a proposed desalter project for this area. The effort is being lead by the City of Camarillo in partnership with other parties.

4.3.8 WEST LAS POSAS BASIN

The West Las Posas basin is the western most of a series of three sub-basins that are referred to collectively as the Las Posas Basin. The other sub-basins of the Las Posas Basin are the East Las Posas Basin and South Las Posas Basin. The West Las Posas Basin is bounded to the north by South Mountain, to the south by the Camarillo Hills, to the west by the Oxnard Plain and to the east by the East Las Posas Basin. Only approximately the western one-third of the West Las Posas basin is included within the boundaries of United Water Conservation District (Figure 1-1).

The Los Posas Basin Users Group (LPUG) is currently in the process of formulating a Basin Specific Groundwater Management Plan for the Las Posas Basin. The portion of the basin within the District, however, is excluded from the Plan. Del Norte Mutual Water Company made a formal request of the LPUG to be excluded from the Las Posas Basin Plan on the basis of groundwater conditions, groundwater source, and political jurisdiction. LPUG agreed that the District's portion of the Las Posas Basin should not be managed under the Las Posas basin plan, because groundwater users pay pump charges for groundwater recharge and management activities conducted by United (LPUG, 2011). Although the United portion of the West Las Posas Basin will not be managed by the LPUG plan, it will be monitored because it is hydraulically connected to the remainder of the West Las Posas sub-basin.

4.3.8.1 WATER LEVELS

Groundwater levels have been monitored for nearly a century in the Las Posas Valley. Groundwater elevations in the West Las Posas Basin are monitored by UWCD and Ventura County Watershed Protection District (VCWPD) with private entities also providing data. Fewer wells are monitored in this basin than for most other basins within the District.

In the West Las Posas basin, piezometric heads range from approximately 100 feet below mean sea level (msl) near the Central Las Posas fault to approximately 50 feet above msl near the

Oxnard Plain, indicating a general northwest to southeast flow direction (LPUG, 2011). The flow pattern in the West Las Posas basin suggests the aquifer is receiving inflow from the Oxnard Plain and recharge along the northern flank of the valley. Groundwater moves across the sub-basin toward an area of focused pumping near Bradley Road where there has been a long history of depressed water levels (LPUG, 2011).

4.3.8.2 GROUNDWATER EXTRACTIONS

During calendar year 2011, a reported 3,536 acre-feet of groundwater were pumped from the portion of West Las Posas basin that lies within United's boundaries. The areal distribution of pumping in the UAS and LAS in 2011 is shown in Figures 4.3-26 and 4.3-27. In addition Del Norte Water Company pumps water from its well yard, located near Highway 118 and Santa Clara Avenue on the Oxnard Plain, for agricultural use in northern portions of the West Las Posas Basin within United's District boundary. In 2011 Del Norte pumped and exported 1,455 acre-feet from the Oxnard Plain to the West Las Posas Basin.

Pumping for domestic or potable supply is minimal in the western portion of the West Las Posas basin, as agriculture remains the predominant land use in this area.

4.3.8.3 WATER QUALITY

Water quality samples from wells in the West Las Posas basin indicate groundwater quality is generally adequate for agricultural and municipal use, however, localized exceedances of the MCL for TDS, nitrates, and sulfates have been reported.

Ventura County Watershed Protection District (2012) reports that six wells in the basin exceeded the MCL for TDS (average of 966 mg/L) with two wells having concentrations above the MCL for nitrate, and three wells having concentrations above the MCL for sulfate. Groundwater with this degree of mineralization is common throughout United's service area, and slightly elevated salt content does not pose a health risk. In the West Las Posas basin TDS and chloride concentrations tend to be higher in the northern and western portions of this basin compared to other areas, suggesting that mountain front recharge along the southern flank of South Mountain and inflow from the Oxnard Plain Basin are the sources of higher TDS and chloride concentrations (LPUG, 2011).

5 SUMMARY

United Water continues to evaluate various strategies to best manage and protect the surface and groundwater resources within the District. Current and on-going considerations include: the characterization of groundwater conditions, the most-efficient use of existing infrastructure and the need for additional or modified facilities, current and future water demands, current and anticipated water quality issues, and effective utilization of existing allocations of imported State Water Project water. United Water's goal is to identify the best use of local water resources and infrastructure, and to work with other agencies to implement these strategies, while honoring a coherent strategy and set of priorities that guides all future infrastructure and water management decisions.

The District's groundwater and surface water projects and programs are keyed to the issues and concerns that impact or potentially impact the water resources of the region. These issues and concerns evolve over time and United Water strives to adjust, modify, or devise new projects or programs in response to changing water resource challenges. Many of the projects and programs undertaken by United Water have long-term implementation schedules (e.g., District-wide groundwater level measurements, conservation releases), however, these types of efforts provide the critical data needed to make sound water resource management decisions that provide for the maintenance of reliable, sustainable, local water resources for the benefit of both agricultural and municipal and industrial water users in central and southern Ventura County.

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7 FIGURES AND TABLES

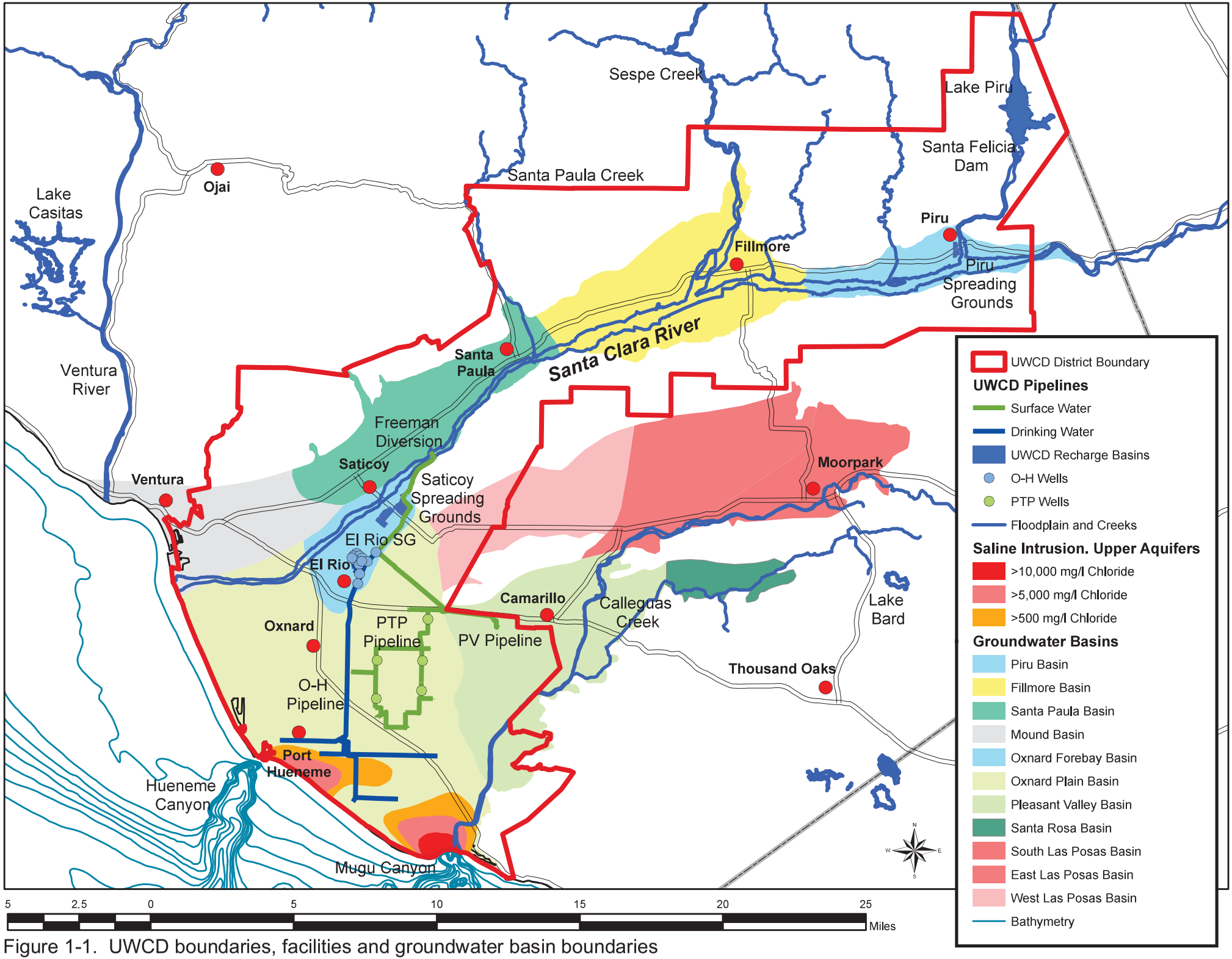


Figure 1-1. UWCD boundaries, facilities and groundwater basin boundaries

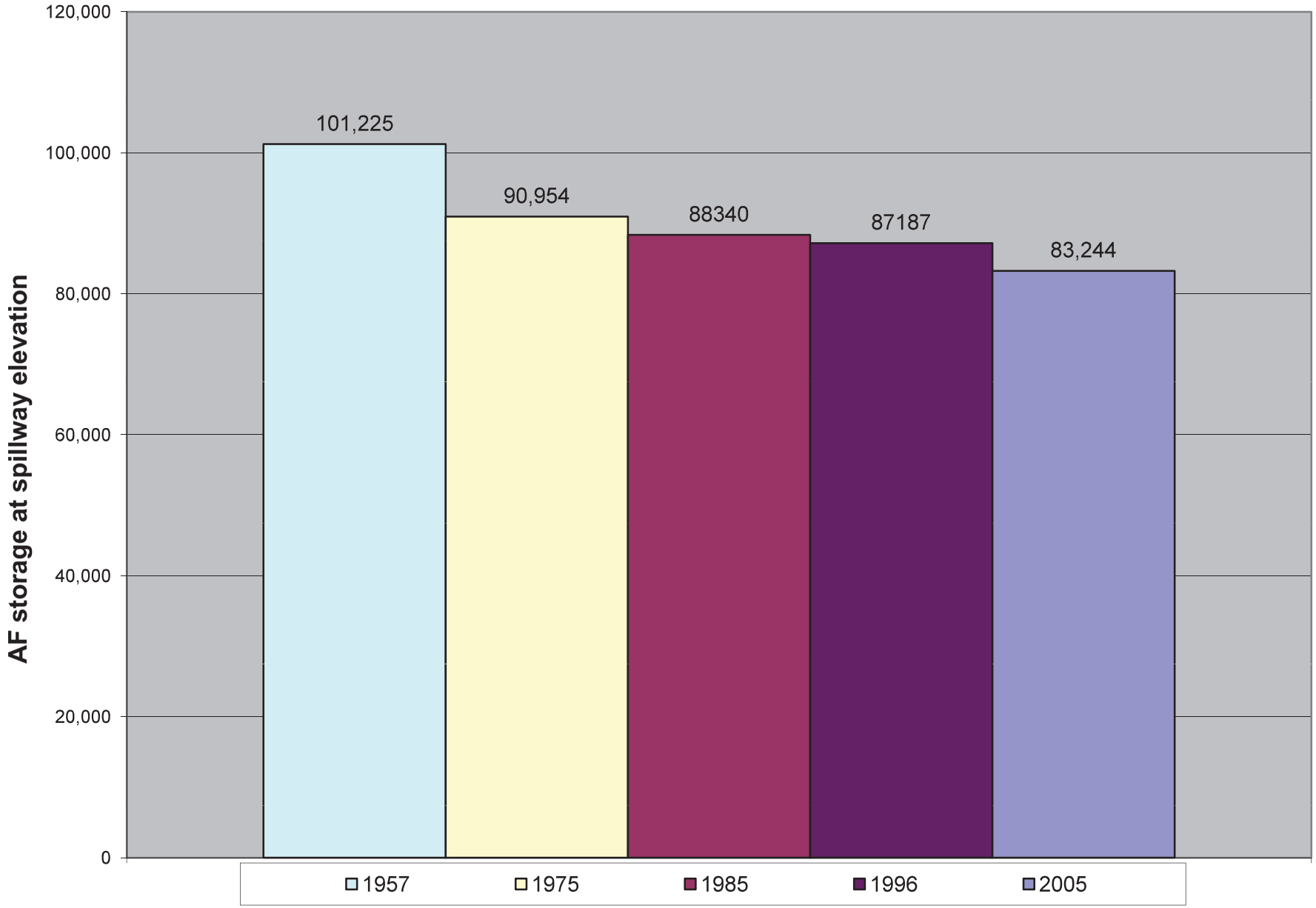


Figure 1.4-1. Silt surveys showing historic storage capacity in Lake Piru

Agricultural Water Deliveries			
	Surface water deliveries to the PTP (AF)	Ground water deliveries to the PTP (AF)	Surface water deliveries to Pleasant Valley Water District (AF)
JAN	346	160.6	385
FEB	362	85.8	453
MAR	376	0.1	643
APR	776	45.6	1,352
MAY	932	63.6	1,433
JUN	776	41.0	1,143
JUL	839	22.1	1,102
AUG	952	60.0	880
SEP	622	79.2	1,255
OCT	1,392	221.4	1,603.4
NOV	544	35.1	849.7
DEC	527	0.8	1,091.7

Figure 1.4-2. (Table showing) surface water deliveries to agriculture, 2011

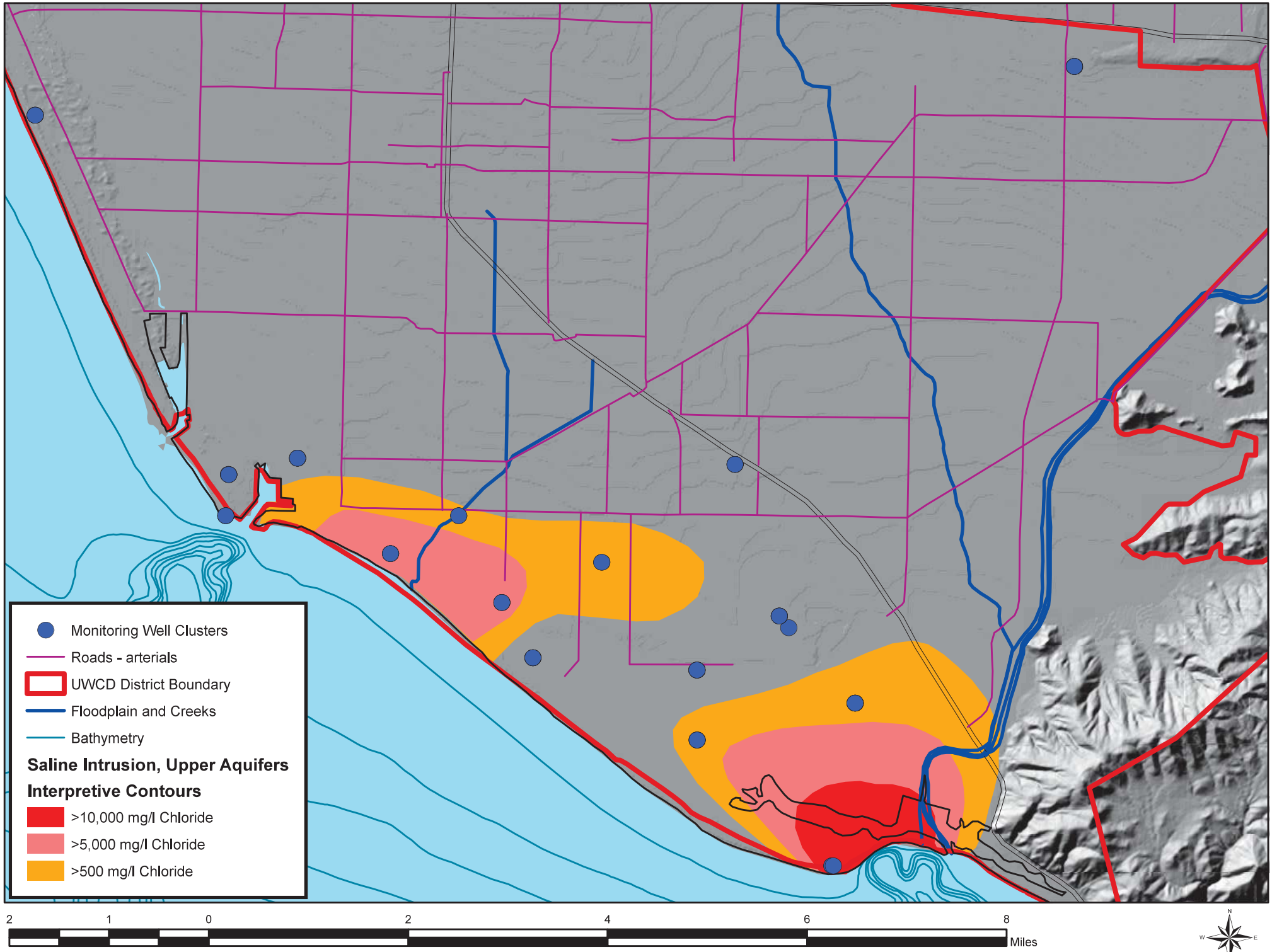


Figure 1.5-1. Locations of RASA coastal monitoring well clusters

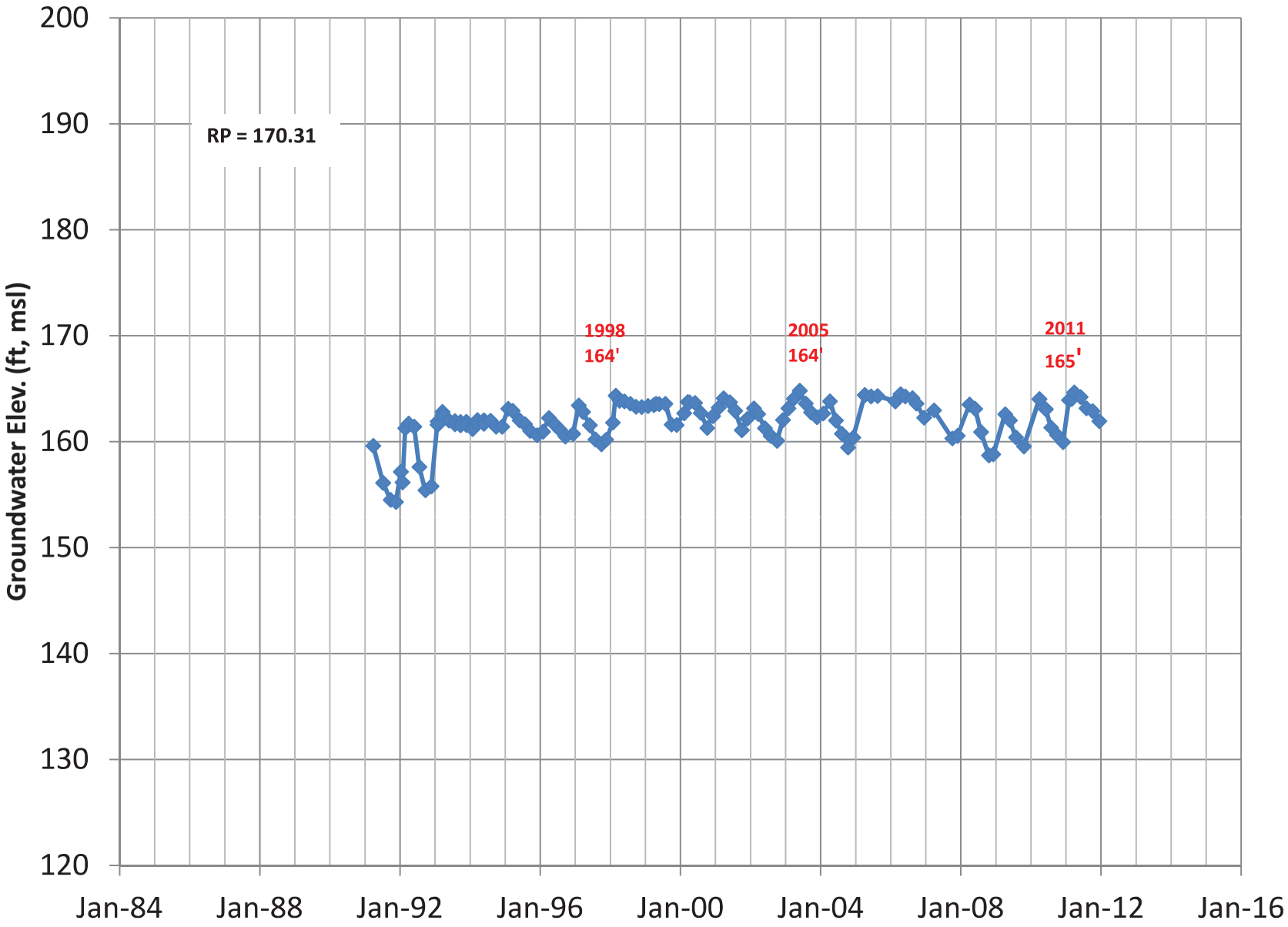


Figure 1.6-1. Groundwater elevations near the Freeman Diversion

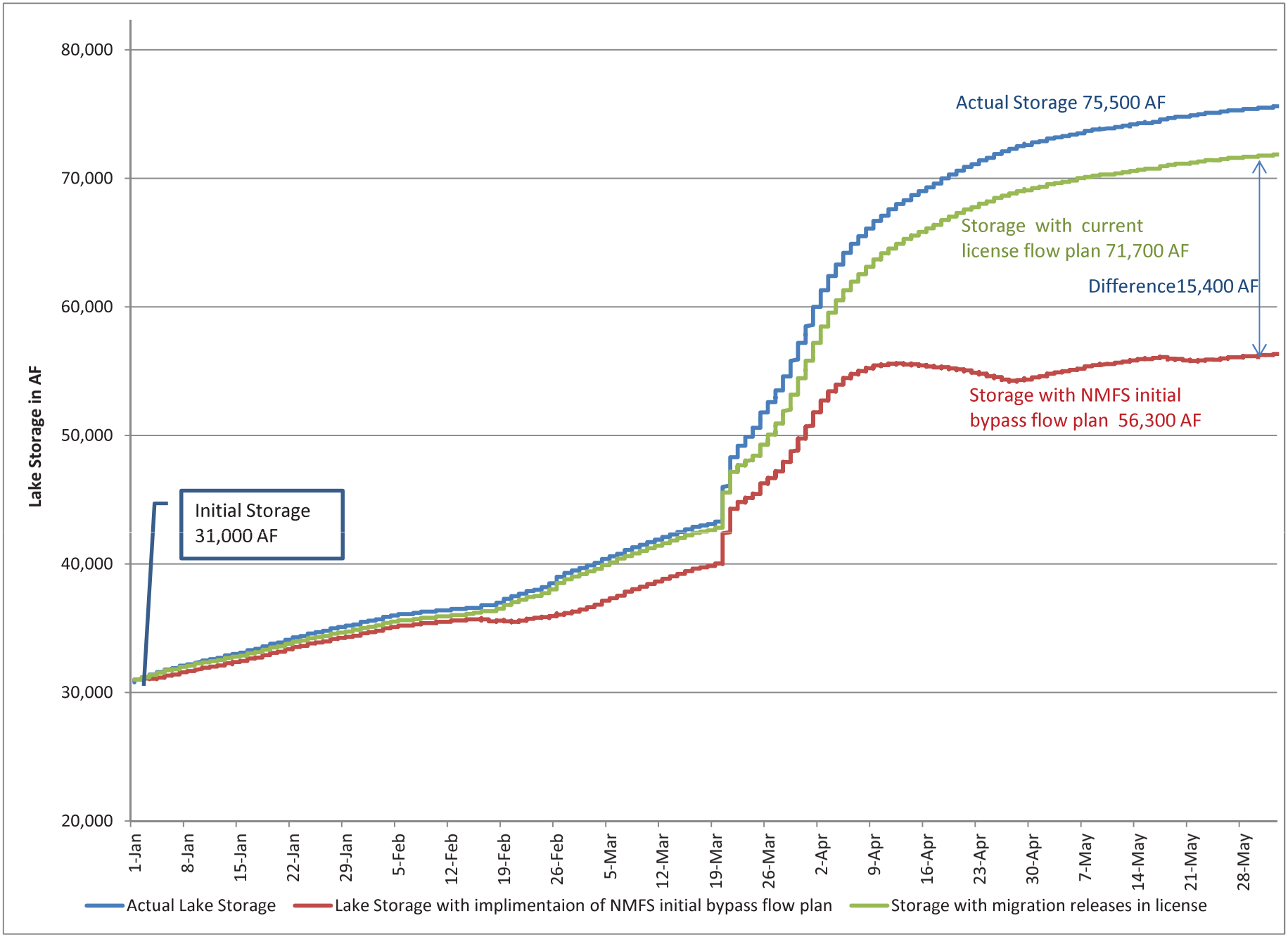


Figure 1.6-2. Possible lake levels with the current FERC license and NMFS recommended flows

Project	Overdraft Conditions	Declining Water Levels	Groundwater Exports	Saline Water Intrusion	Upwelling Saline Water	Riverbed Stabilization	Biological Opinion-SFD	Biological Opinion-VFD	VFD Operation	Aquifer Mapping	Recharge Optimization	Water Quality Degradation
Update Regional GW Flow Model	X	X	X	X	X	X				X	X	X
AB3030 Piru/Fillmore GW Management Plan Update			X								X	X
Santa Paula Basin TAC and Specialty Studies		X	X			X			X	X	X	
District-Wide GW Level Measurements / Piezometers	X	X	X	X	X	X	X	X	X		X	X
District-Wide Water Quality Sampling & Analyses	X	X	X	X	X						X	X
District-Wide Stream Gauging	X	X				X	X	X	X		X	X
Surface Geophysical Studies (Seismic Reflection, TDEM)	X	X		X						X	X	
SCR/Forebay Piezometer Installation		X					X	X	X		X	

Figure 2.1-1. Groundwater issues and concerns versus projects

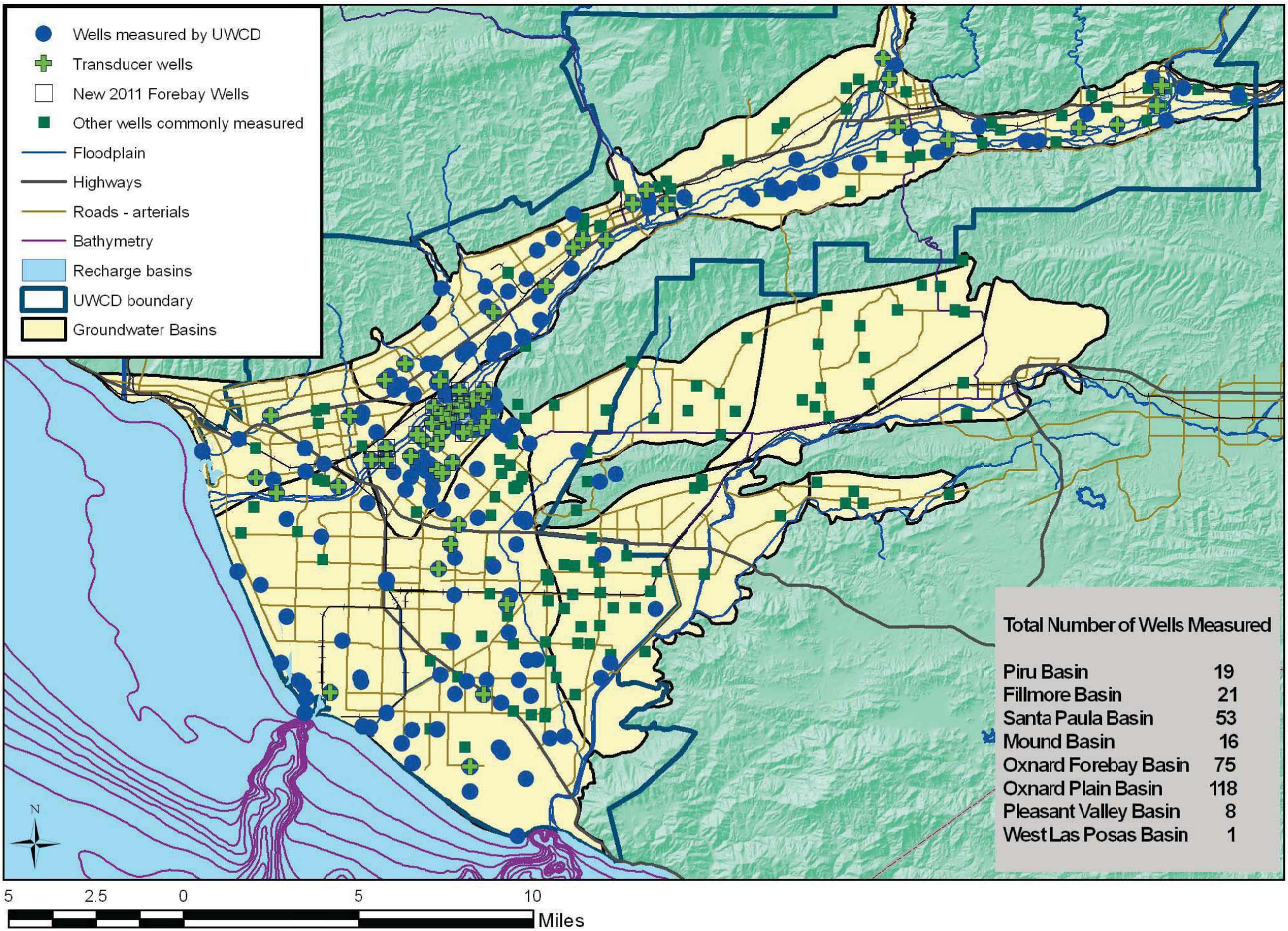


Figure 2.1-2. Wells monitored by United for water levels

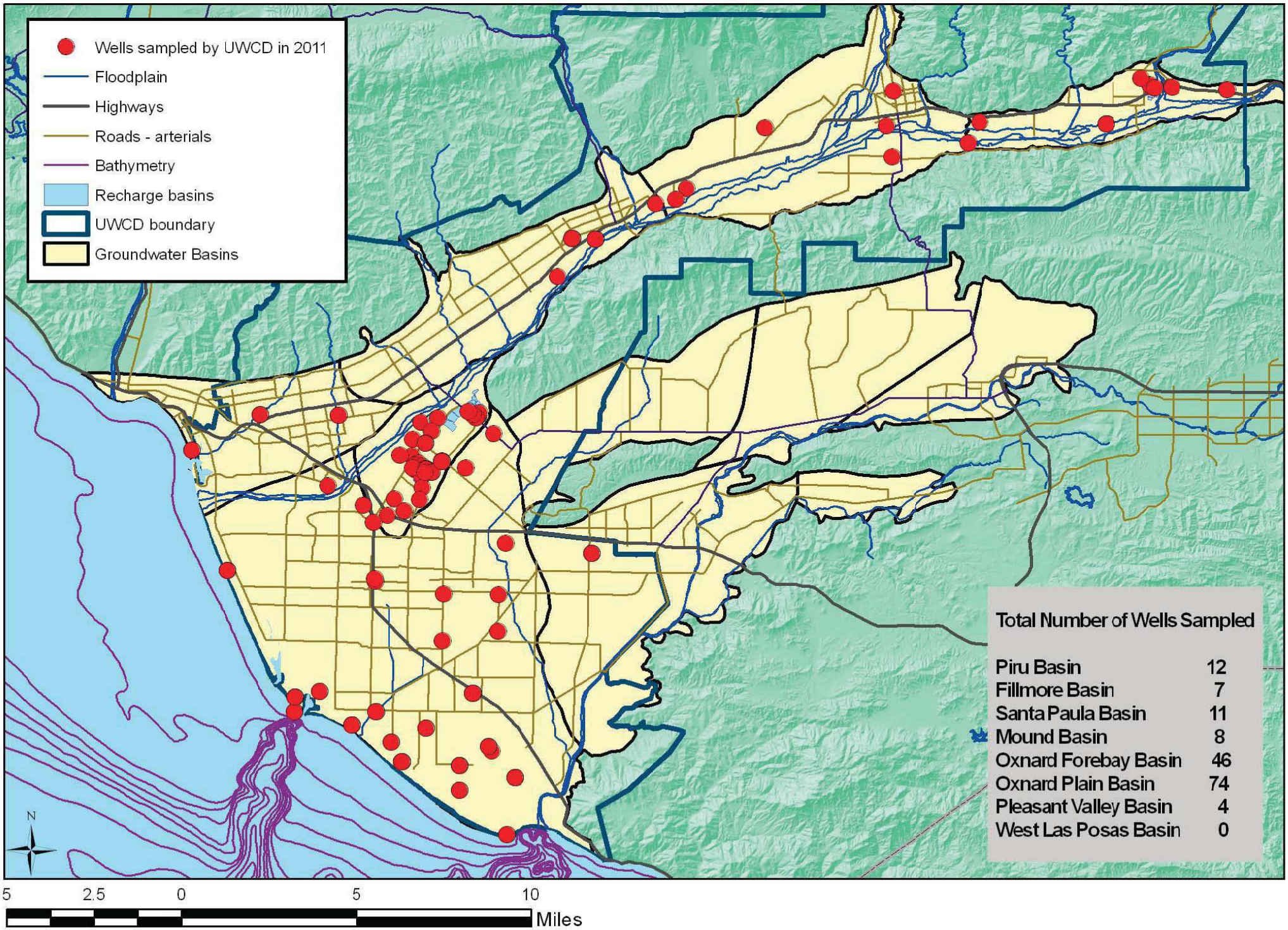


Figure 2.1-3. Wells sampled by United for water quality

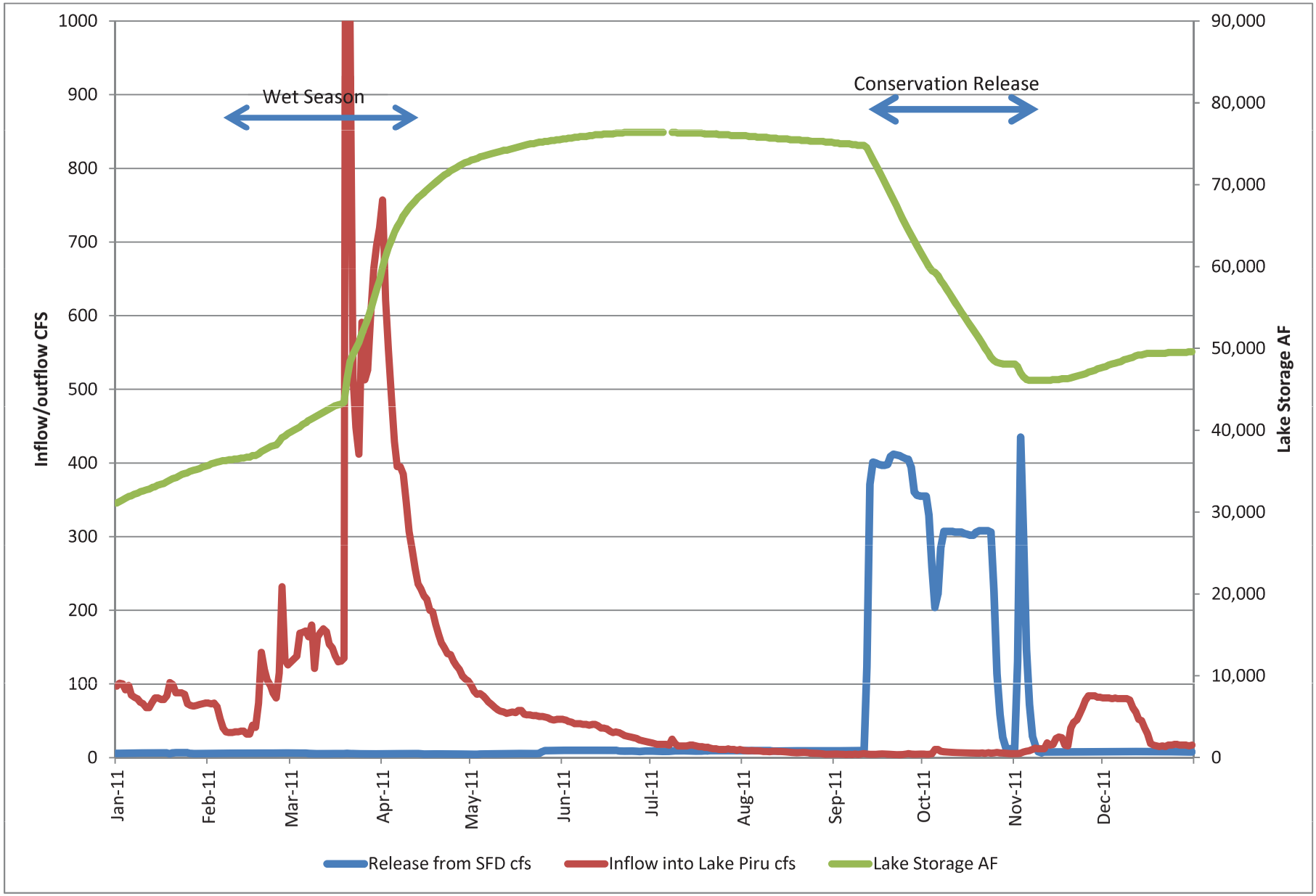


Figure 2.2-1. Basic hydrology for 2011 at Lake Piru

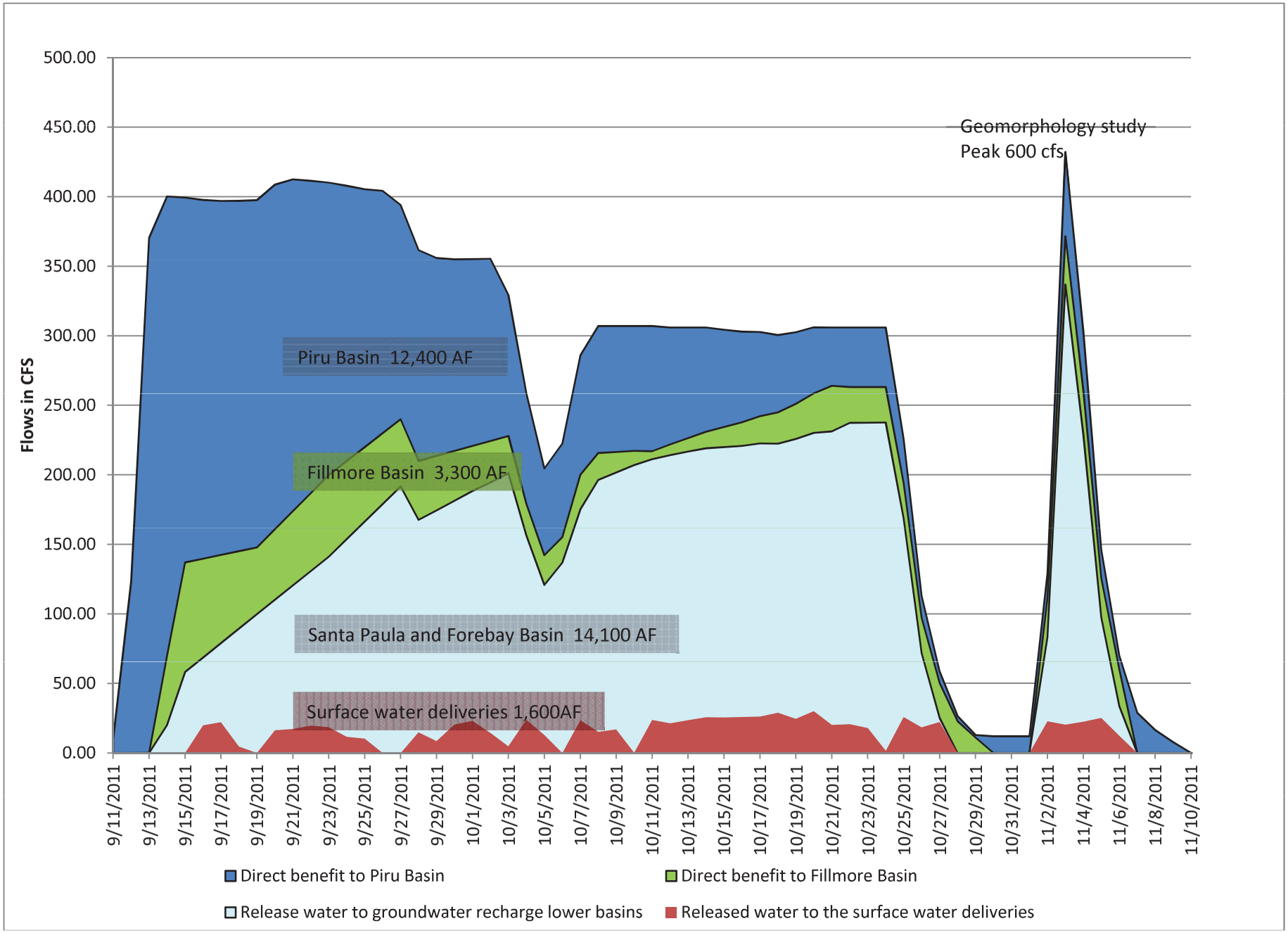


Figure 2.2-2. Benefit to each basin from direct percolation during 2011 conservation release

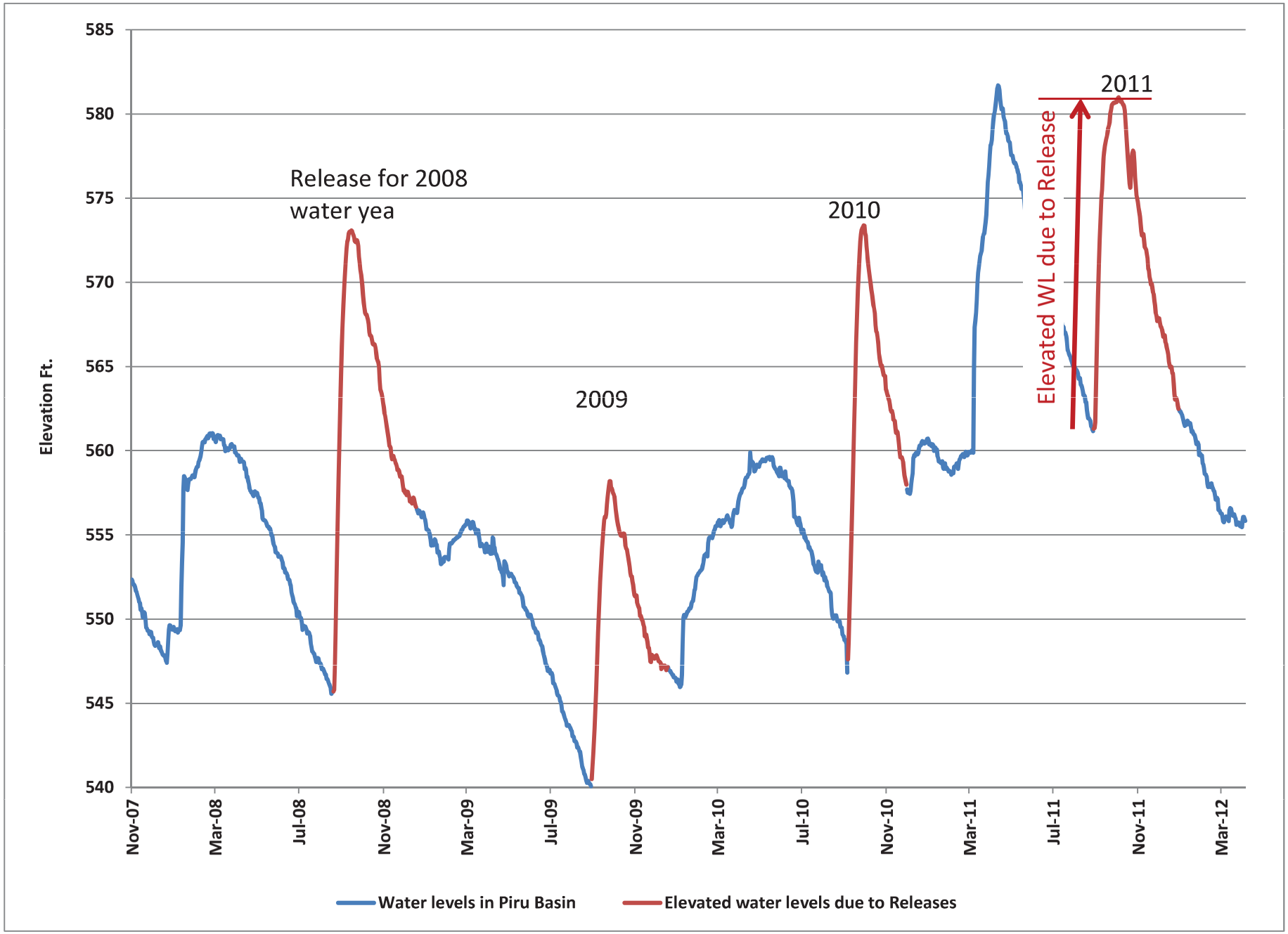


Figure 2.2-3. Groundwater response in the Piru Basin to conservation release from Santa Felicia Dam (well 04N18W31D07S)

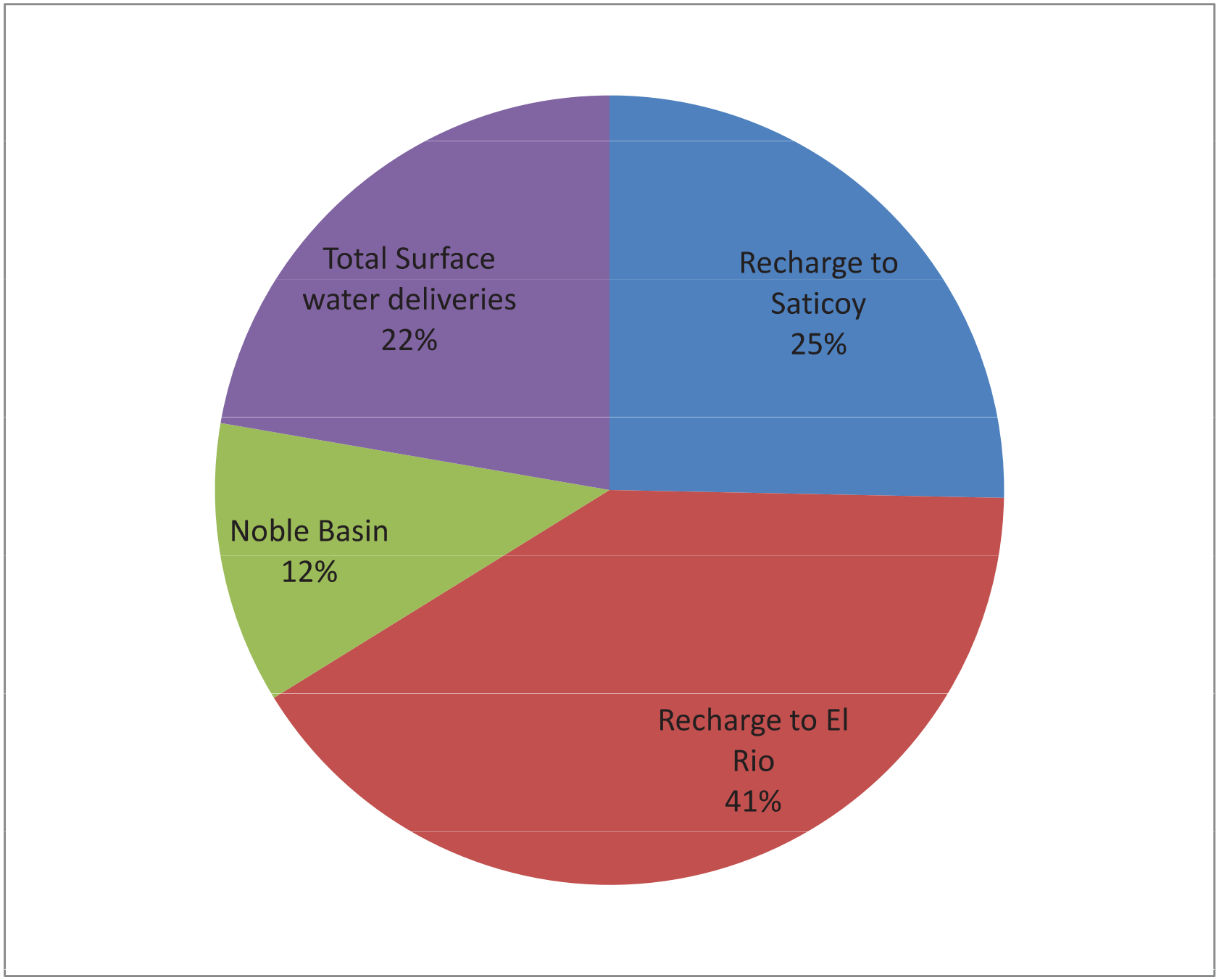


Figure 2.2-4. Distribution of water diverted at Freeman Diversion, 2011

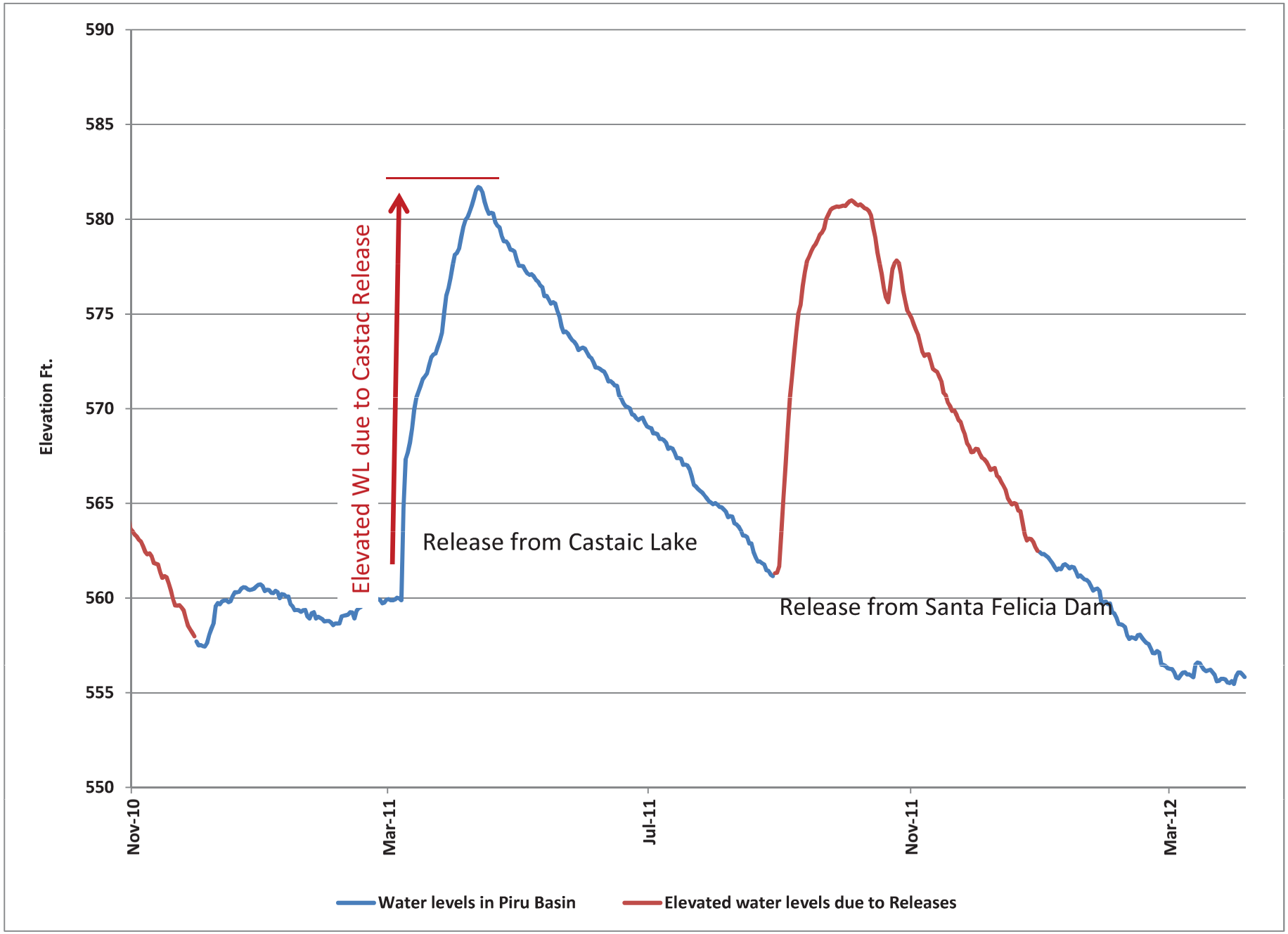


Figure 2.2-5. Groundwater response in the Piru Basin to Castaic floodflow release (well 04N18W31D07S)

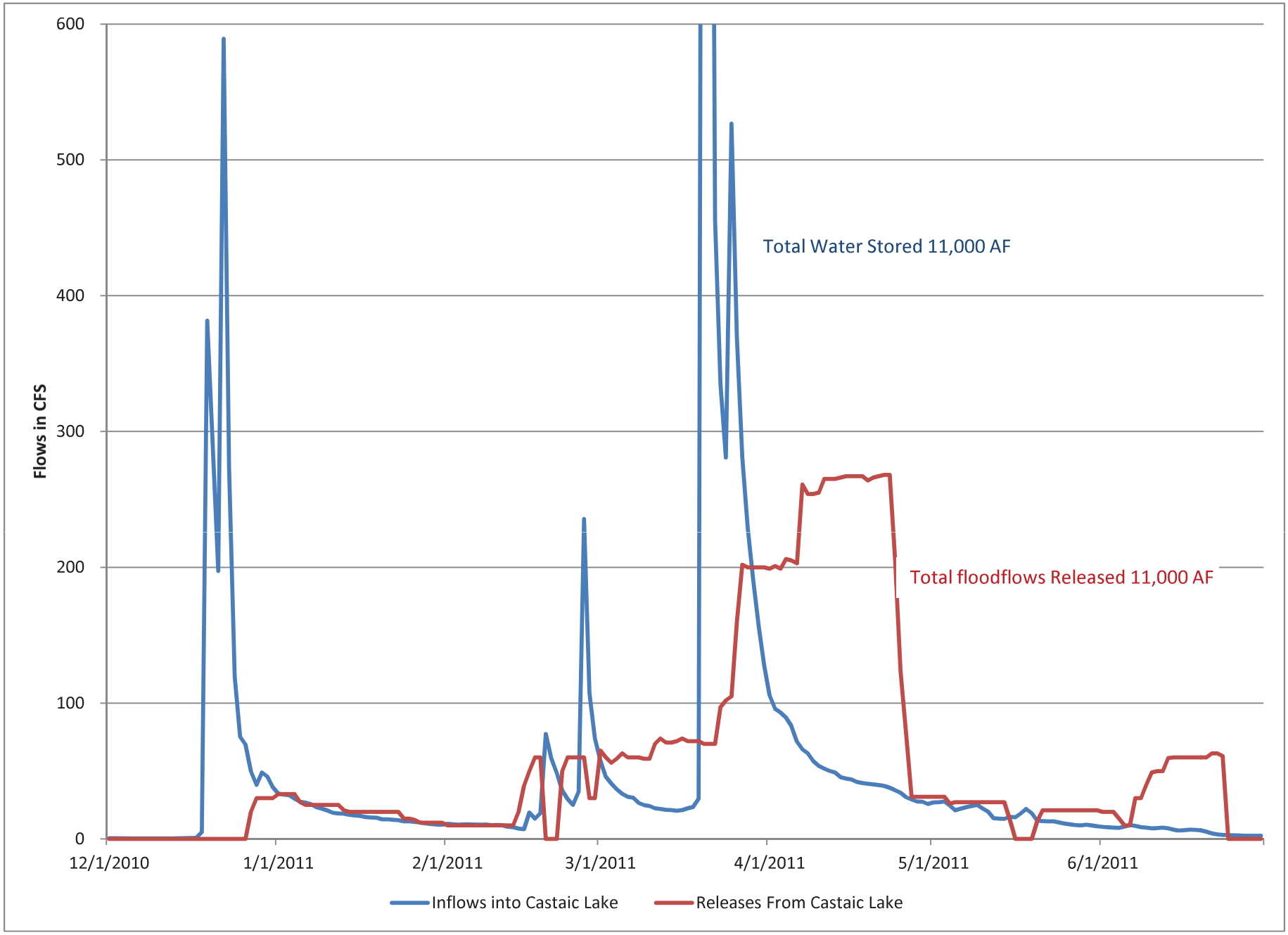


Figure 2.2-6. Conservation release from Castaic Lake for downstream water users

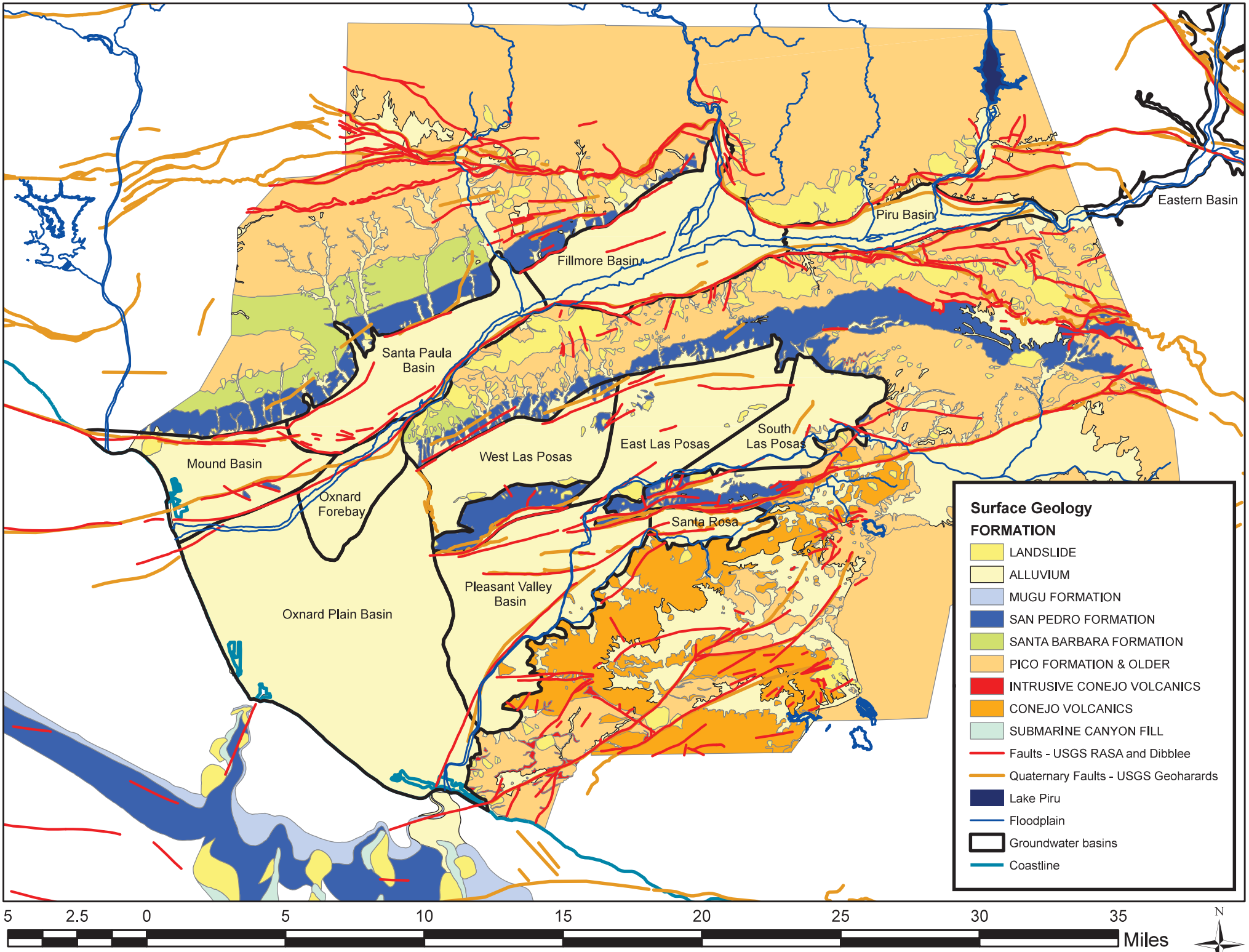


Figure 3.1-1. Surface geology and faults

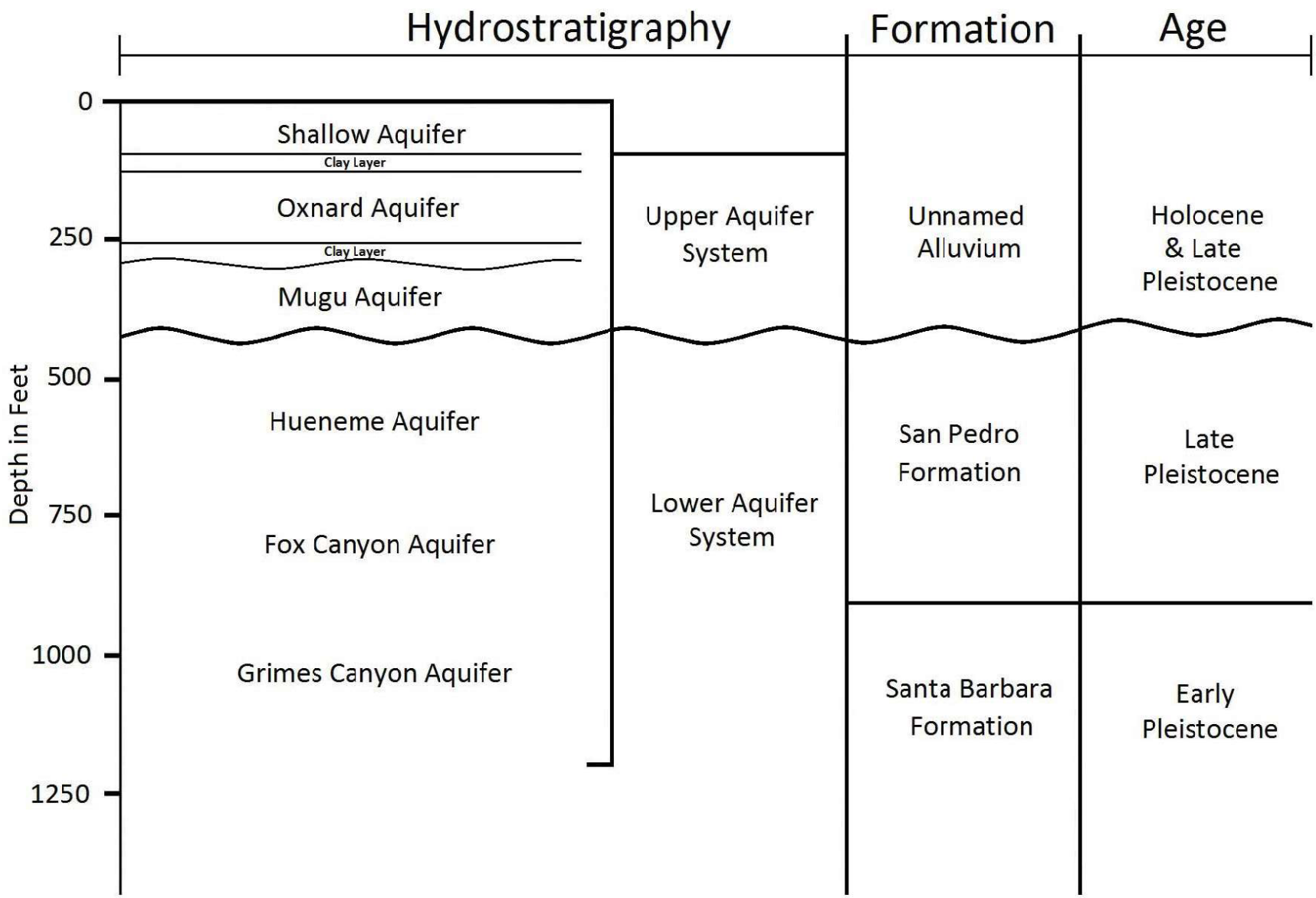


Figure 3.2-1. Schematic of UAS and LAS aquifer systems

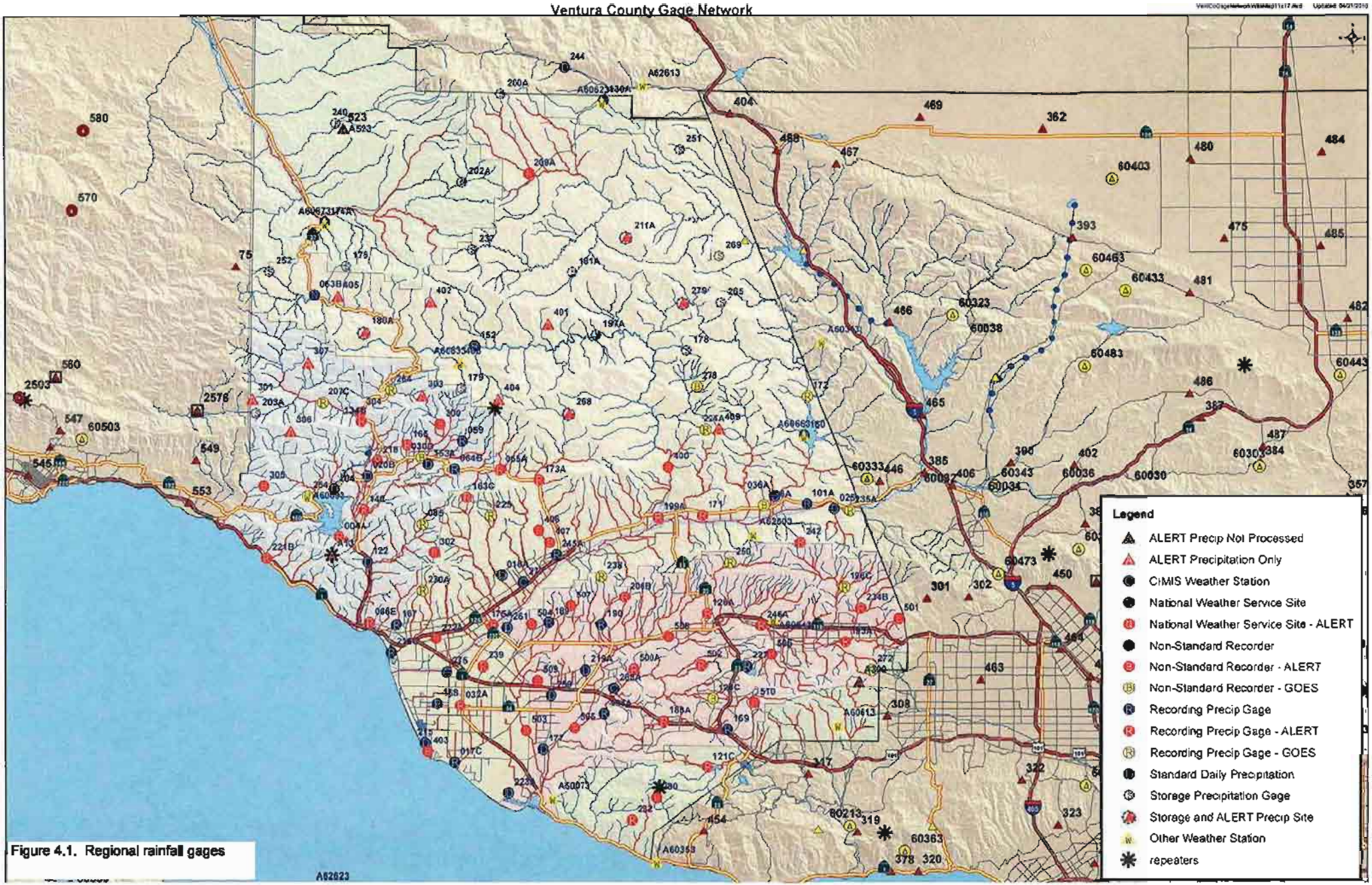


Figure 4.1. Regional rainfall gages

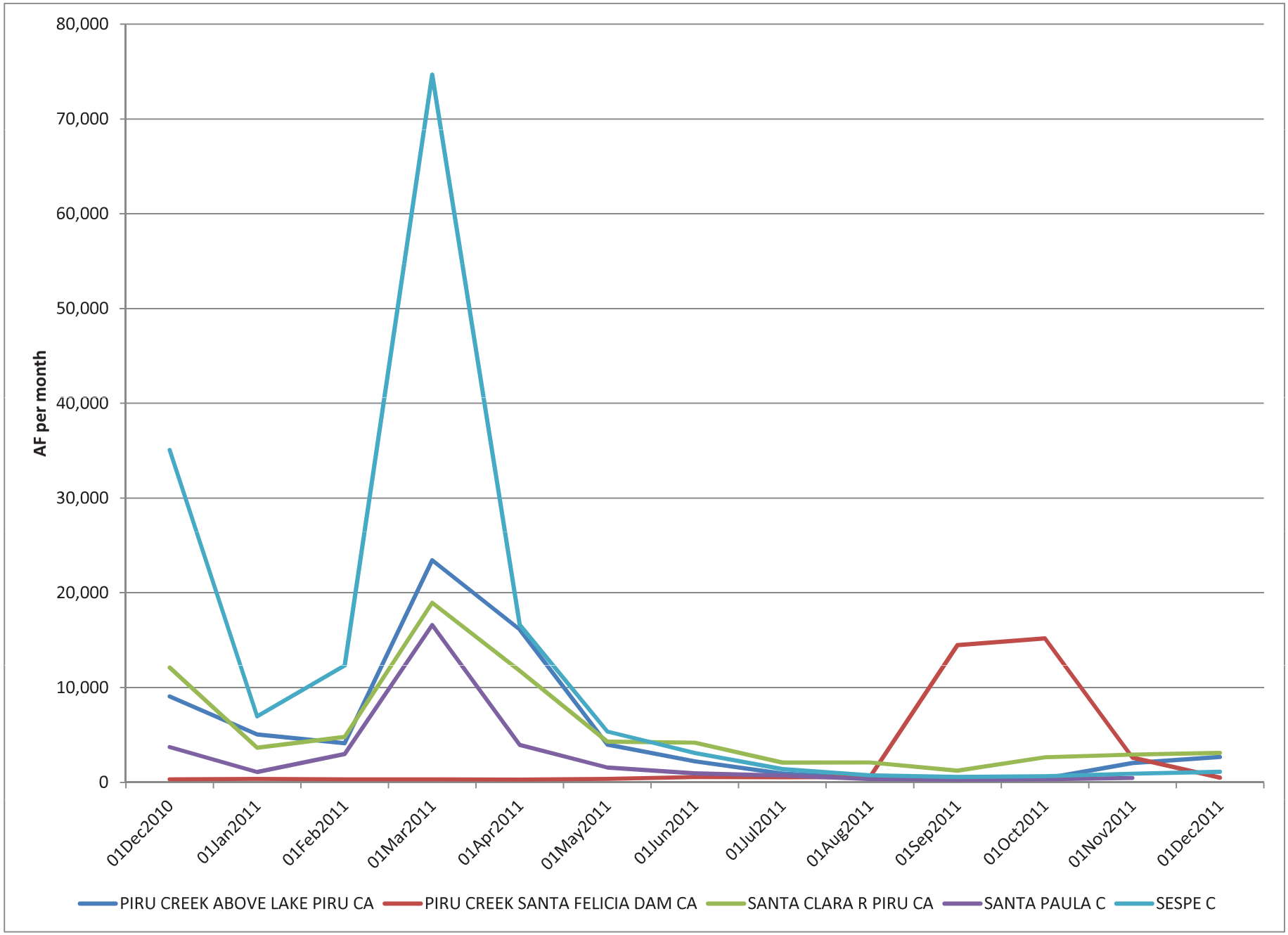


Figure 4.2-1. Monthly flows of the major tributaries in the Santa Clara River Watershed

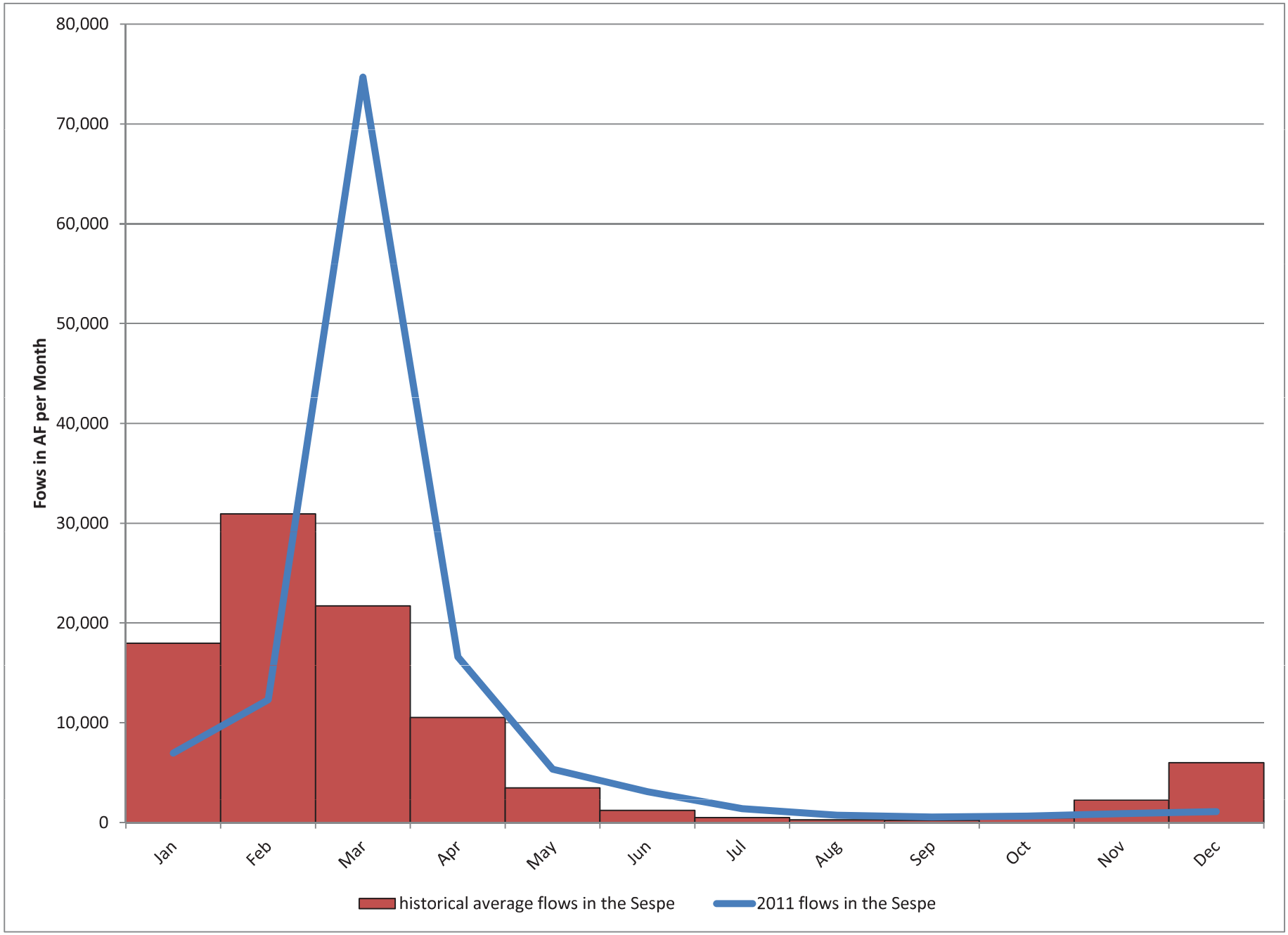


Figure 4.2-2. 2011 Flows in the Sespe Creek compared to average flows (1972-2010)

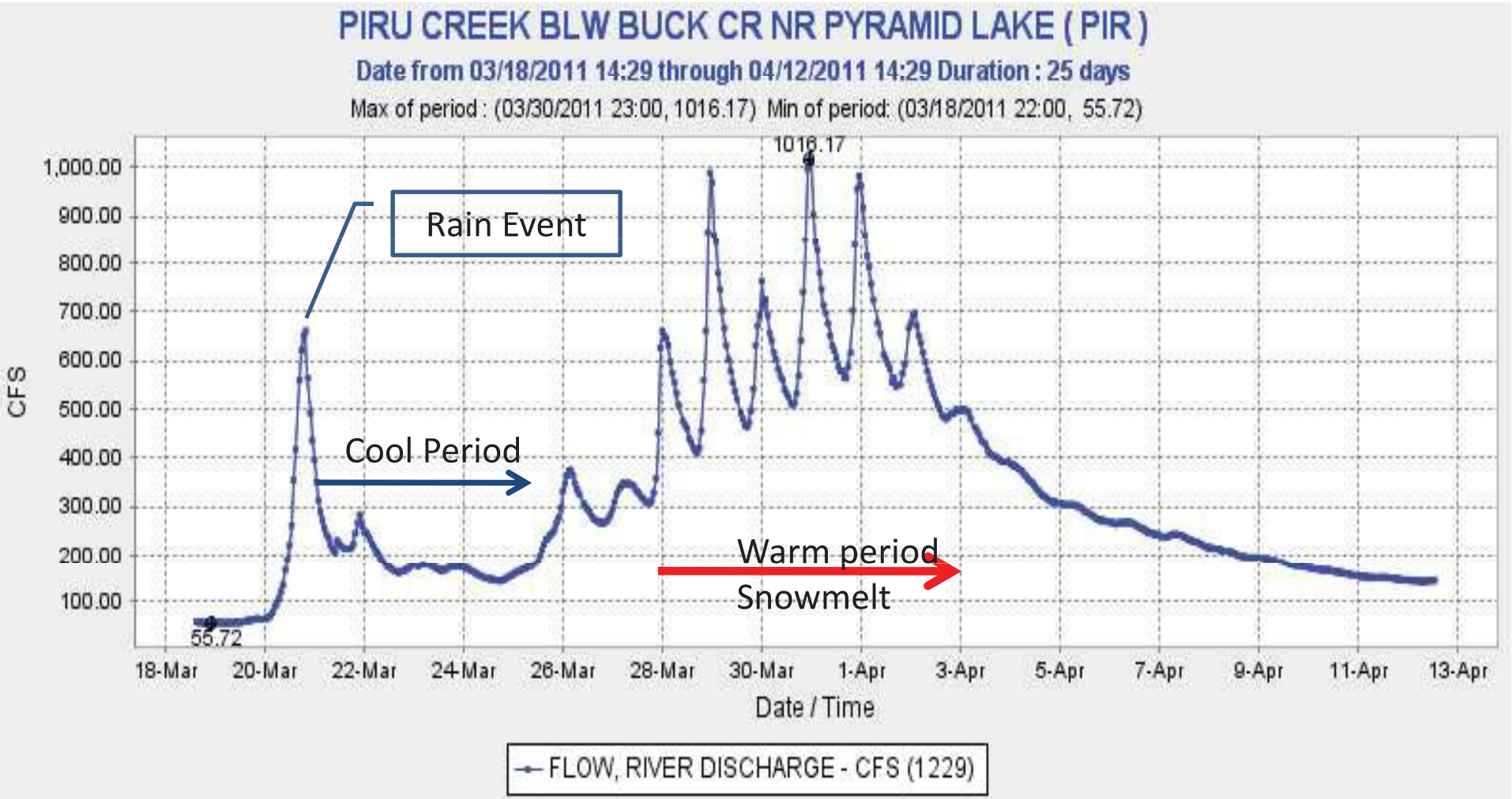


Figure 4.2-3. Spring 2011 snowmelt event in the Piru Watershed

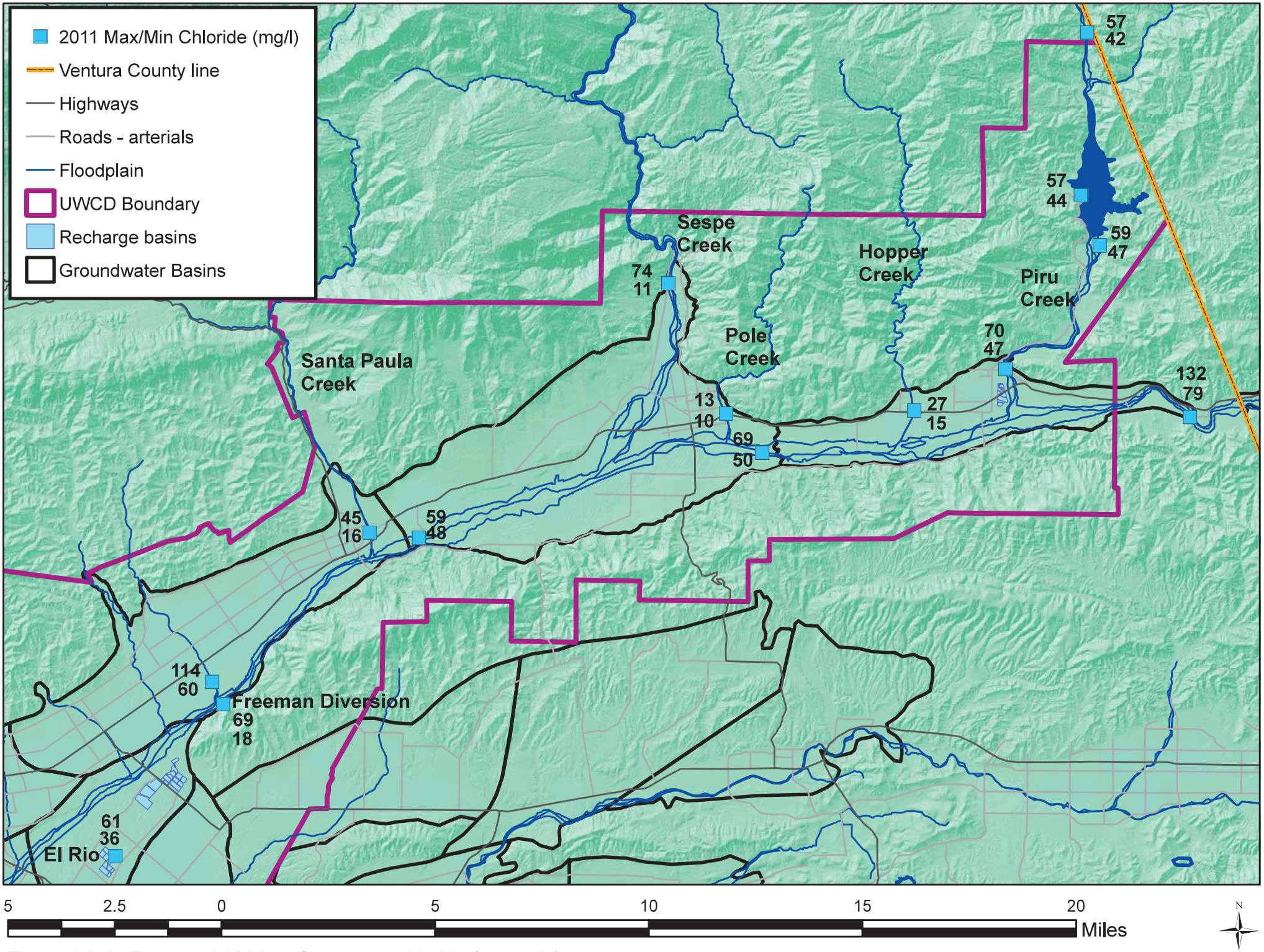


Figure 4.2-4. Recorded 2011 surface water chloride (max-min)

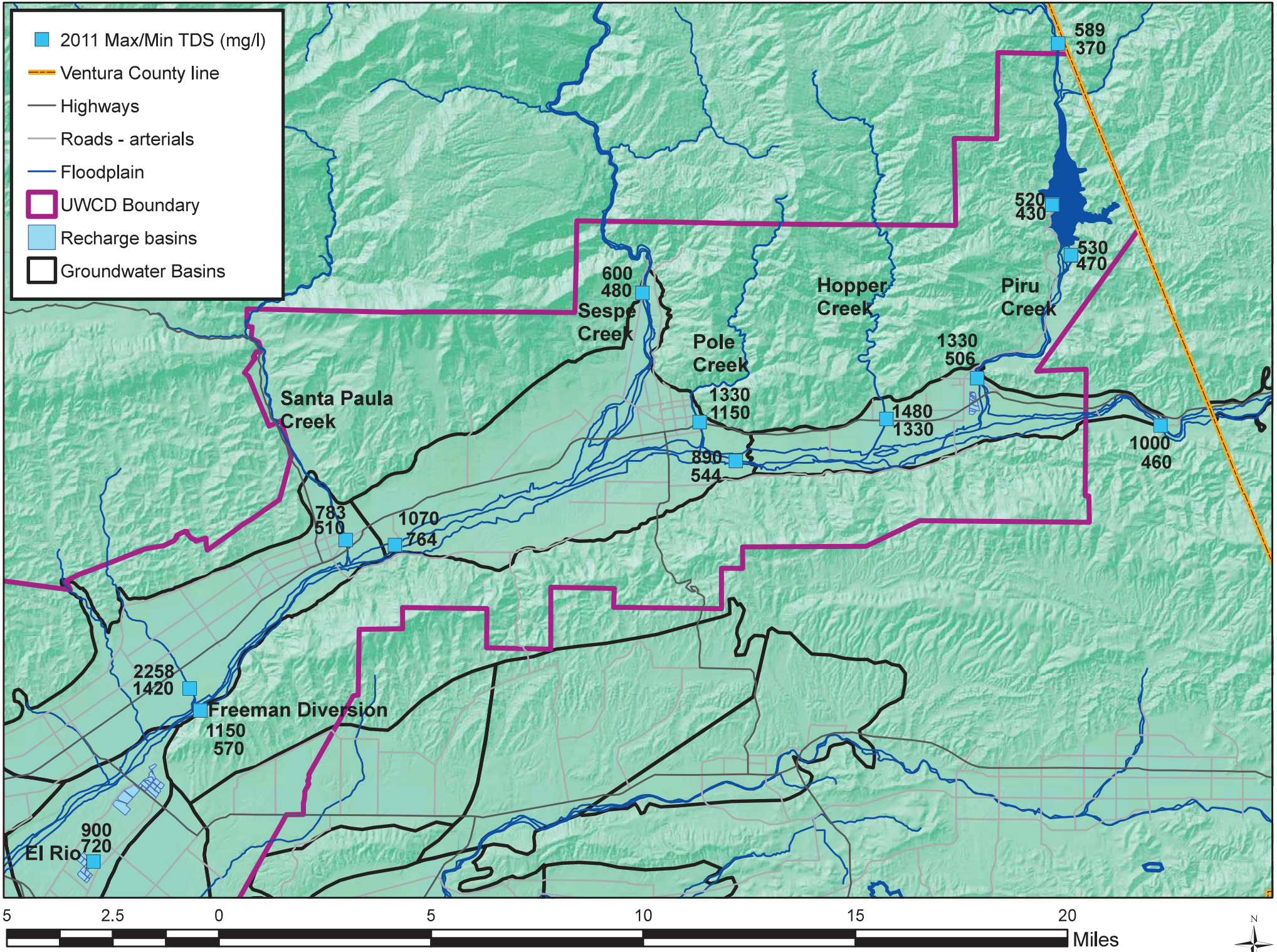


Figure 4.2-5. Recorded 2011 surface water TDS (max-min)

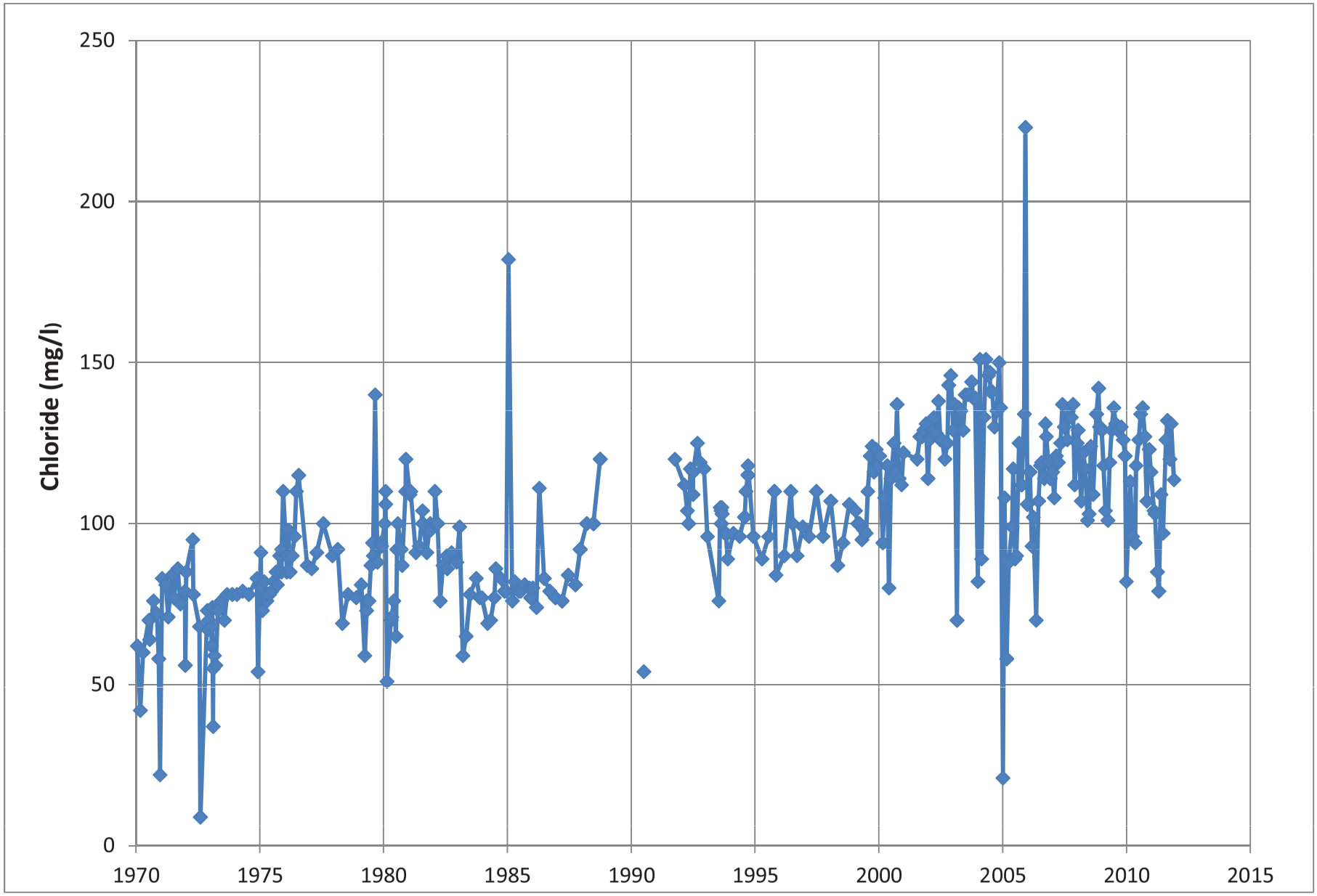


Figure 4.2-6. Historical chloride concentrations in the Santa Clara River near the Ventura-Los Angeles County line

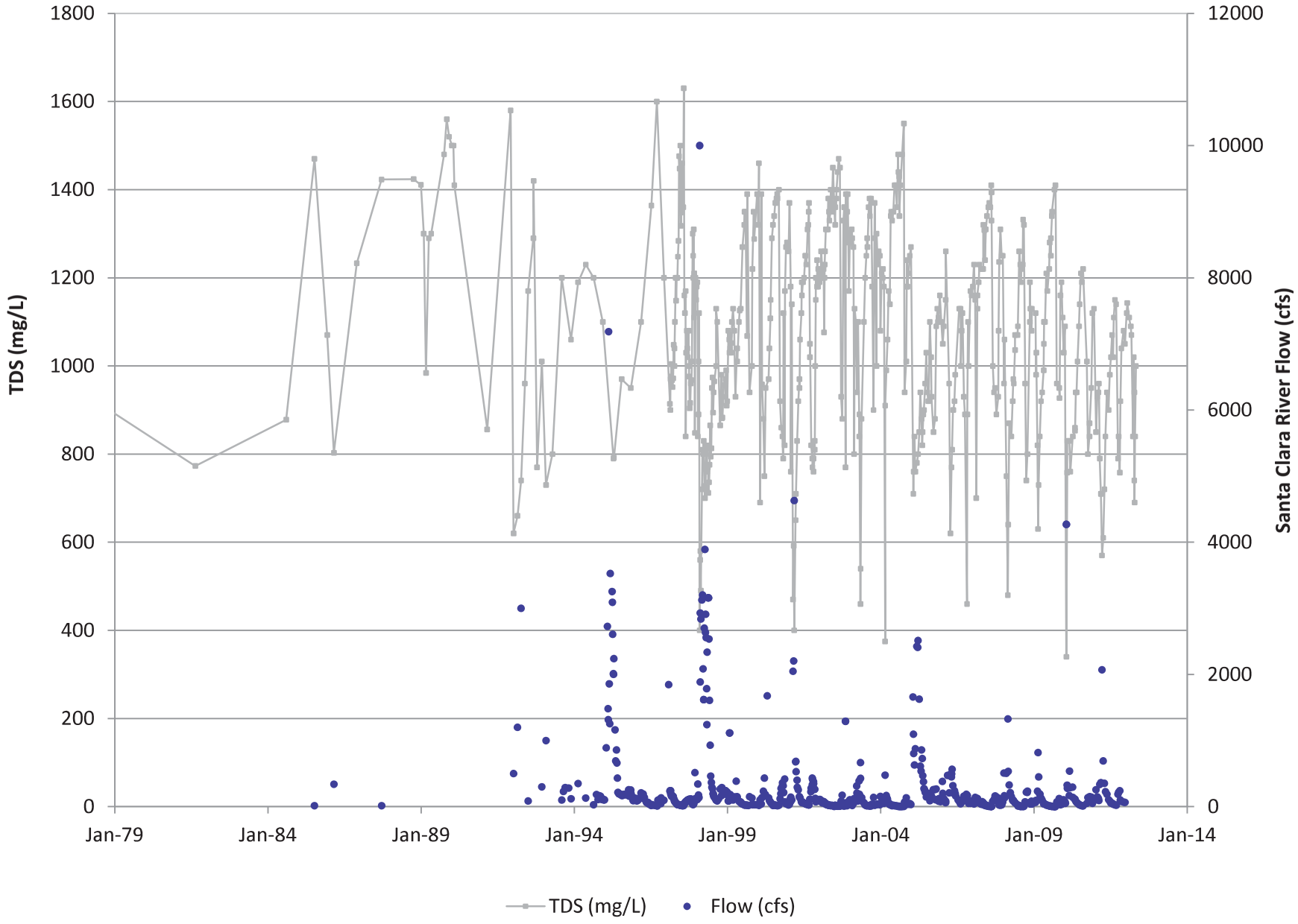


Figure 4.2-7. Historical TDS concentrations in the Santa Clara River at the Freeman Diversion

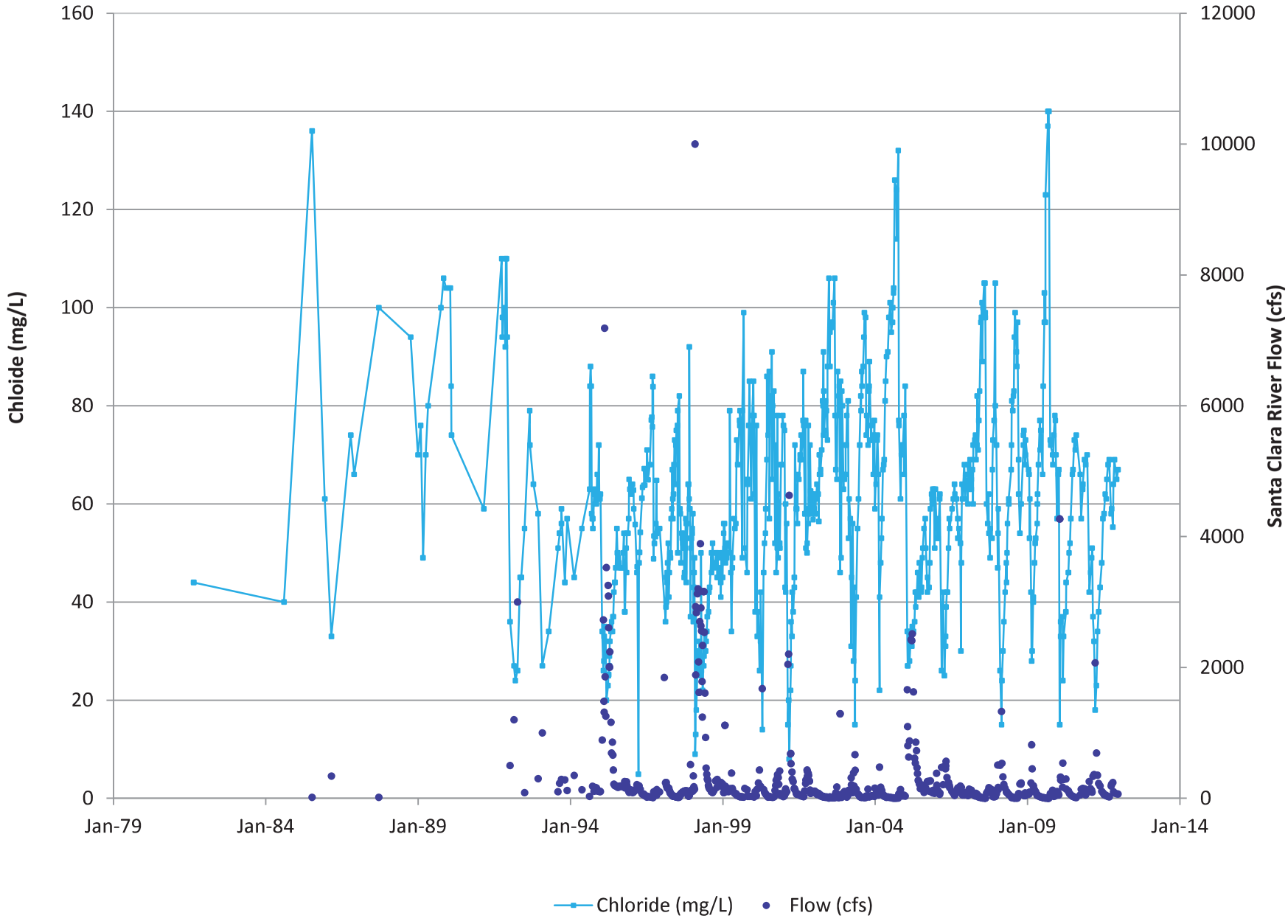


Figure 4.2-8. Historical chloride concentrations in the Santa Clara River at the Freeman Diversion

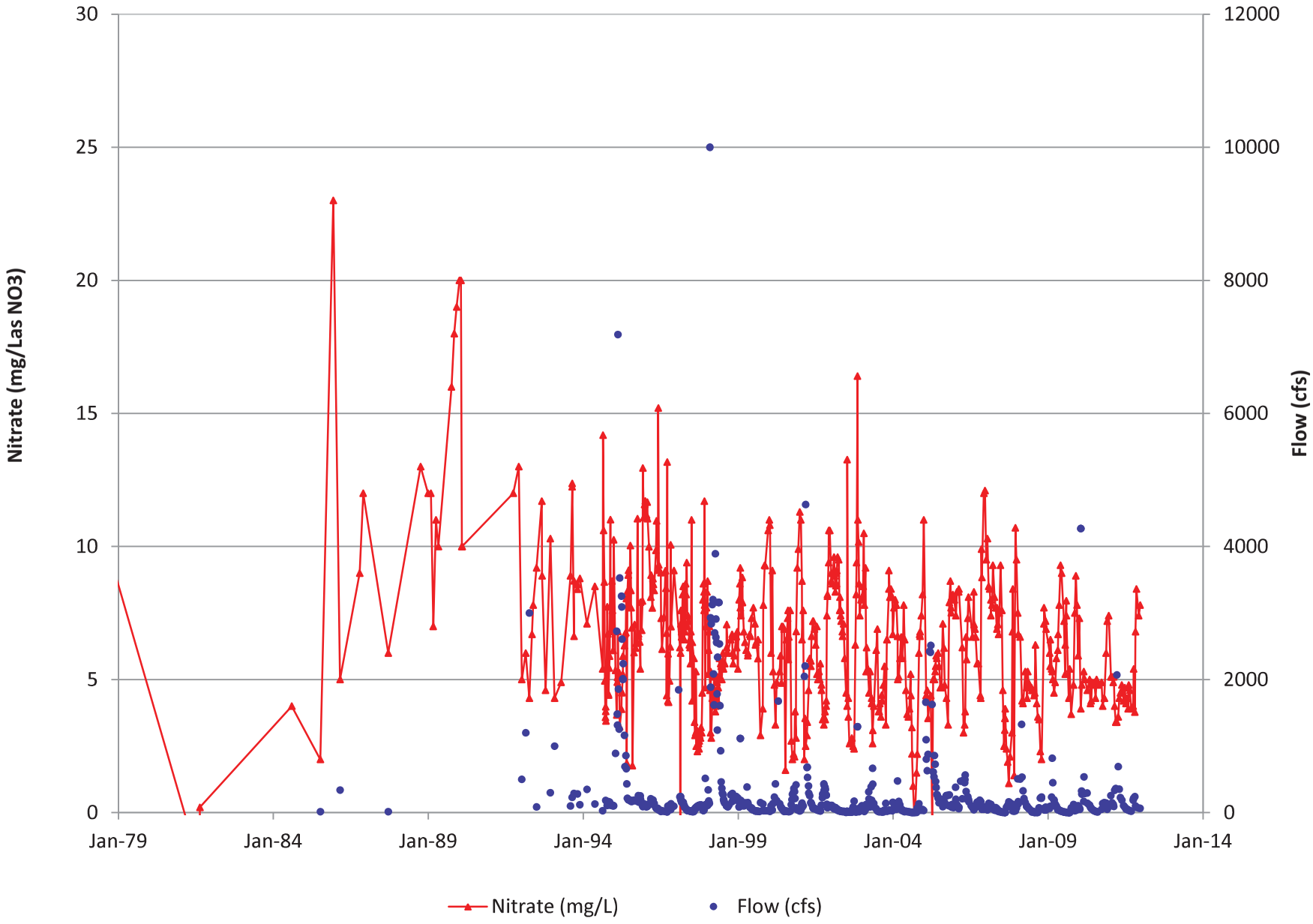


Figure 4.2-9. Historical nitrate (NO3) concentrations in the Santa Clara River at the Freeman Diversion

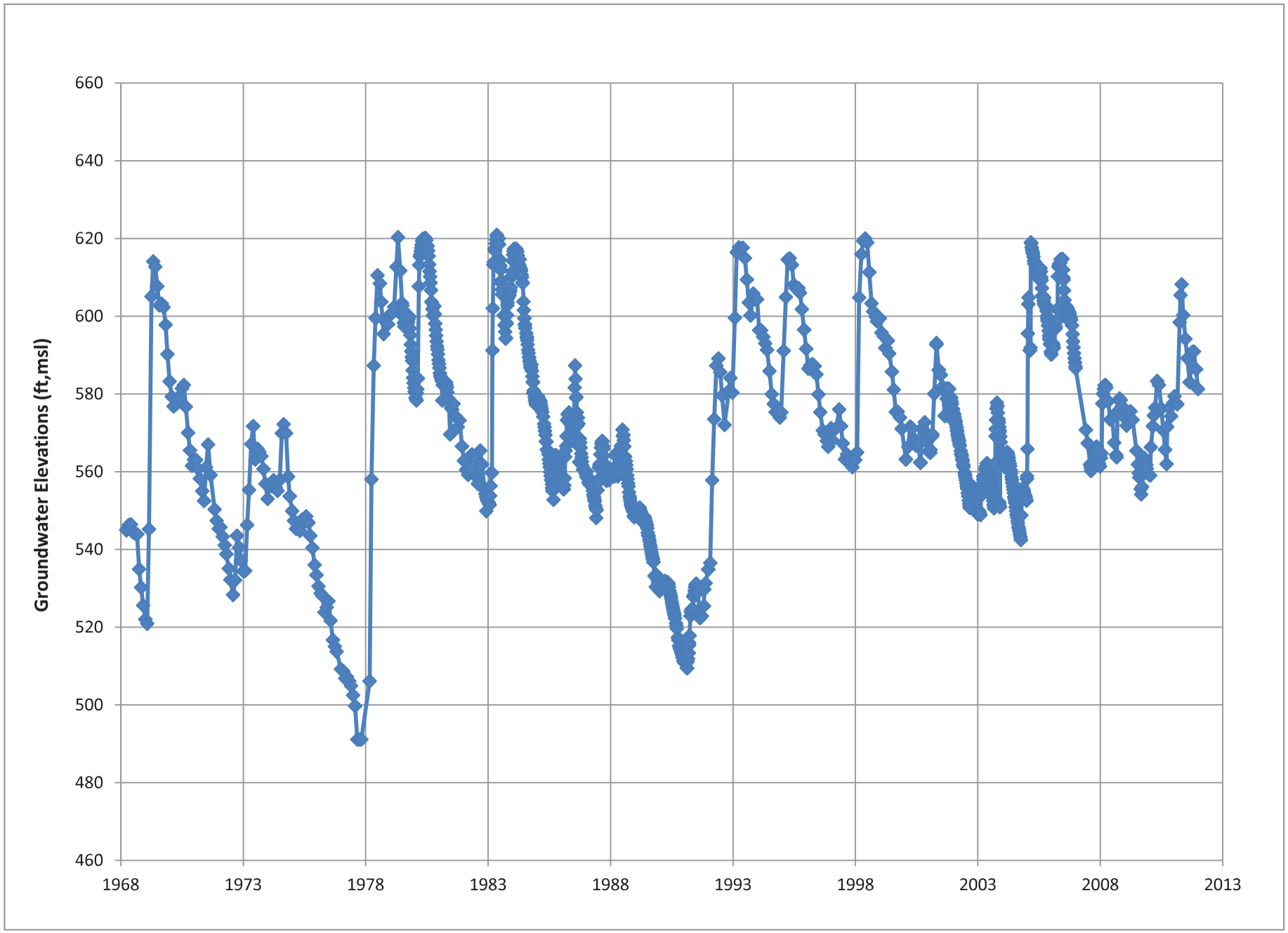


Figure 4.3-1. Historical groundwater elevations in Piru Basin key well

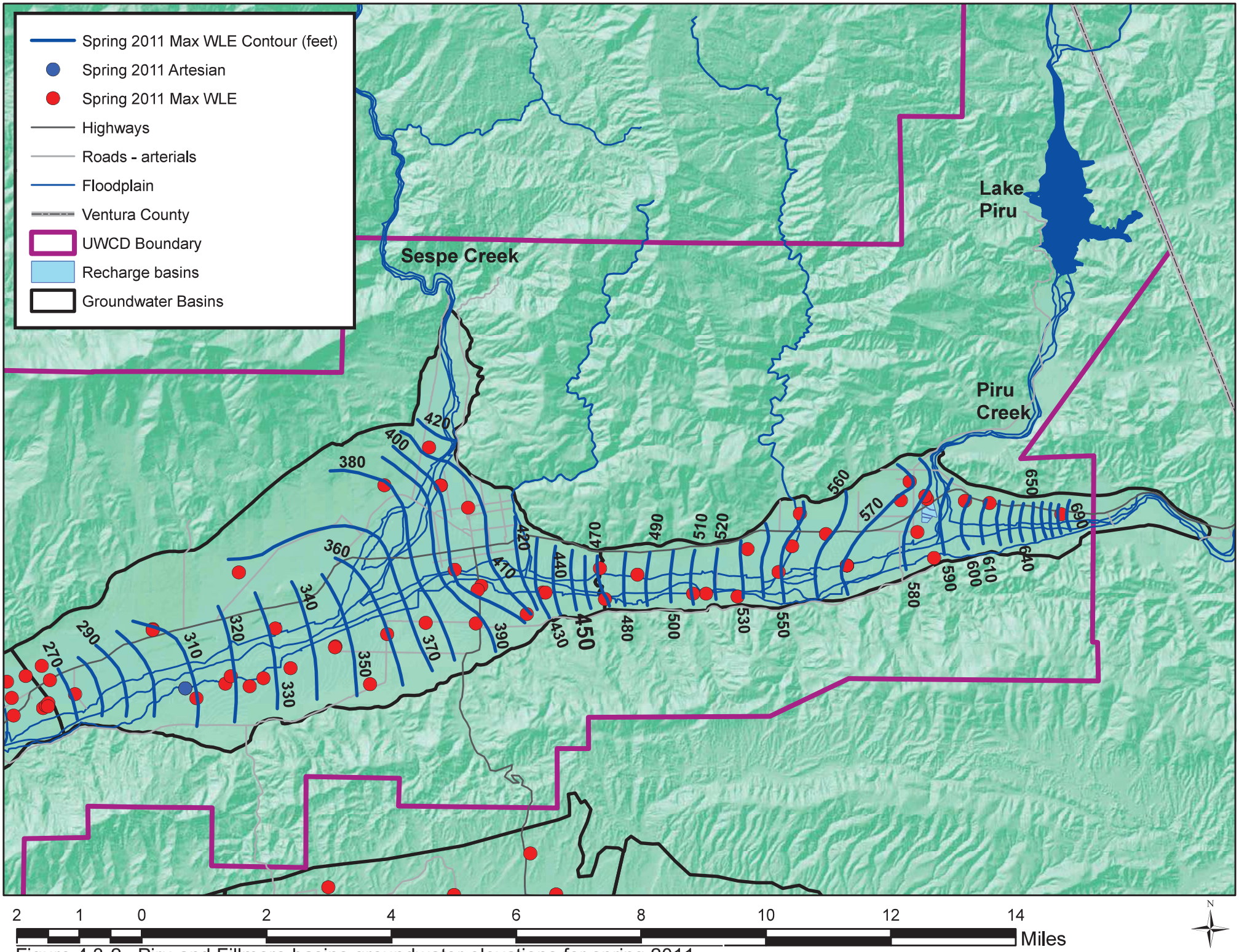


Figure 4.3-2. Piru and Fillmore basins groundwater elevations for spring 2011

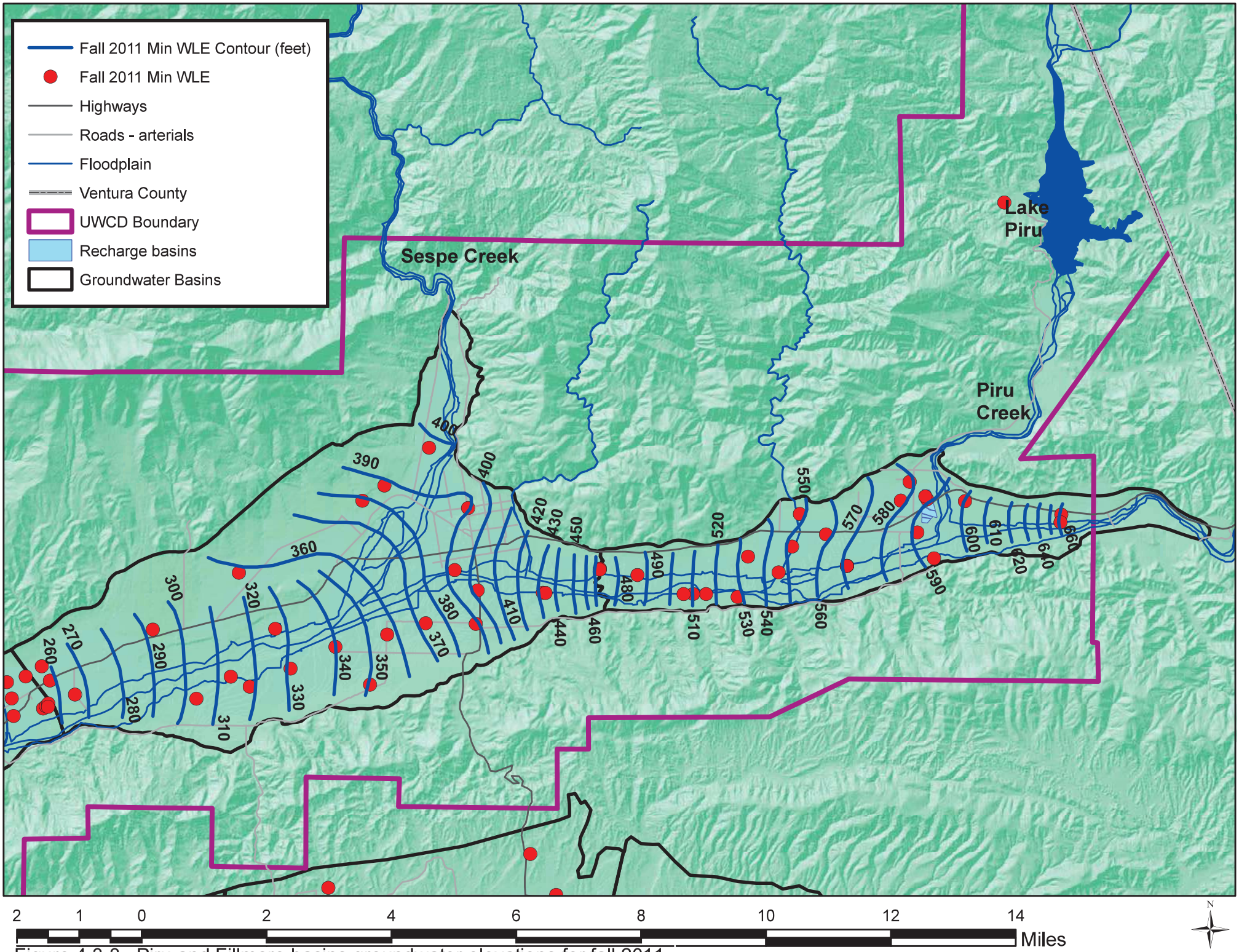


Figure 4.3-3. Piru and Fillmore basins groundwater elevations for fall 2011

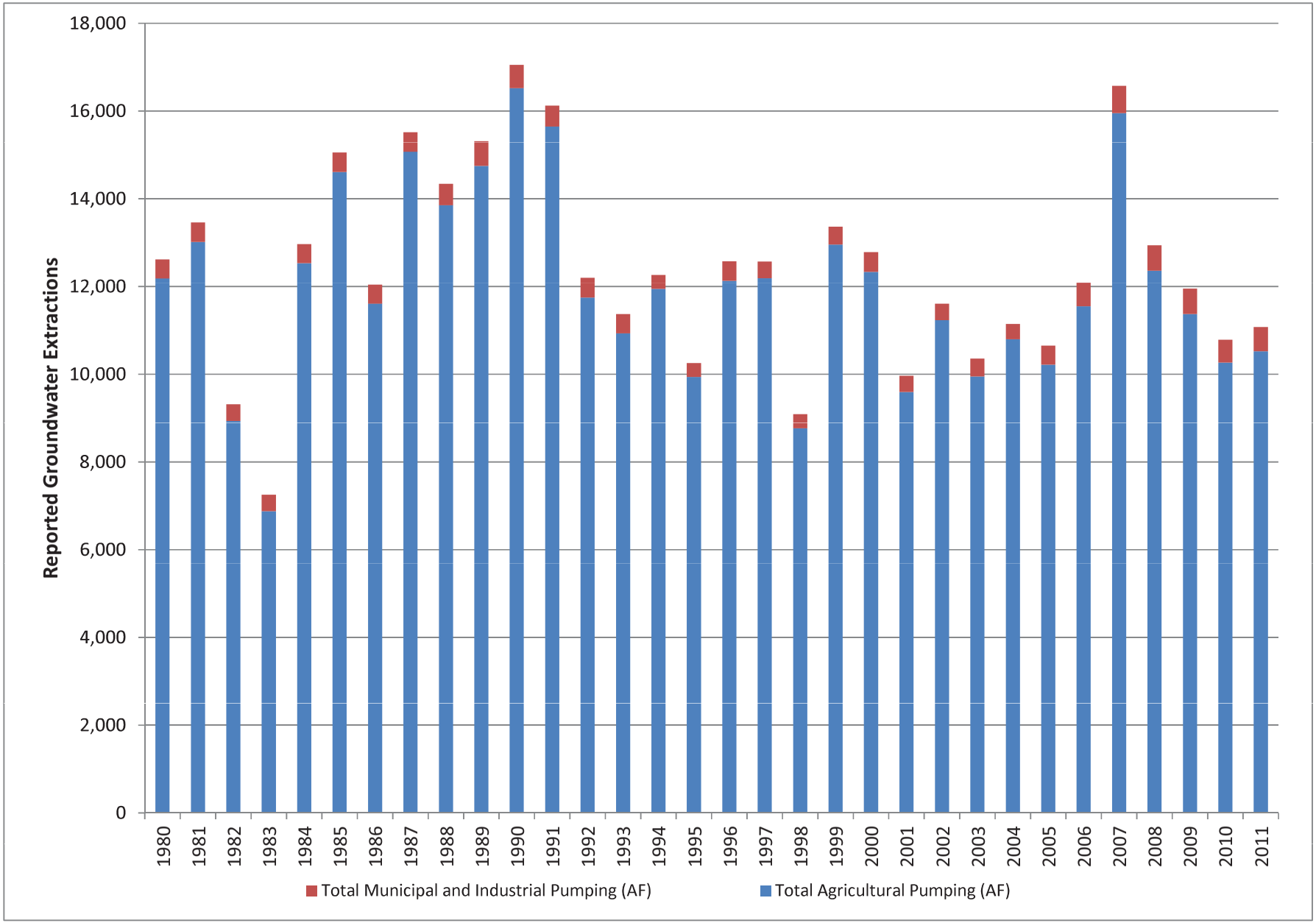


Figure 4.3-4. Historical reported groundwater extractions for the Piru Basin

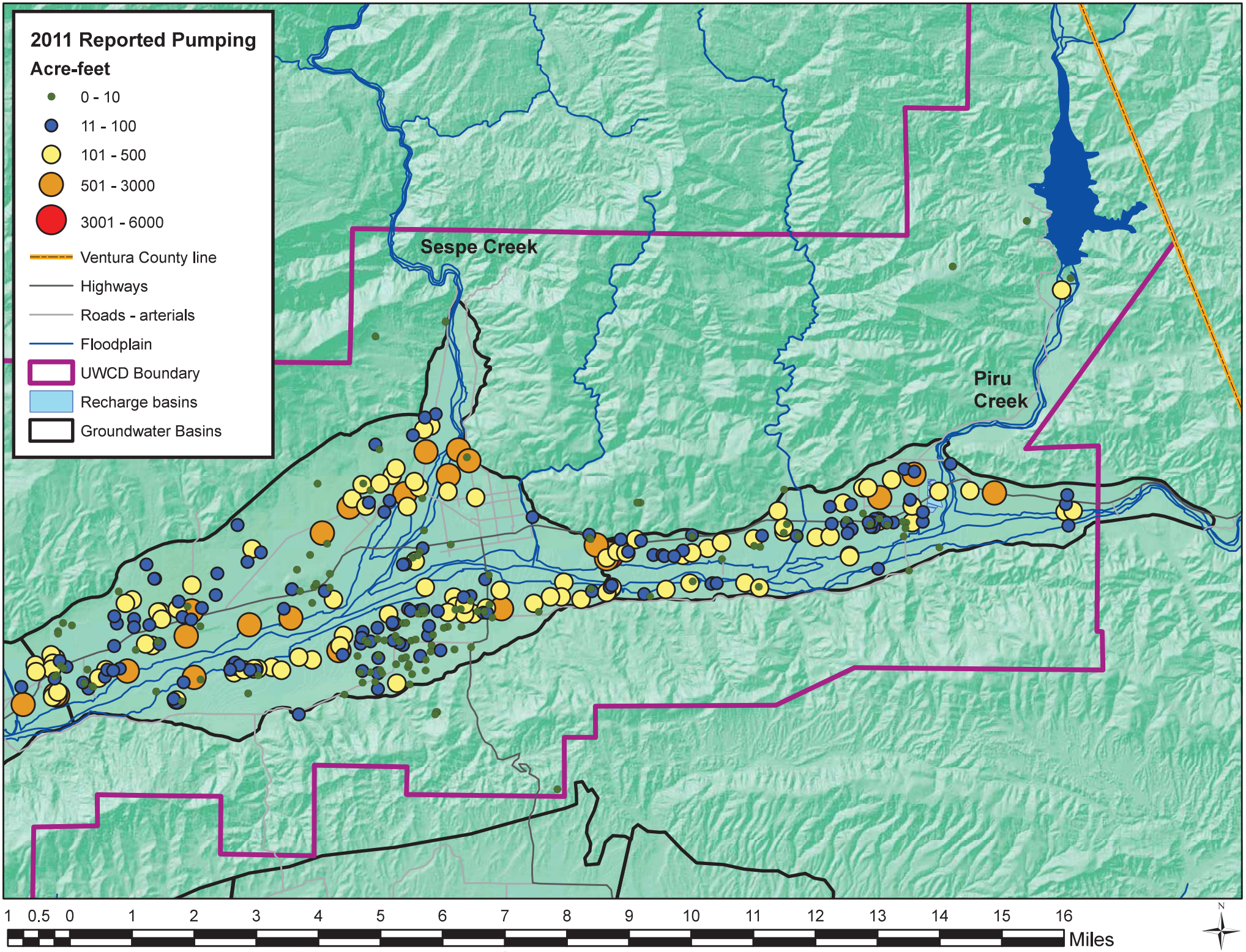


Figure 4.3-5. Reported Piru and Fillmore basin pumping for 2011

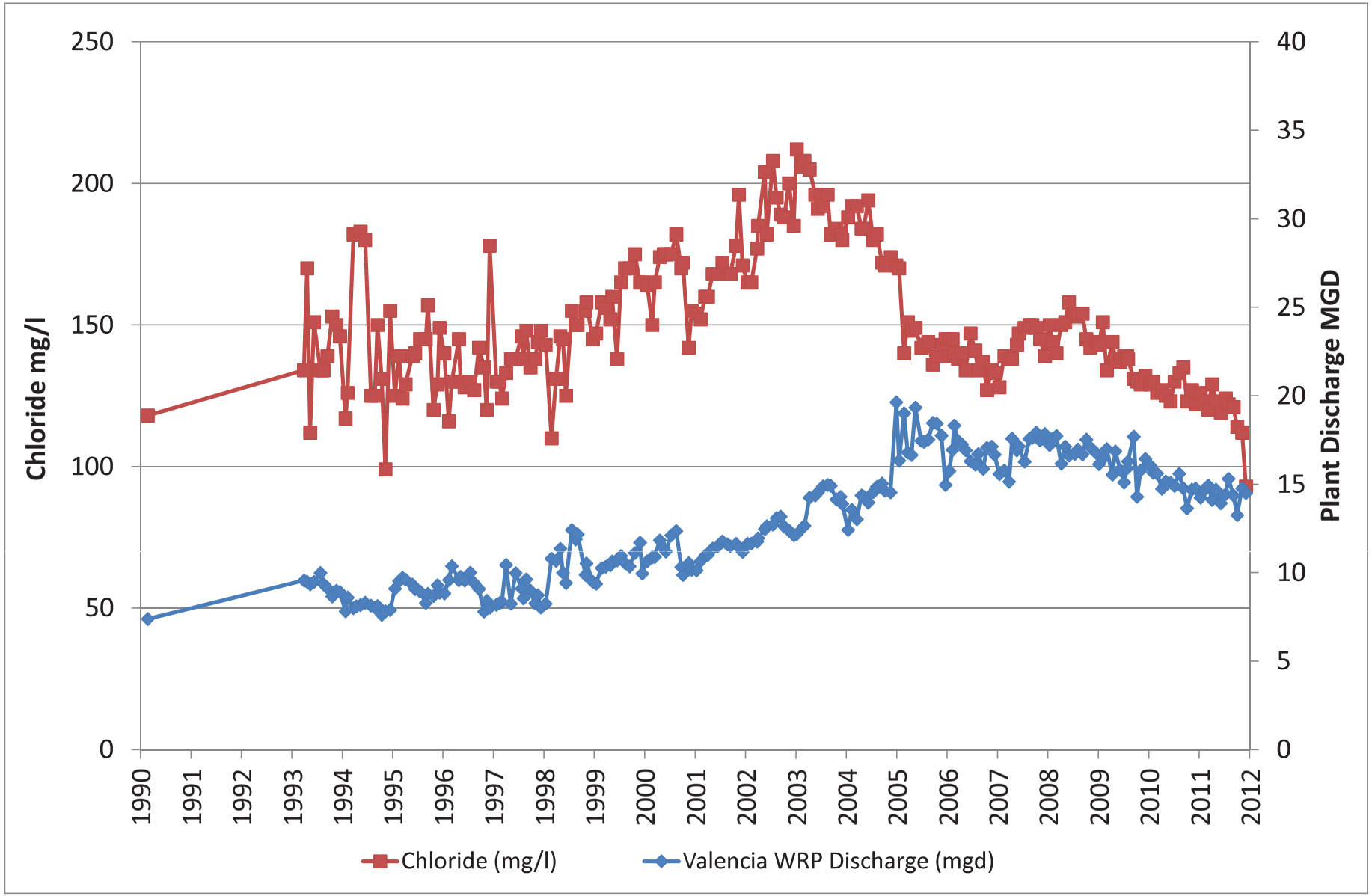


Figure 4.3-6. Historical chloride and discharge volumes at Valencia WRP

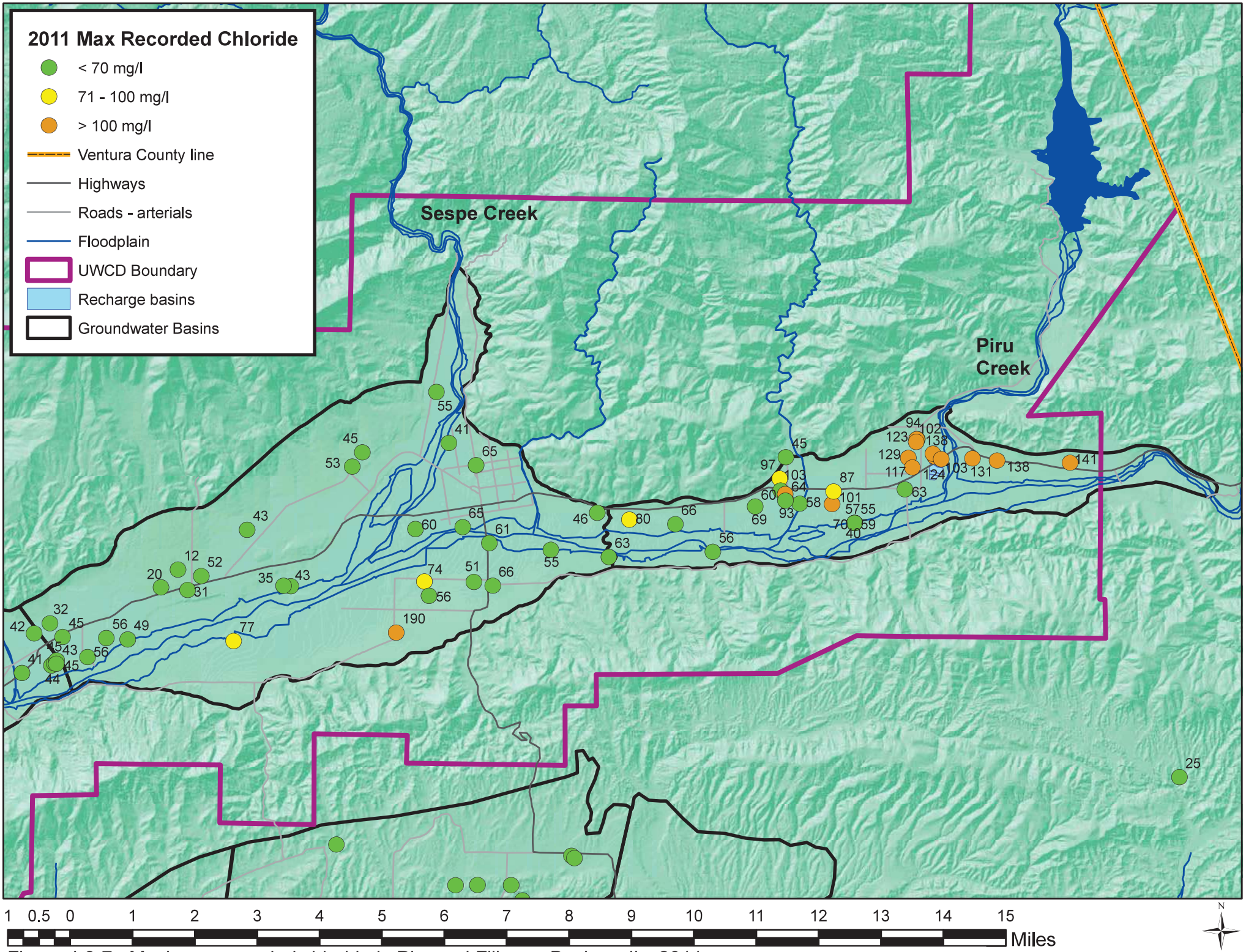


Figure 4.3-7. Maximum recorded chloride in Piru and Fillmore Basin wells, 2011

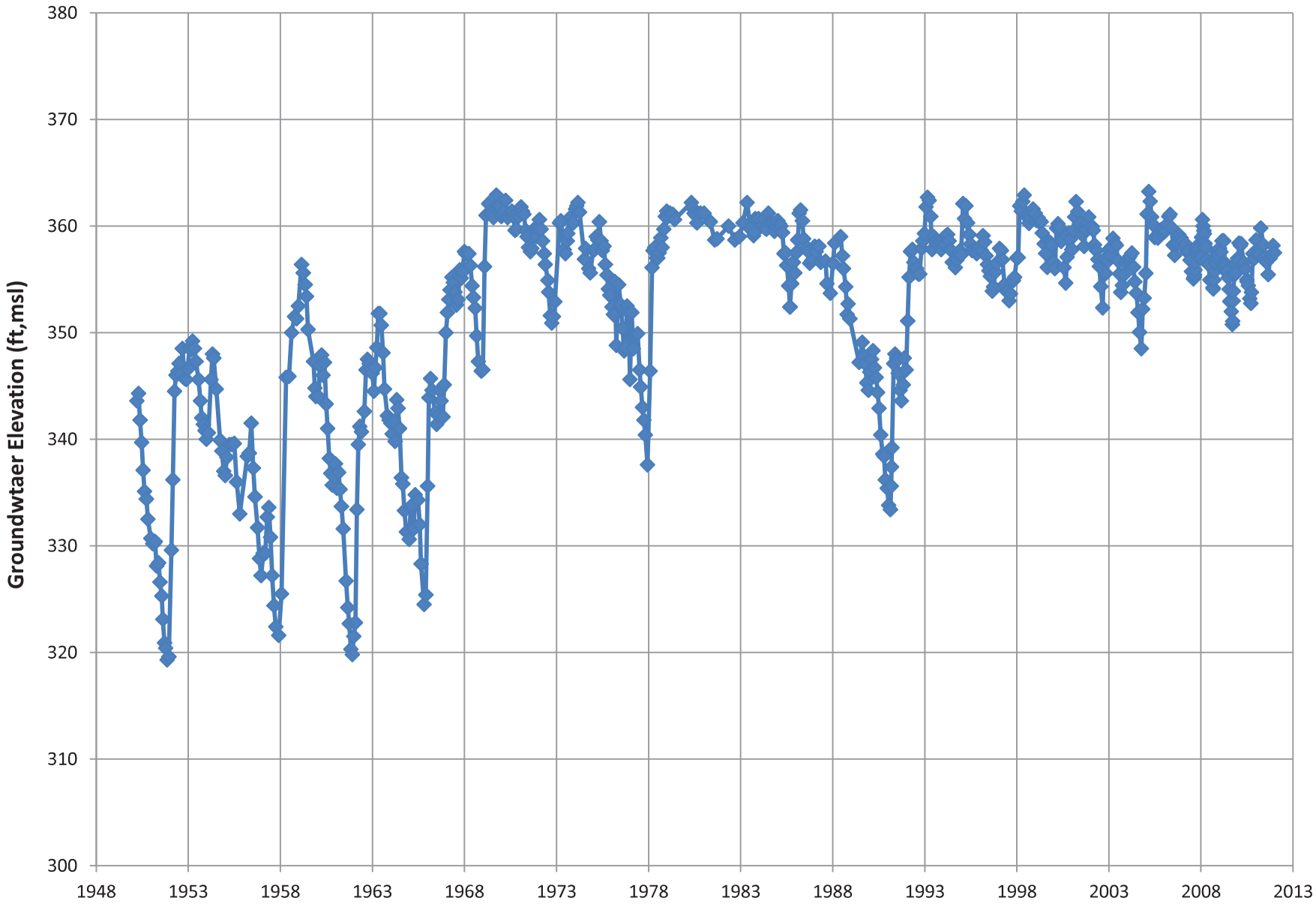


Figure 4.3-8. Historical groundwater elevations in Fillmore Basin key well

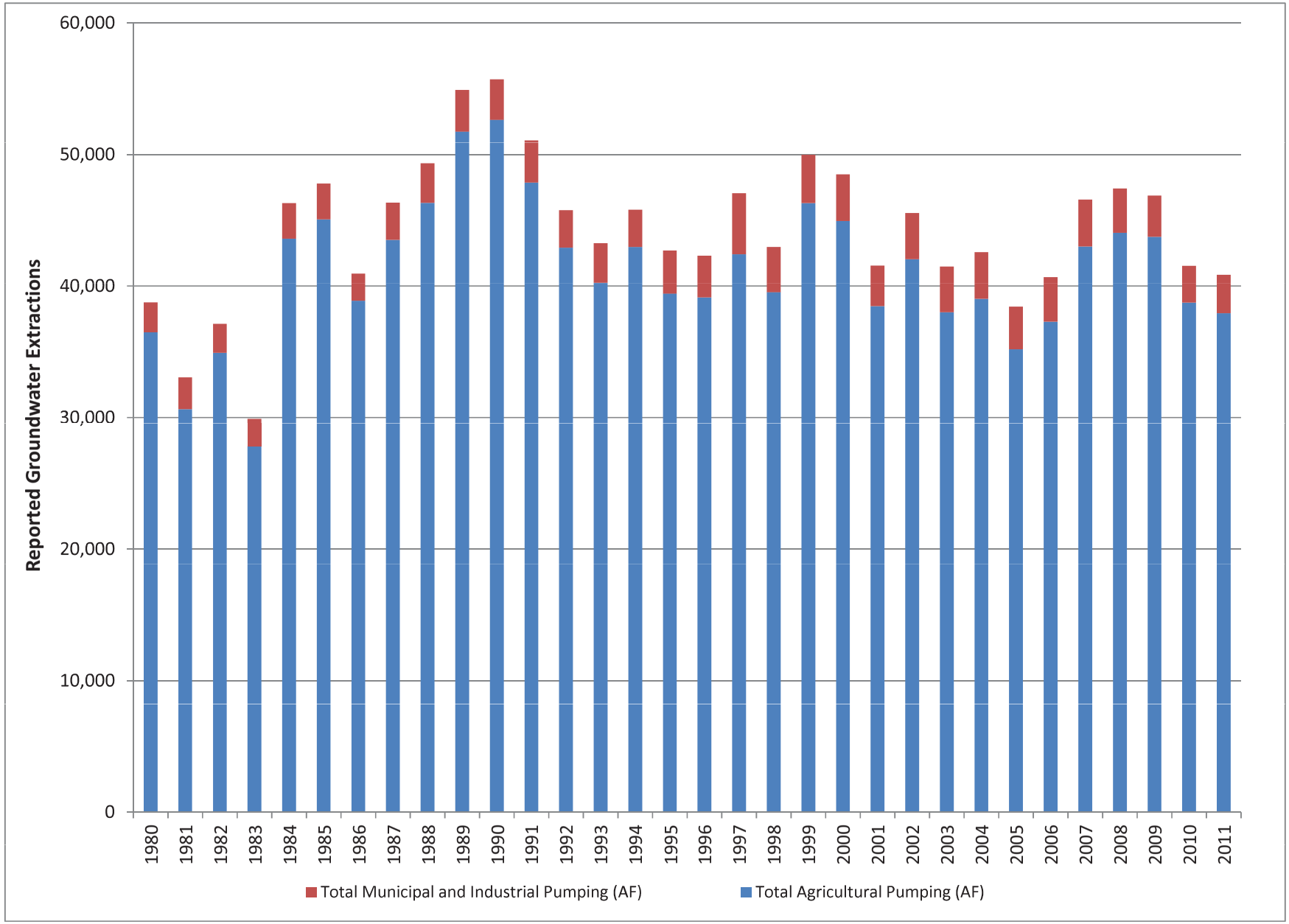


Figure 4.3-9. Historical reported groundwater extractions for the Fillmore Basin

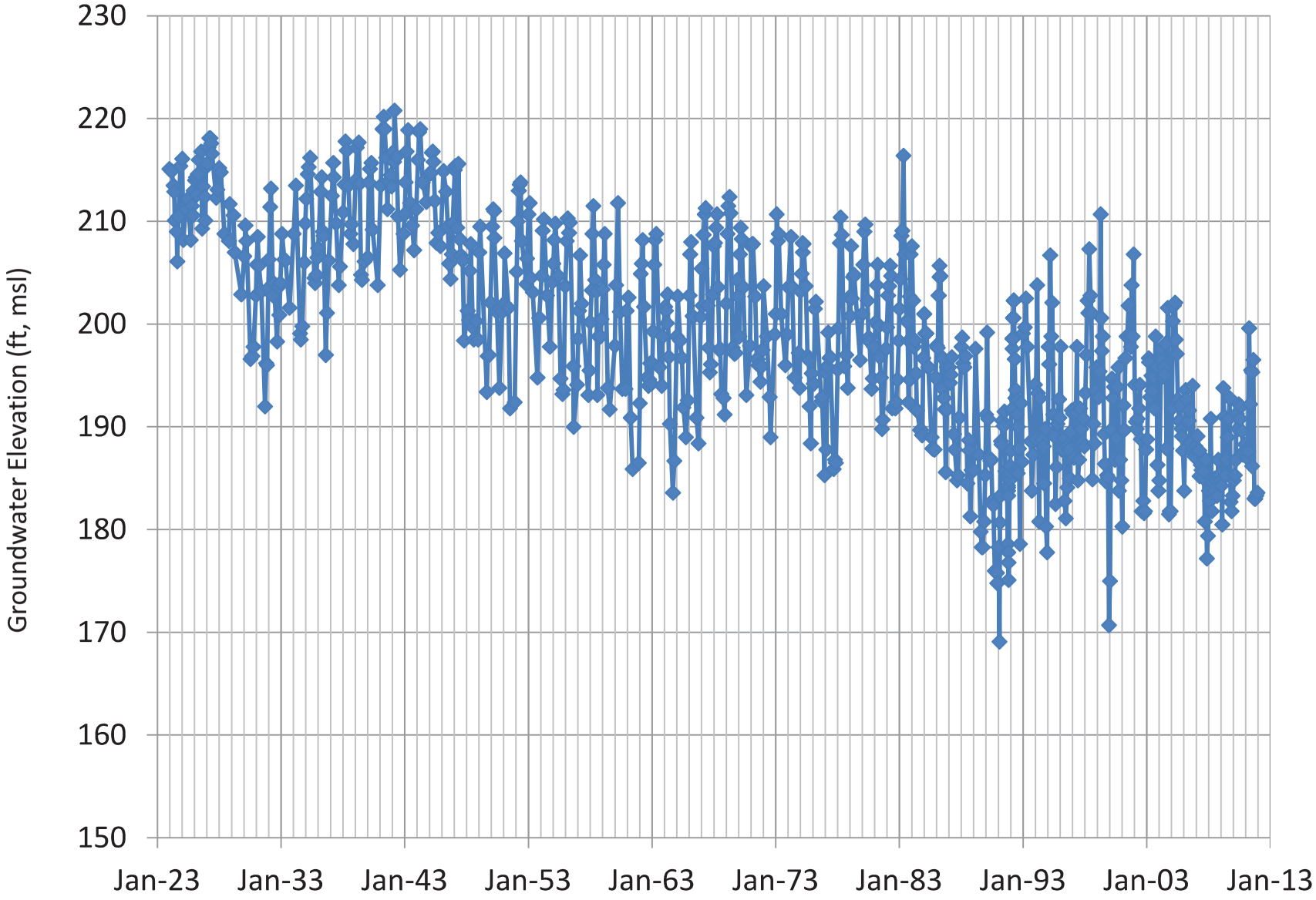


Figure 4.3-10. Historical groundwater elevations in Santa Paula Basin key well

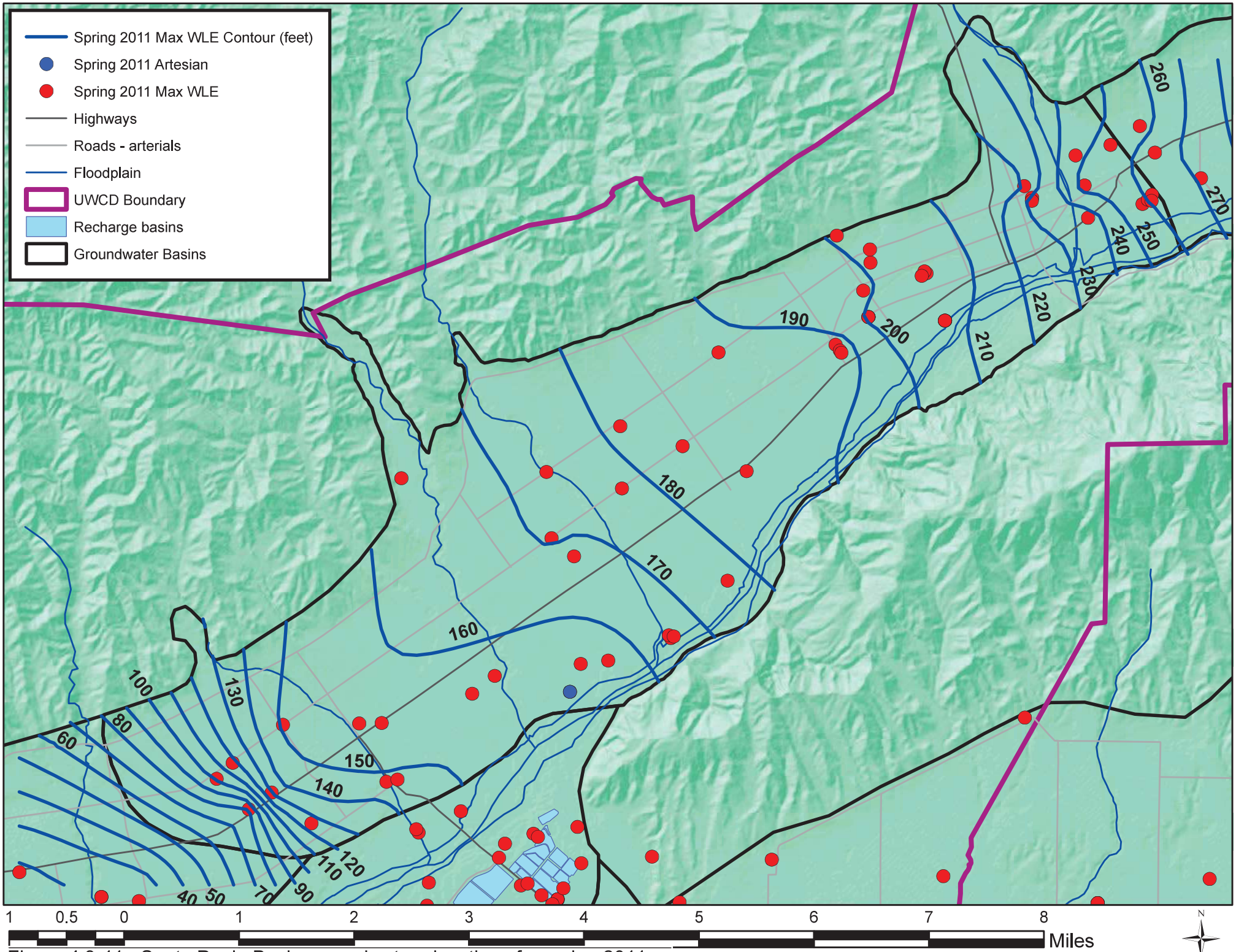


Figure 4.3-11. Santa Paula Basin groundwater elevations for spring 2011

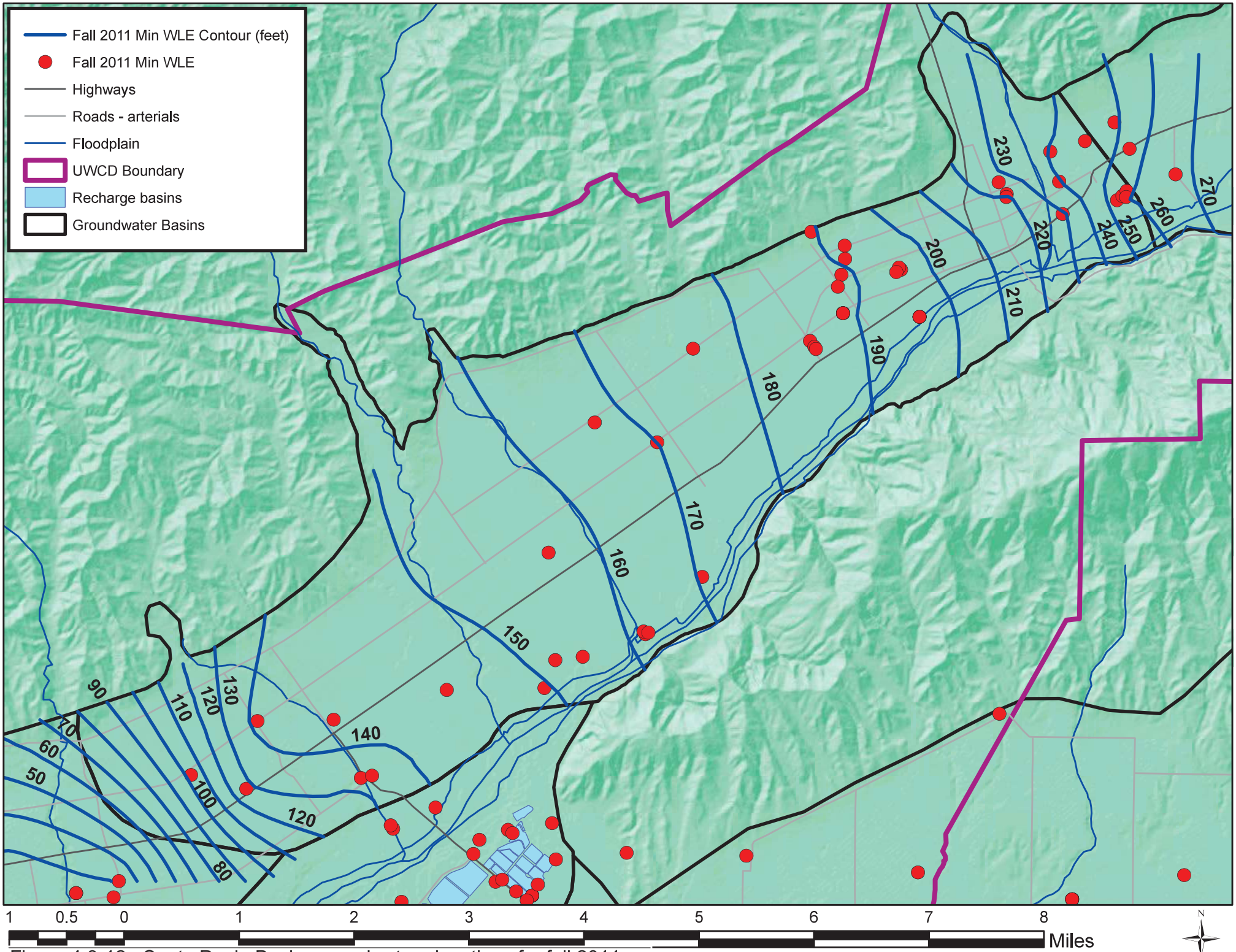


Figure 4.3-12. Santa Paula Basin groundwater elevations for fall 2011

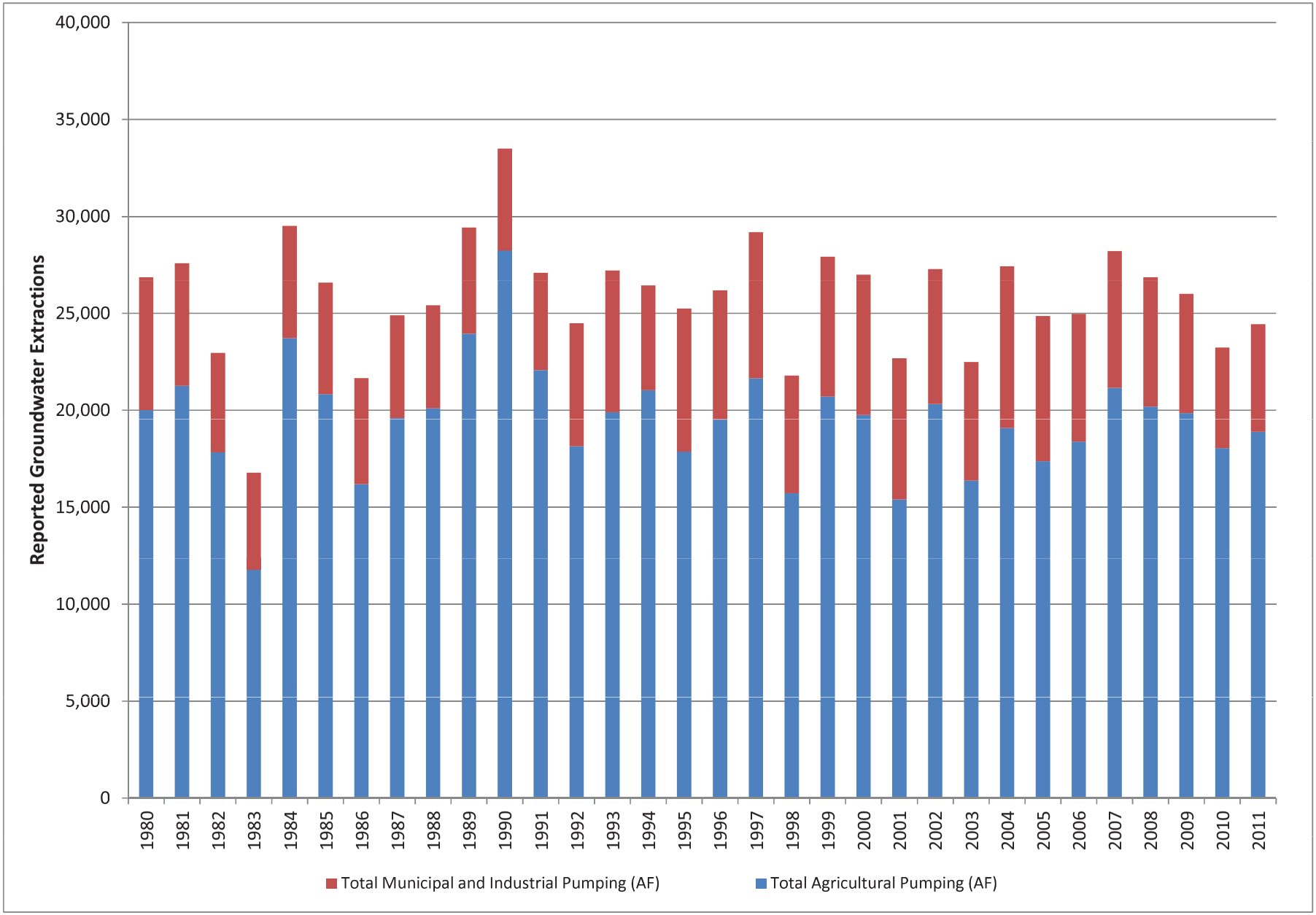


Figure 4.3-13. Historical reported groundwater extractions for the Santa Paula Basin

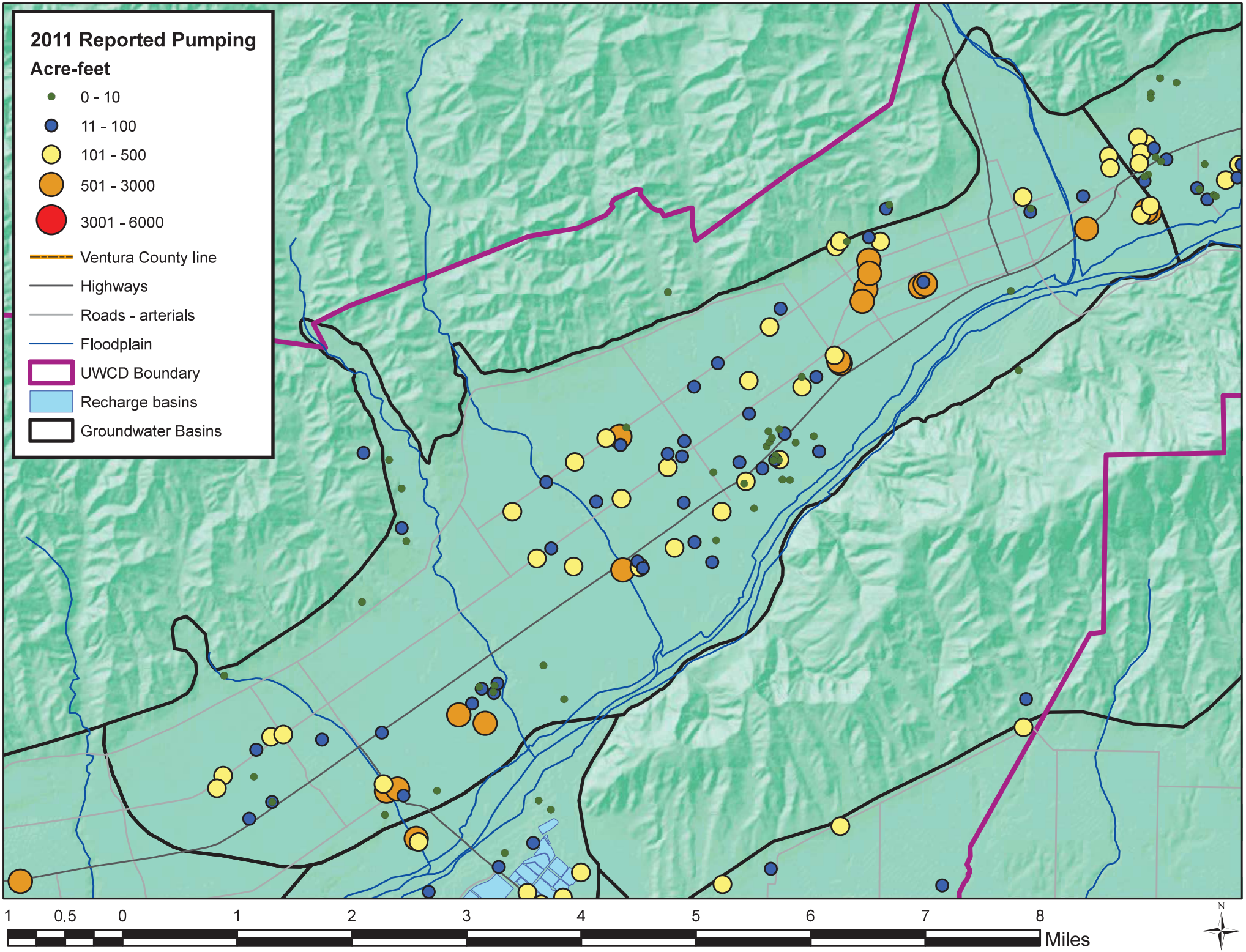


Figure 4.3-14. Reported Santa Paula Basin pumping for 2011

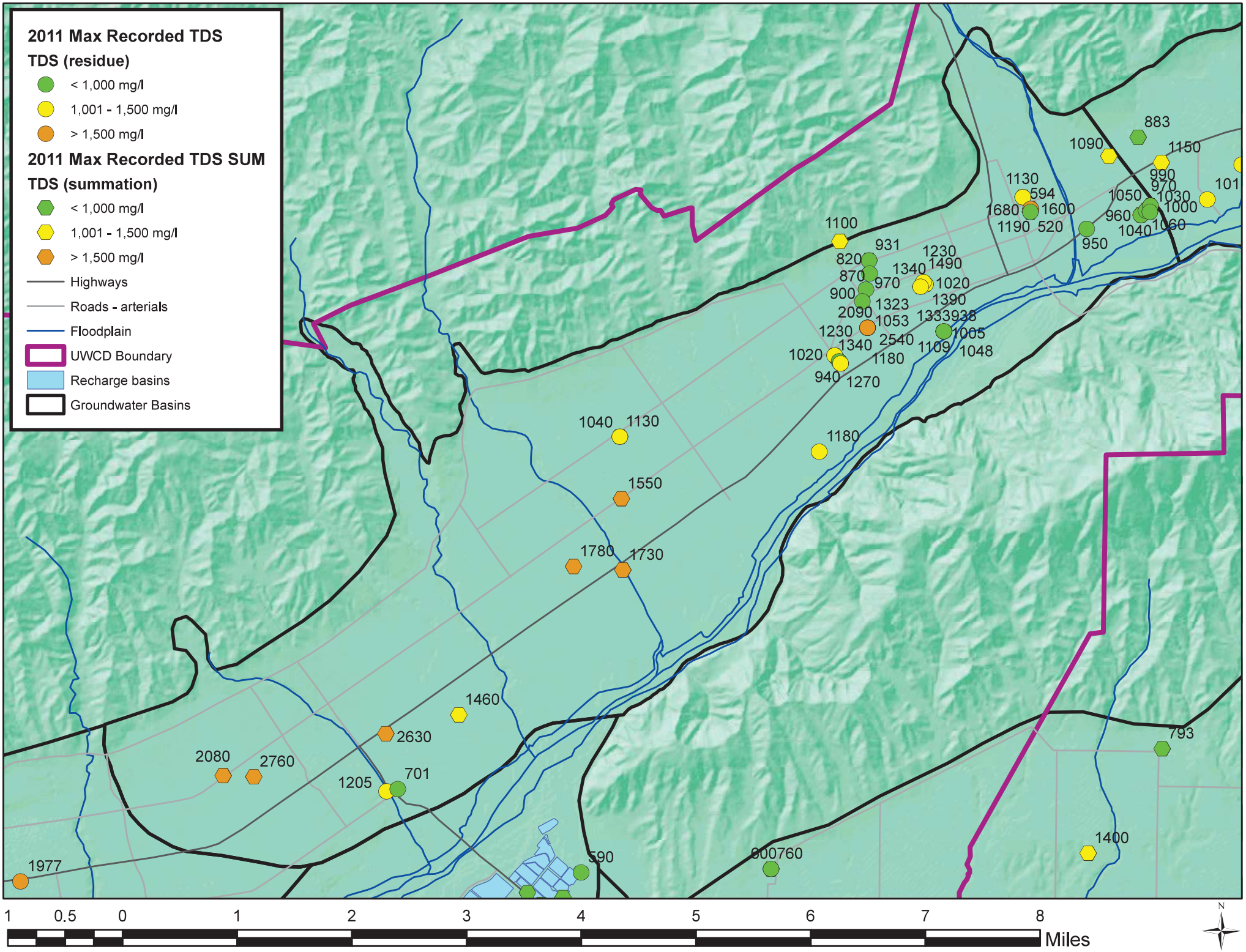


Figure 4.3-15. Maximum recorded TDS in Santa Paula Basin wells, 2011

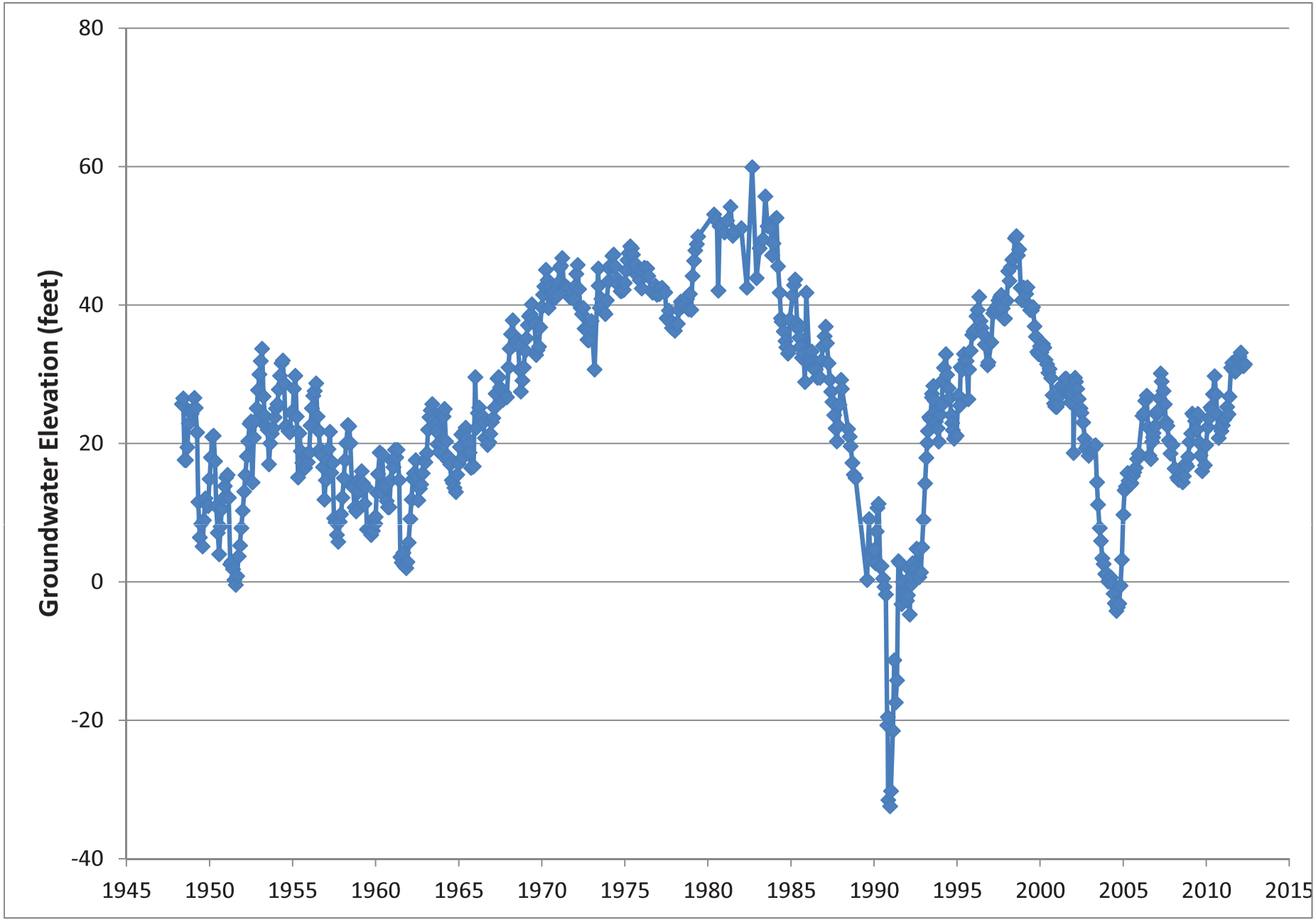


Figure 4.3-16. Historical groundwater elevations in Mound Basin key well

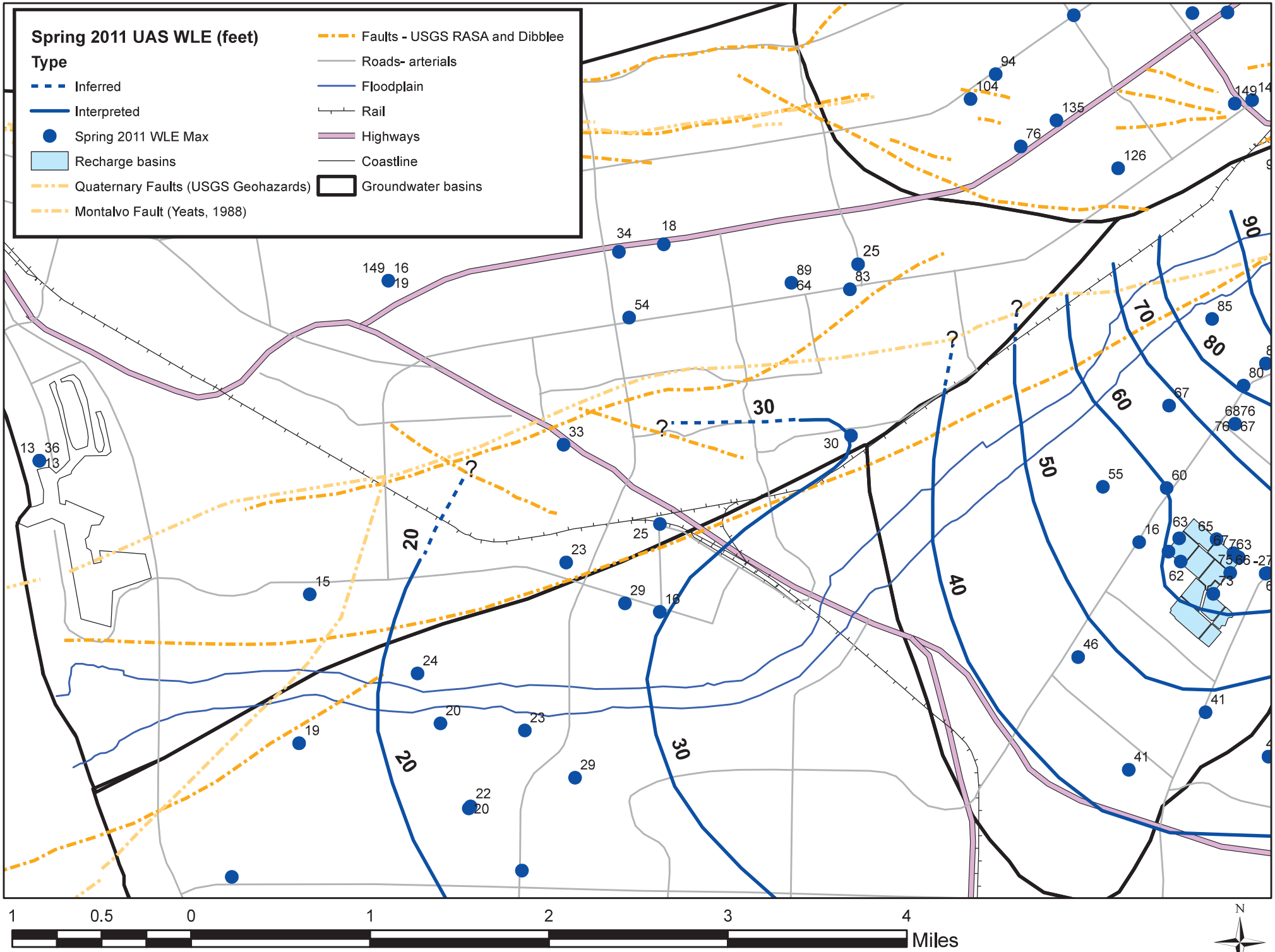


Figure 4.3-17. Mound Basin groundwater elevations for spring 2011

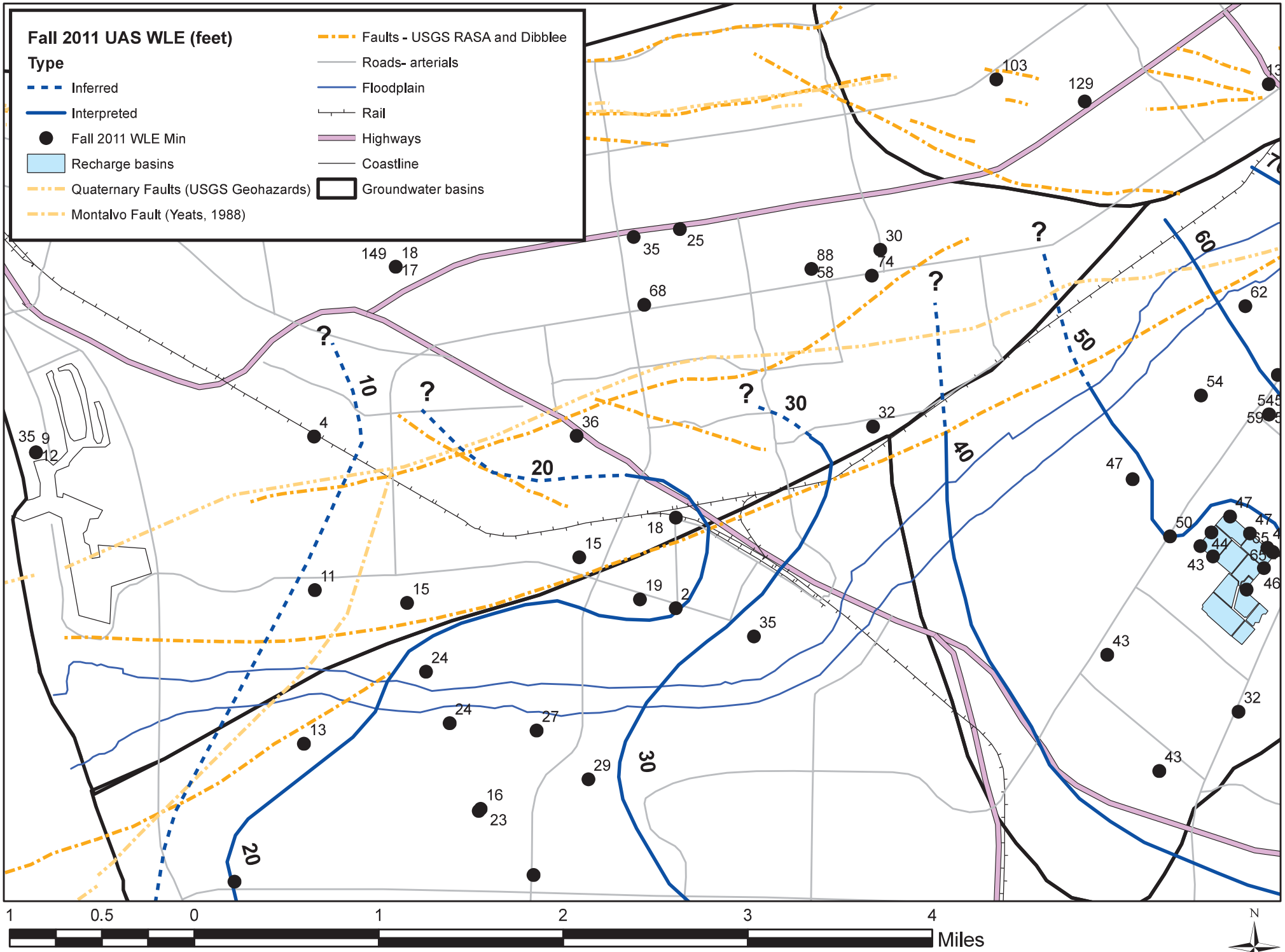


Figure 4.3-18. Mound Basin groundwater elevations for fall 2011

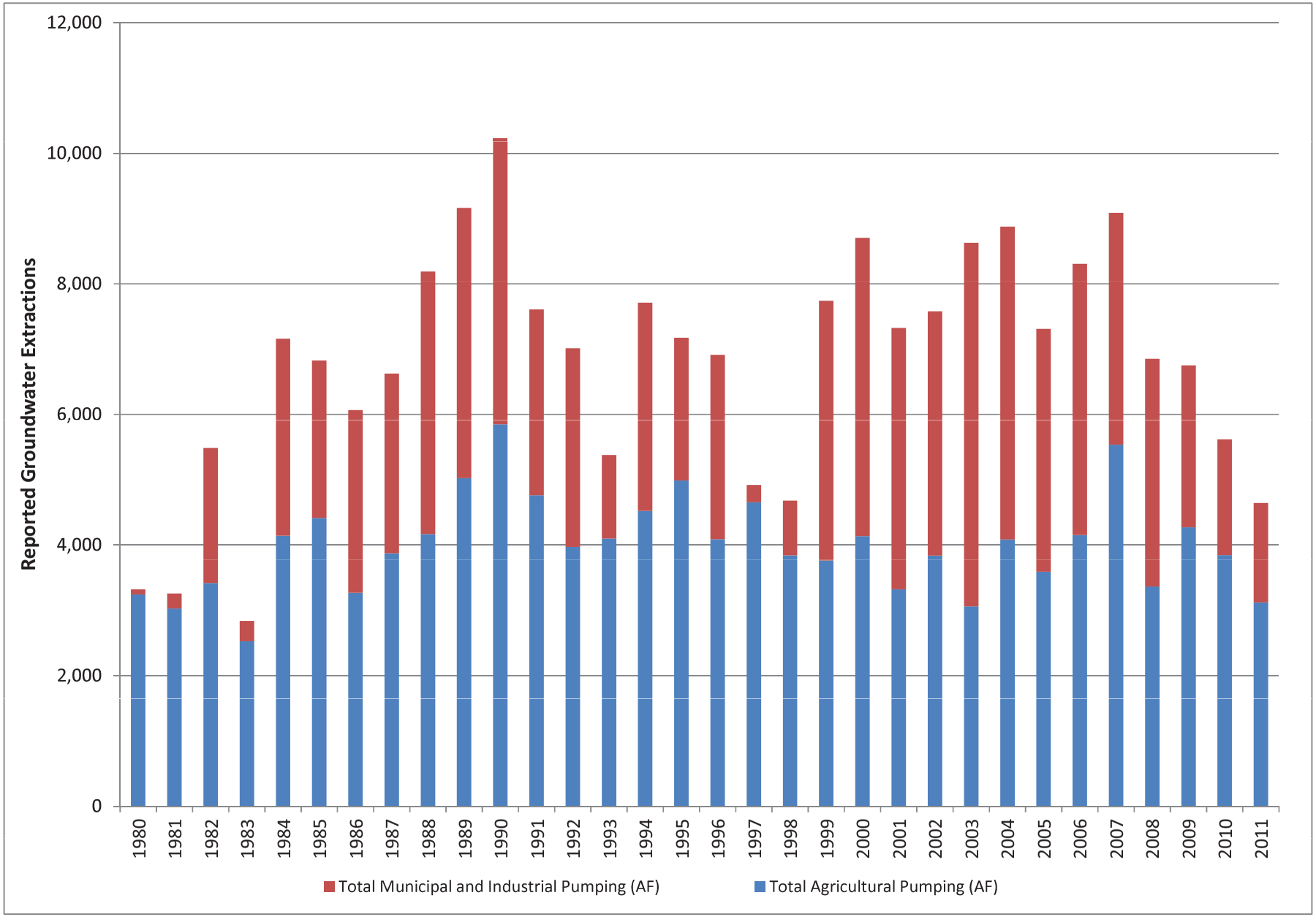


Figure 4.3-19. Historical reported groundwater extractions for the Mound Basin

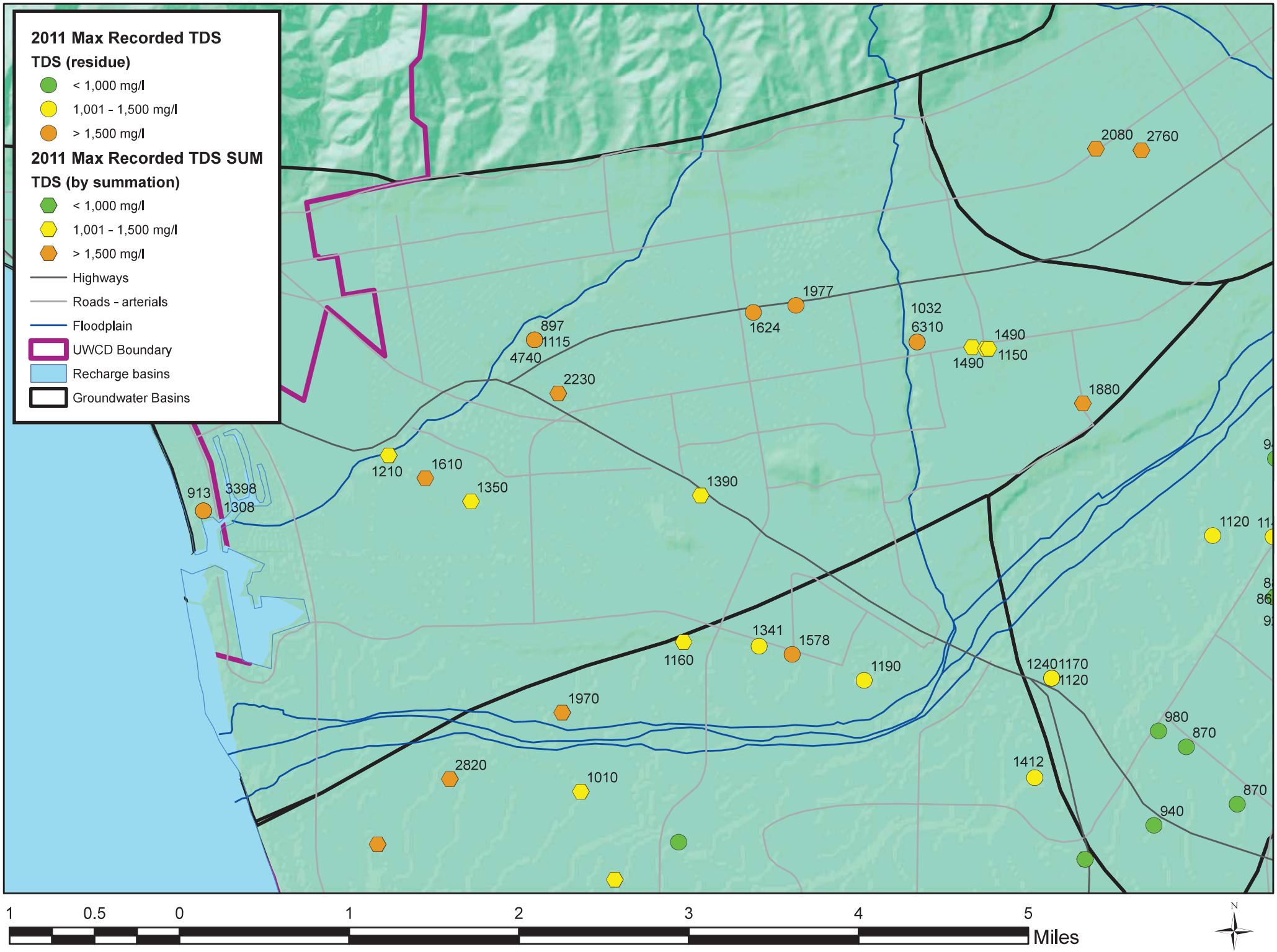


Figure 4.3-20. Maximum recorded TDS in Mound Basin wells, 2011

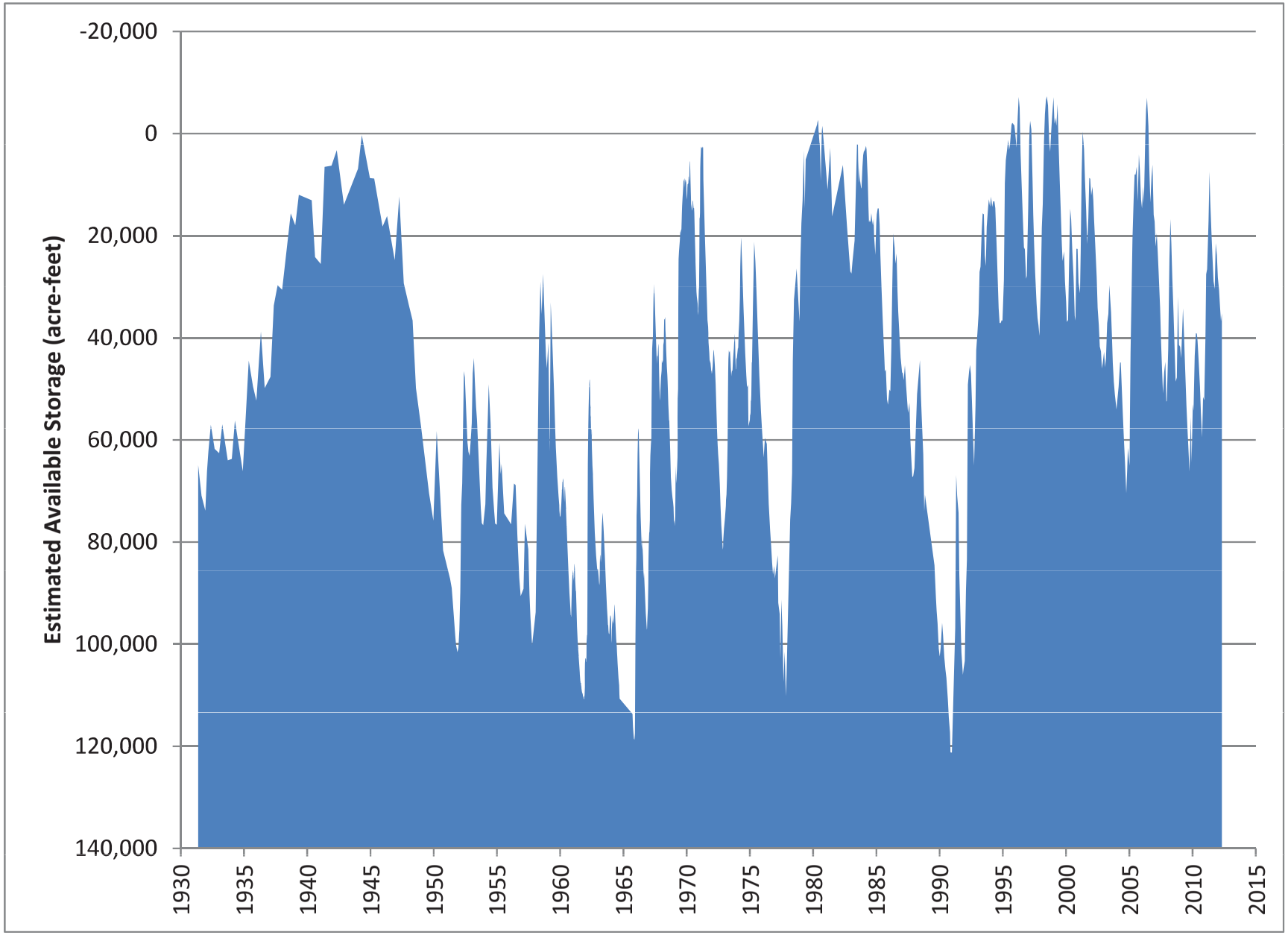


Figure 4.3-21. Historical estimates of available groundwater storage, Oxnard Forebay Basin

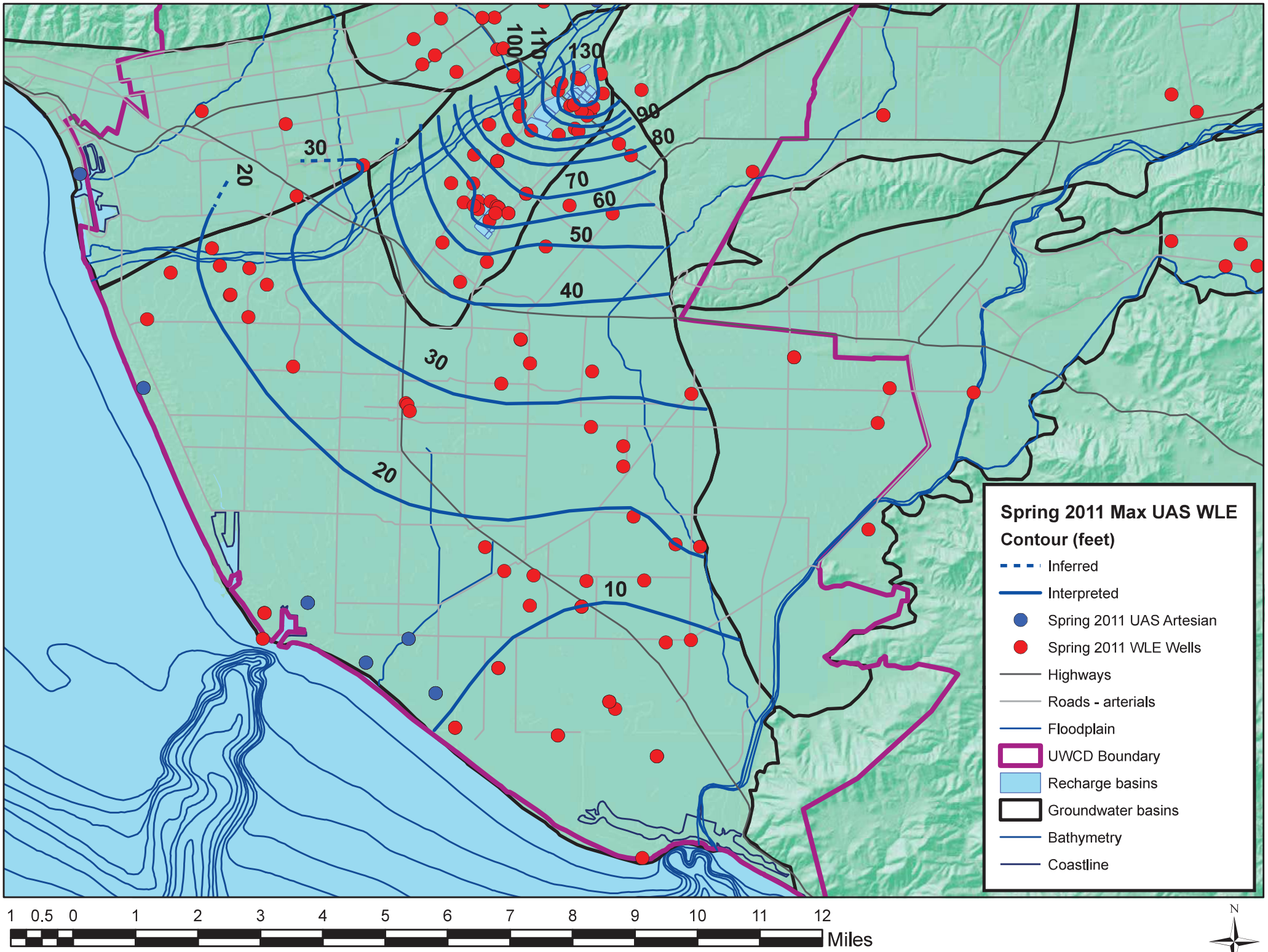


Figure 4.3-22. Oxnard Forebay-Oxnard Plain Upper Aquifer System (UAS) groundwater elevations for spring 2011

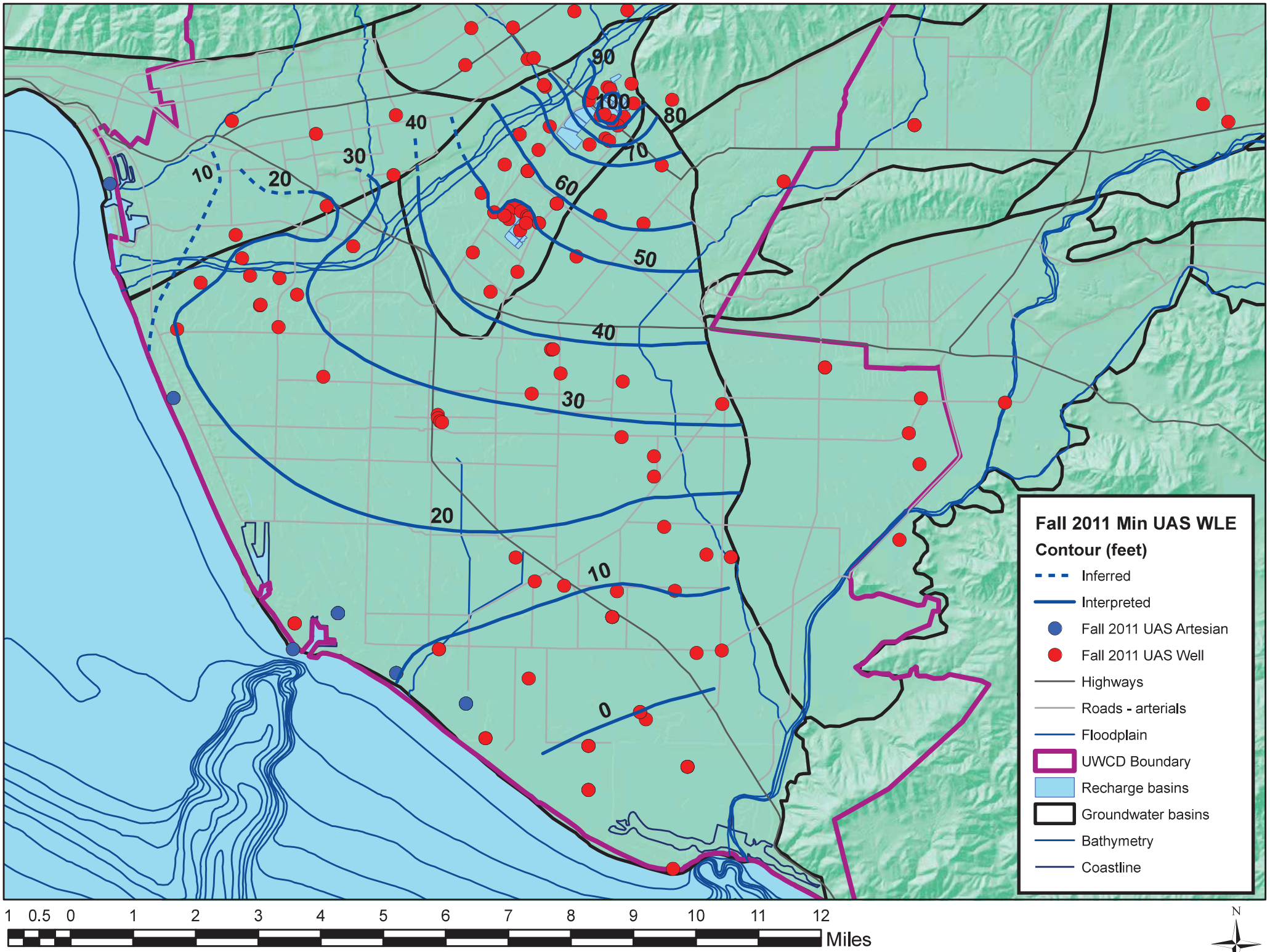
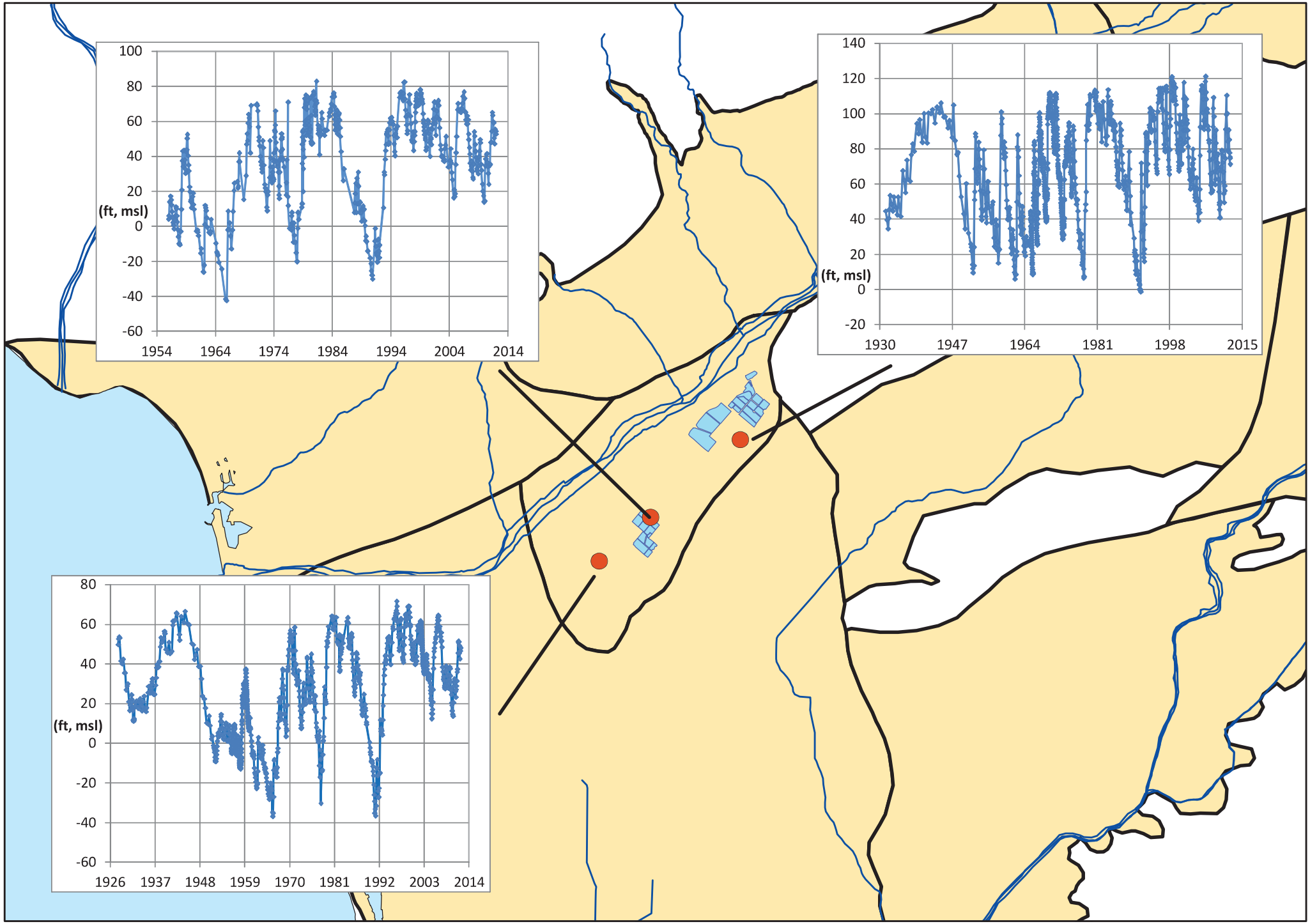


Figure 4.3-23. Oxnard Forebay-Oxnard Plain Upper Aquifer System (UAS) groundwater elevations for fall 2011



1 0.5 0 1 2 3 4 5 6 7 8 9 10 Miles

N W E S

Figure 4.3-24. Oxnard Forebay Upper Aquifer System (UAS) groundwater elevation hydrographs, selected wells

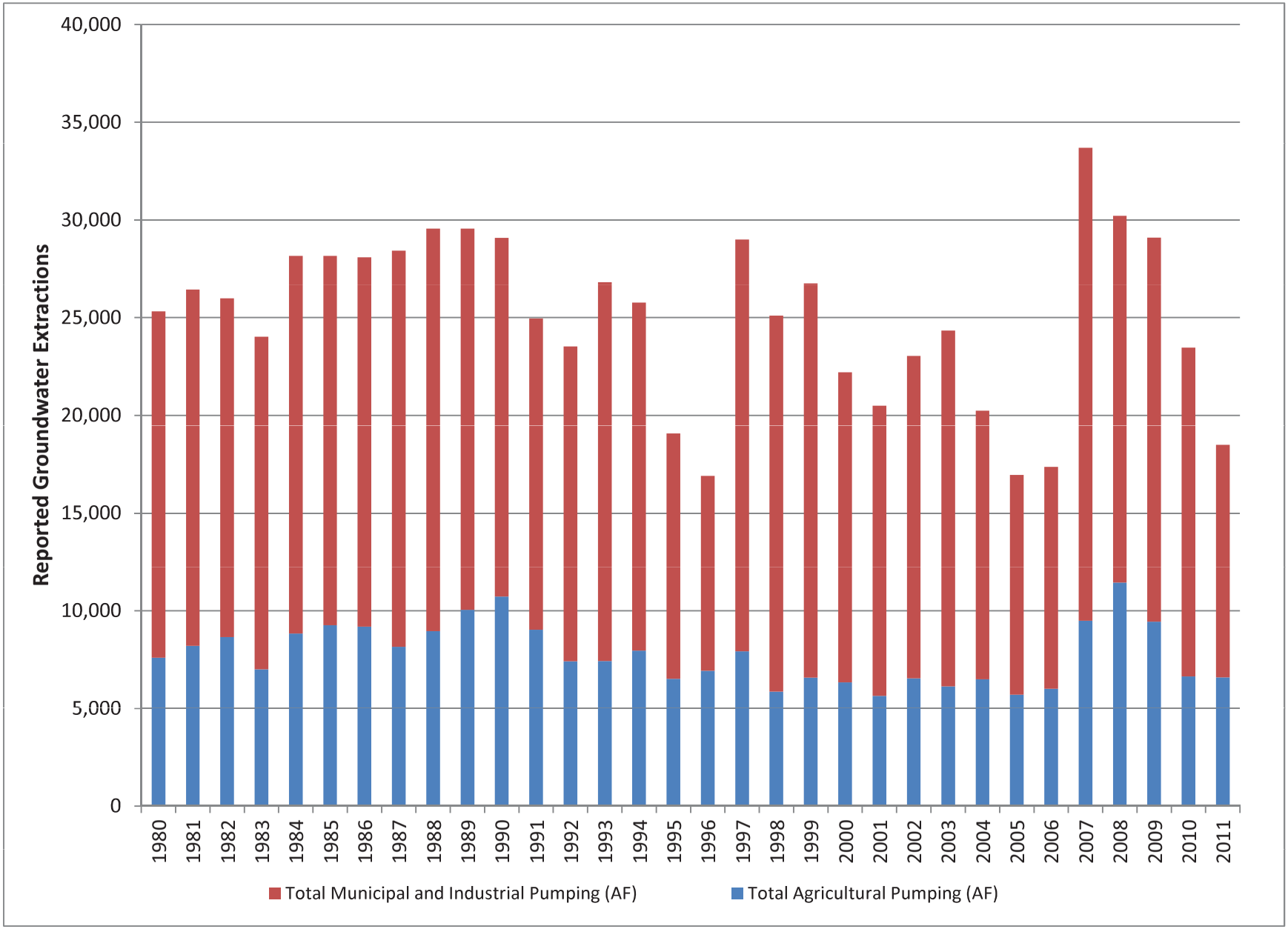


Figure 4.3-25. Historical reported groundwater extractions for the Oxnard Forebay

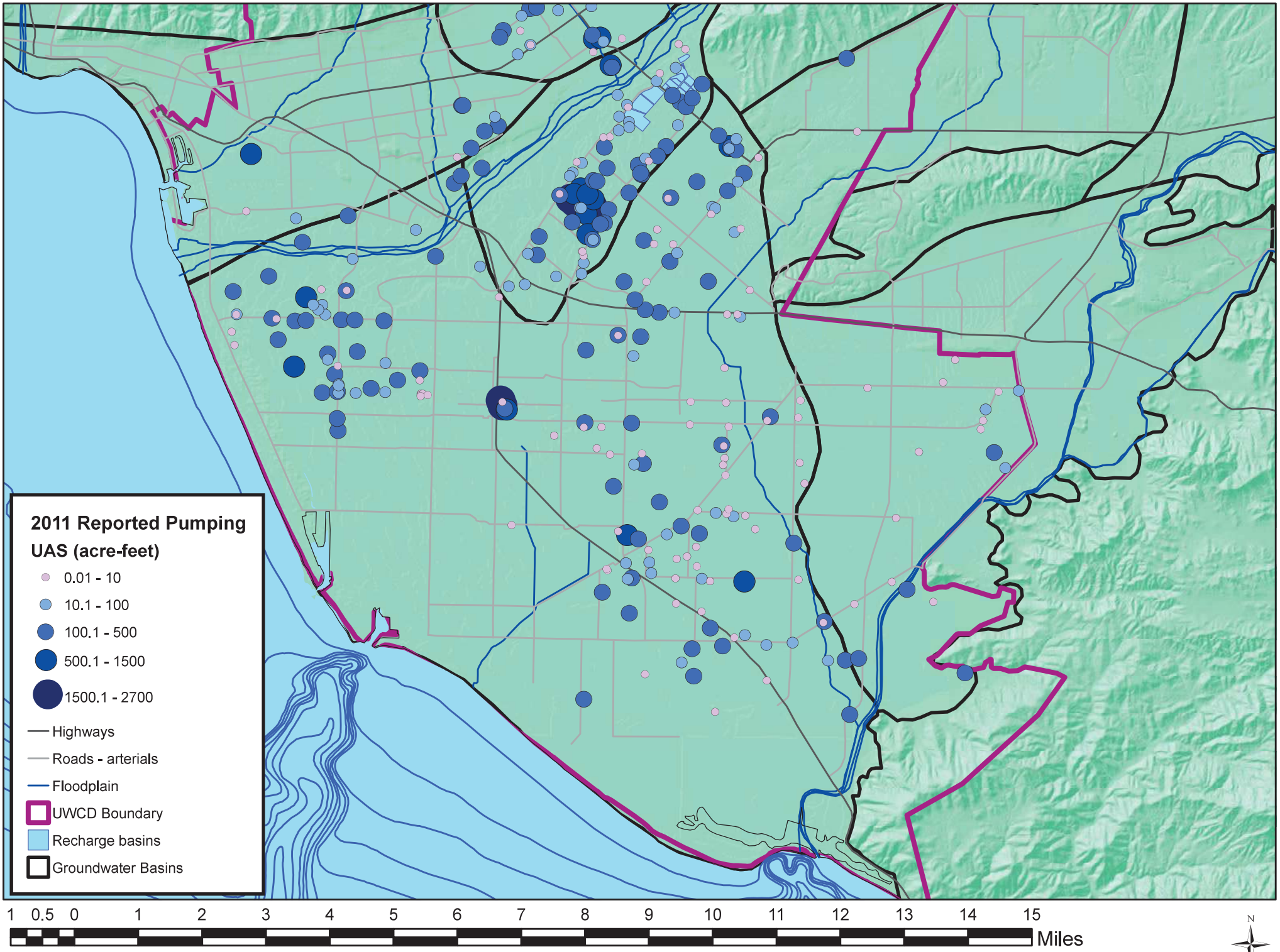


Figure 4.3-26. Reported Oxnard Forebay- Oxnard Plain Reported Upper Aquifer System (UAS) Pumping for 2011

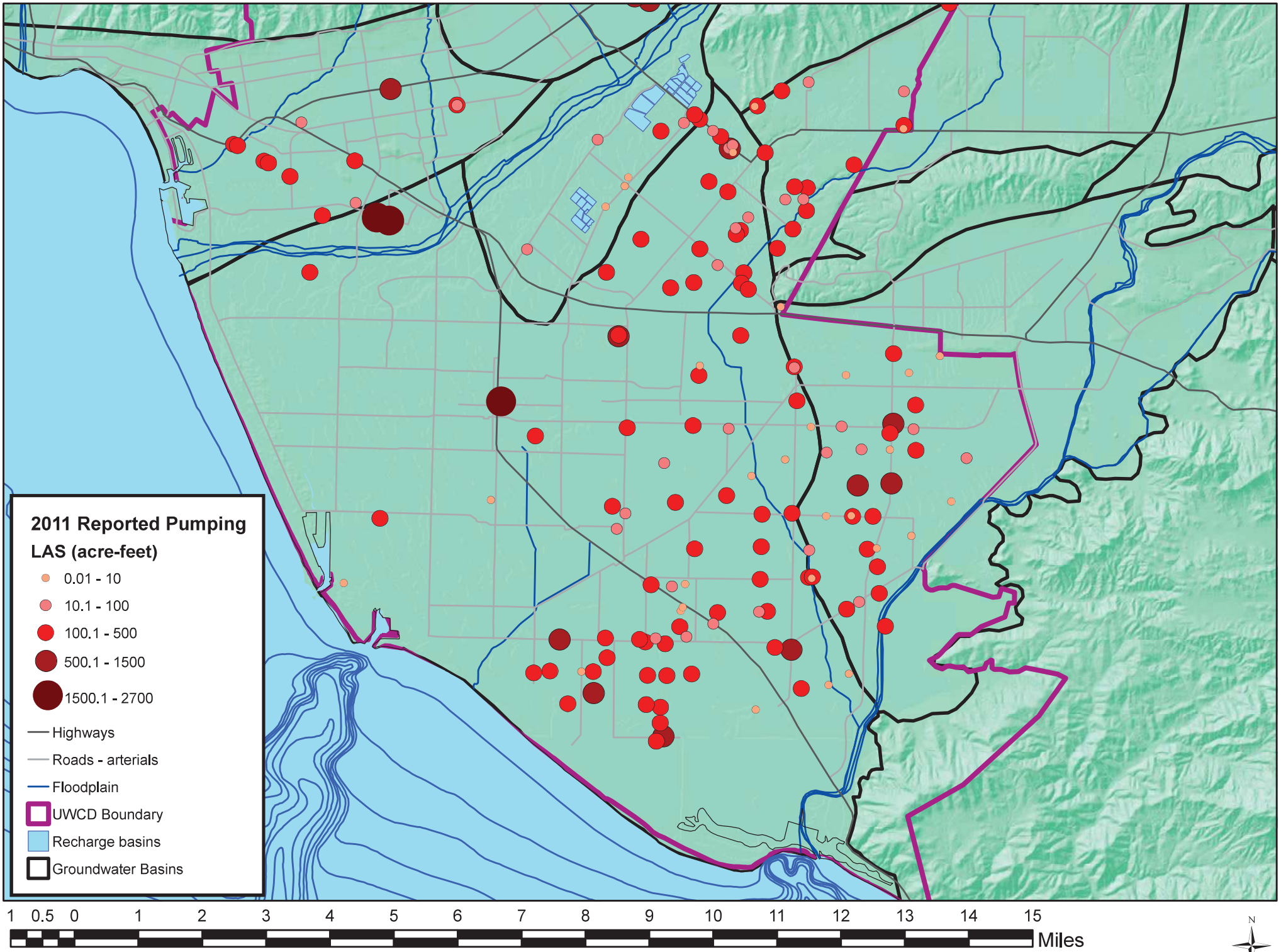


Figure 4.3-27. Reported Oxnard Forebay-Oxnard Plain Lower Aquifer System (LAS) Pumping for 2011

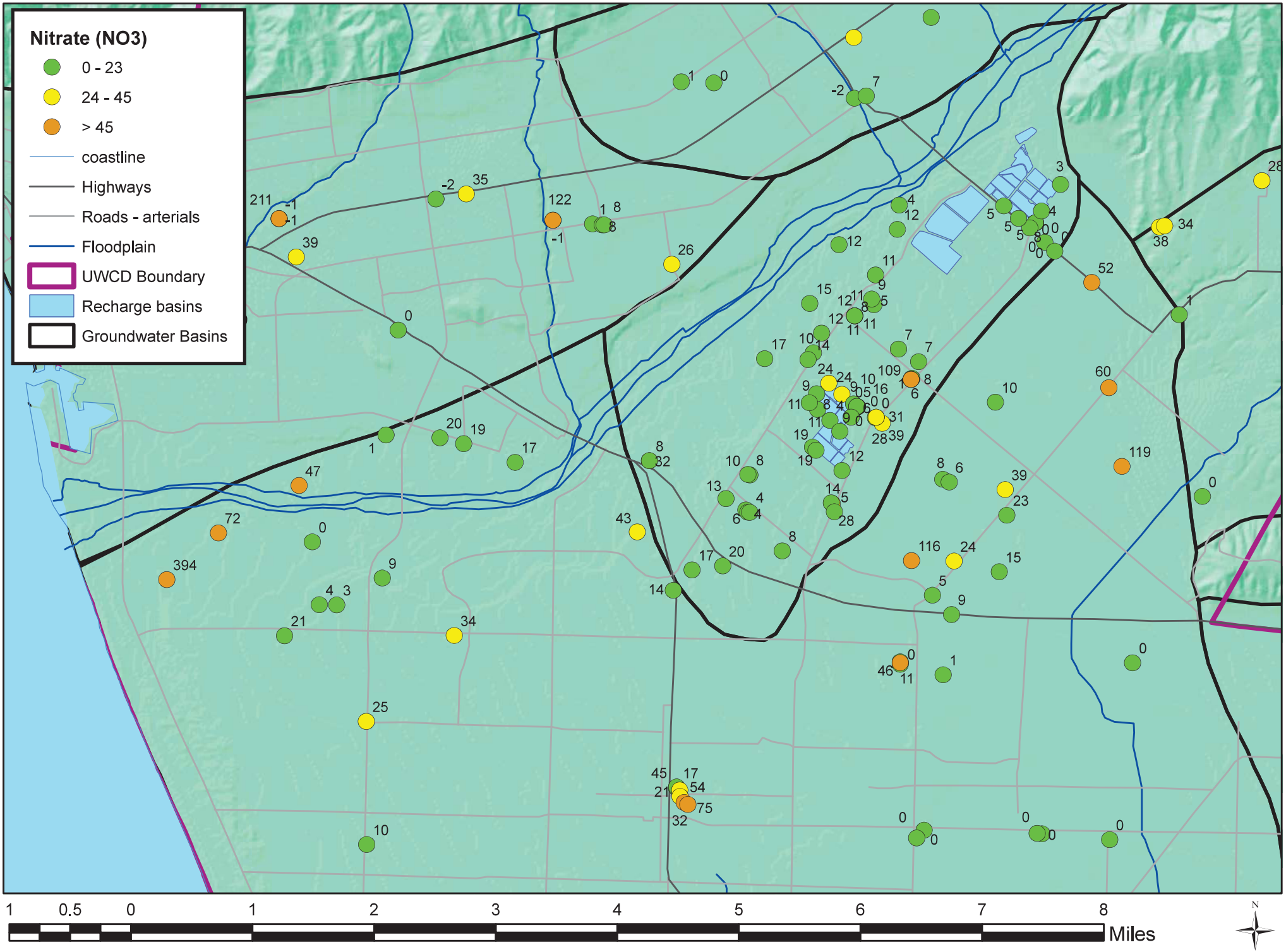


Figure 4.3-28. Maximum recorded nitrate (NO3) in Oxnard Forebay-Oxnard Plain wells, 2011

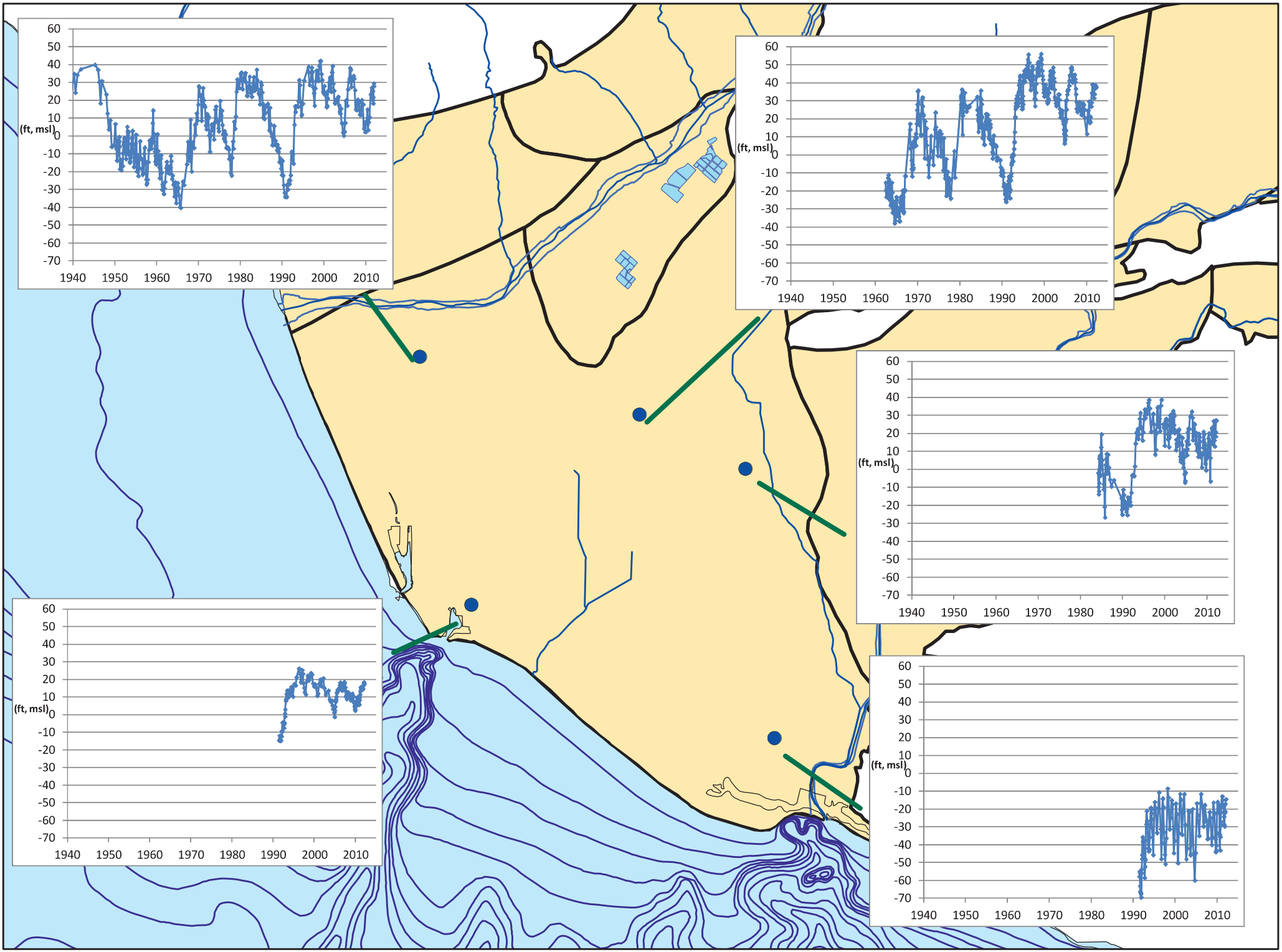


Figure 4.3-29. Oxnard Plain Upper Aquifer System (UAS) groundwater elevation hydrographs, selected wells

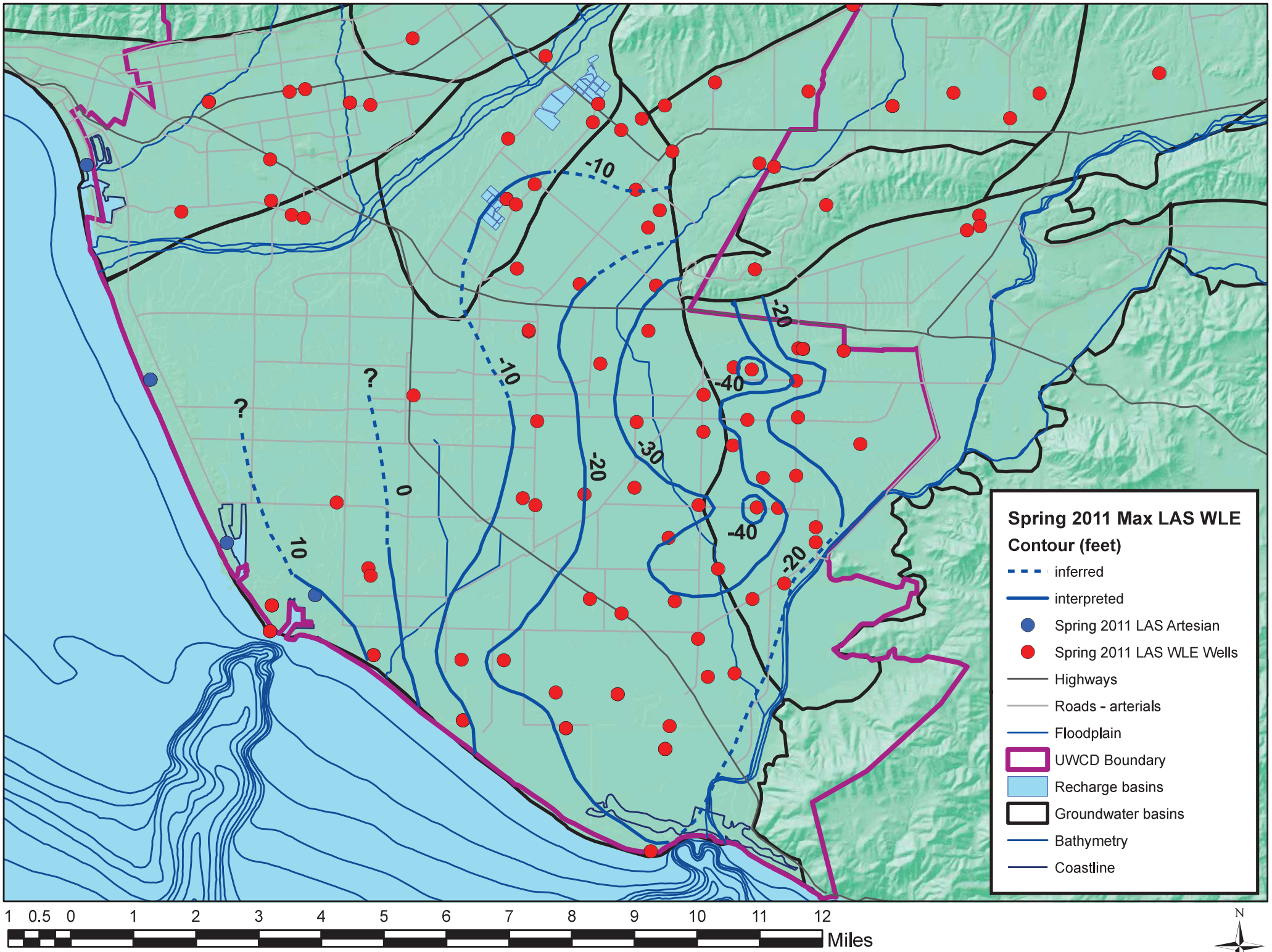


Figure 4.3-30. Oxnard Forebay-Oxnard Plain Lower Aquifer System (LAS) groundwater elevations for spring 2011

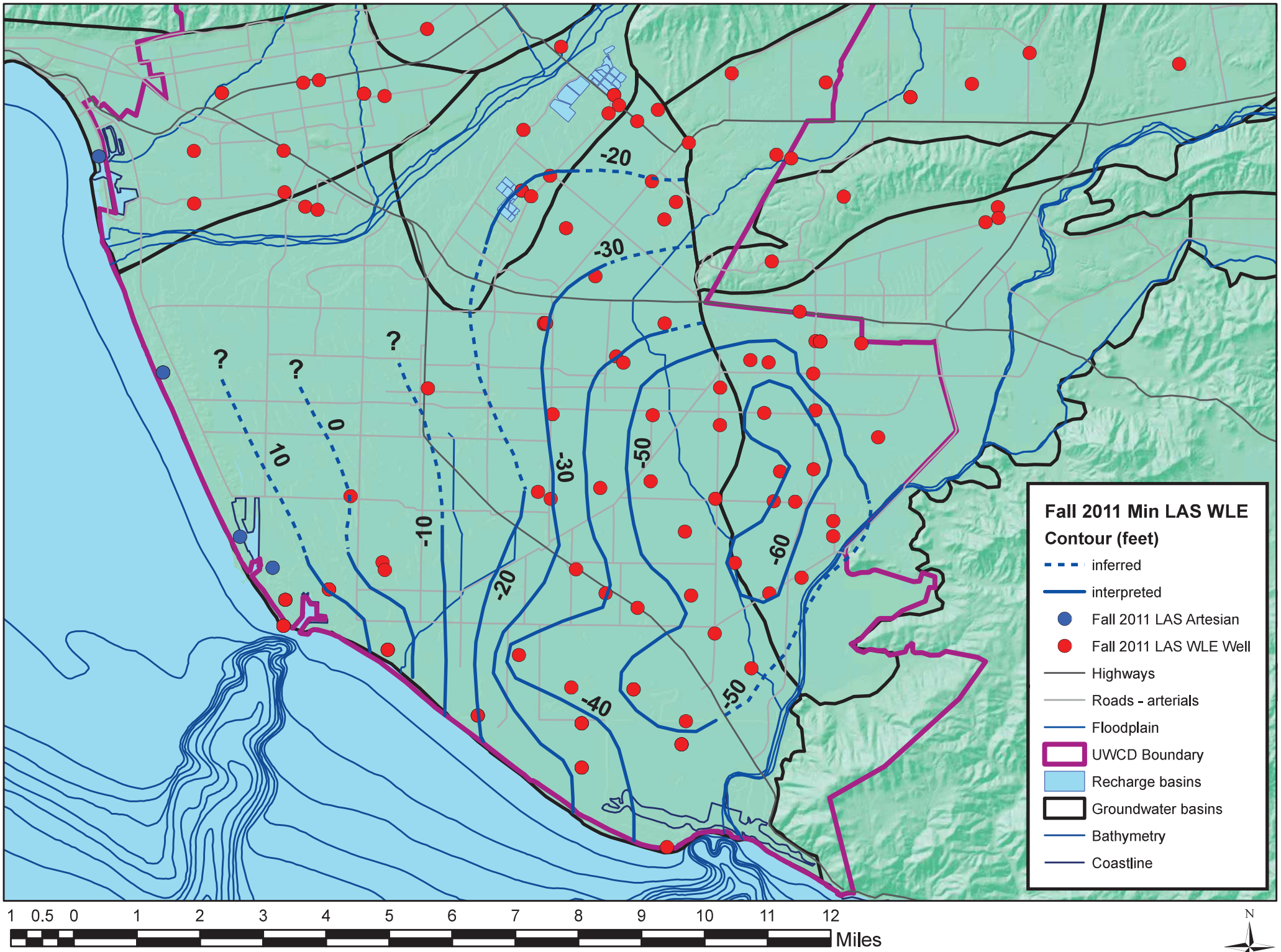


Figure 4.3-31. Oxnard Forebay-Oxnard Plain Lower Aquifer System (LAS) groundwater elevations for fall 2011

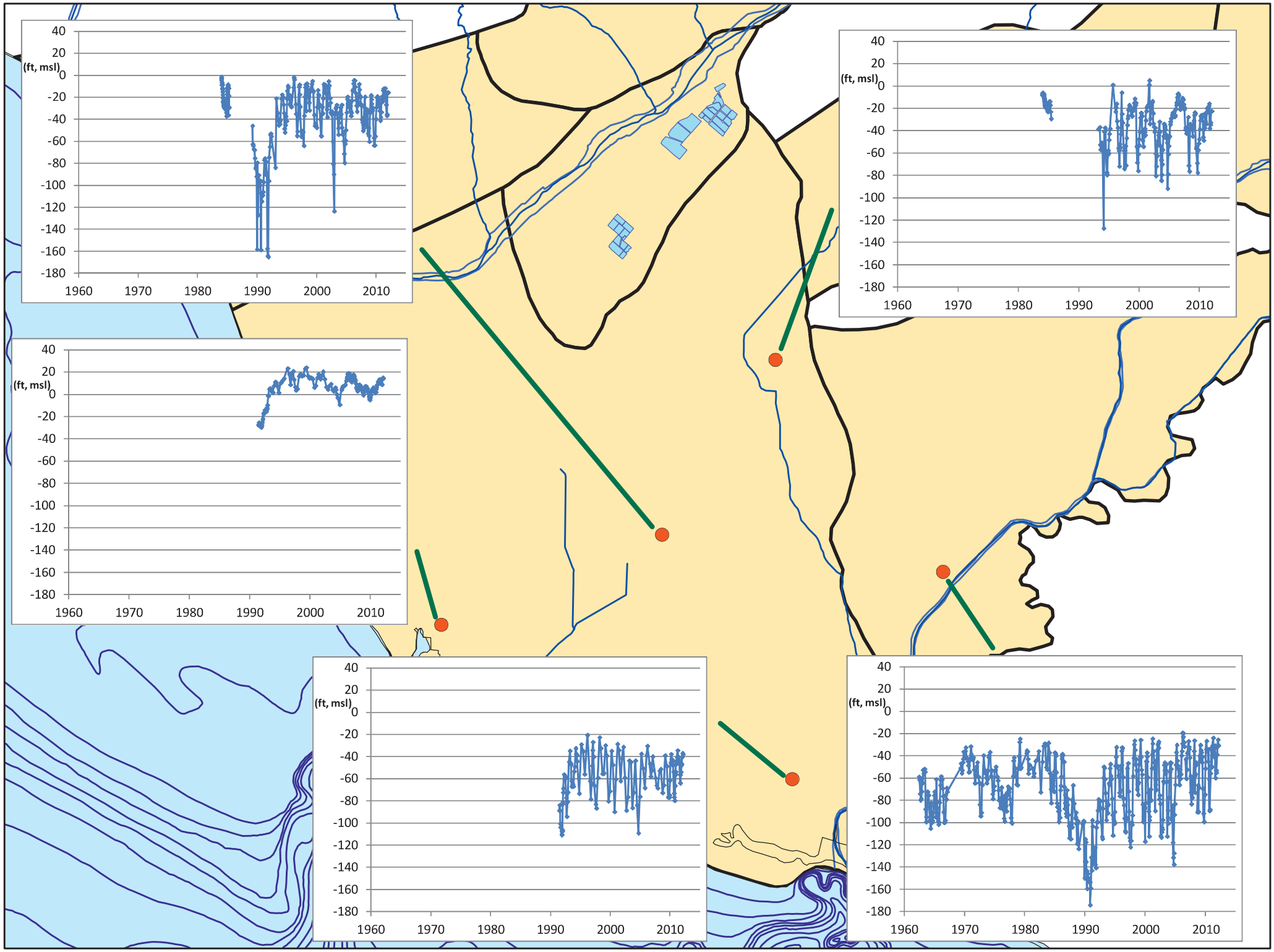


Figure 4.3-32. Oxnard Plain Lower Aquifer System (LAS) groundwater elevation hydrographs, selected wells

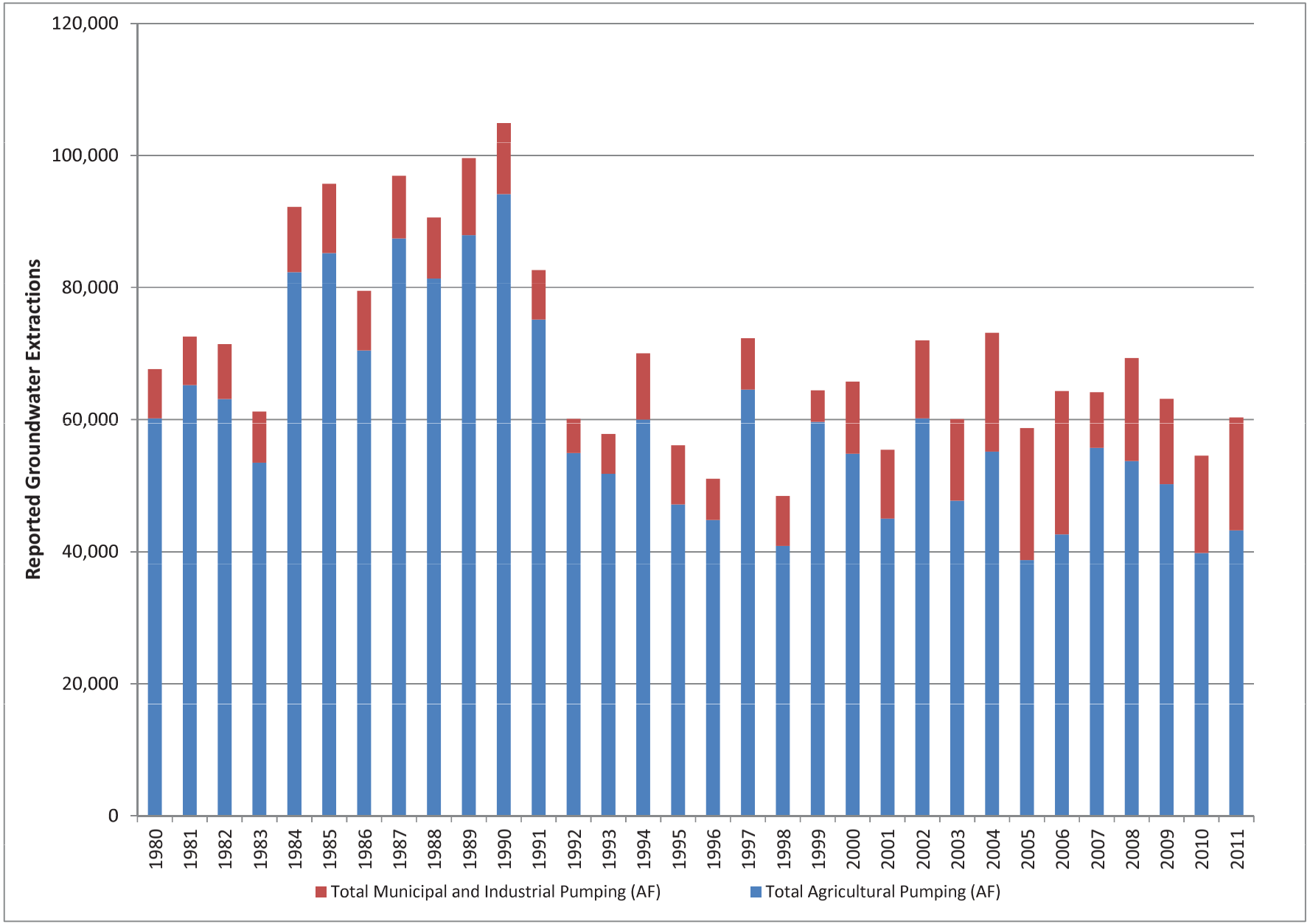


Figure 4.3-33. Historical reported groundwater extractions for the Oxnard Plain and portions of Pleasant Valley and the West Las Posas Basin

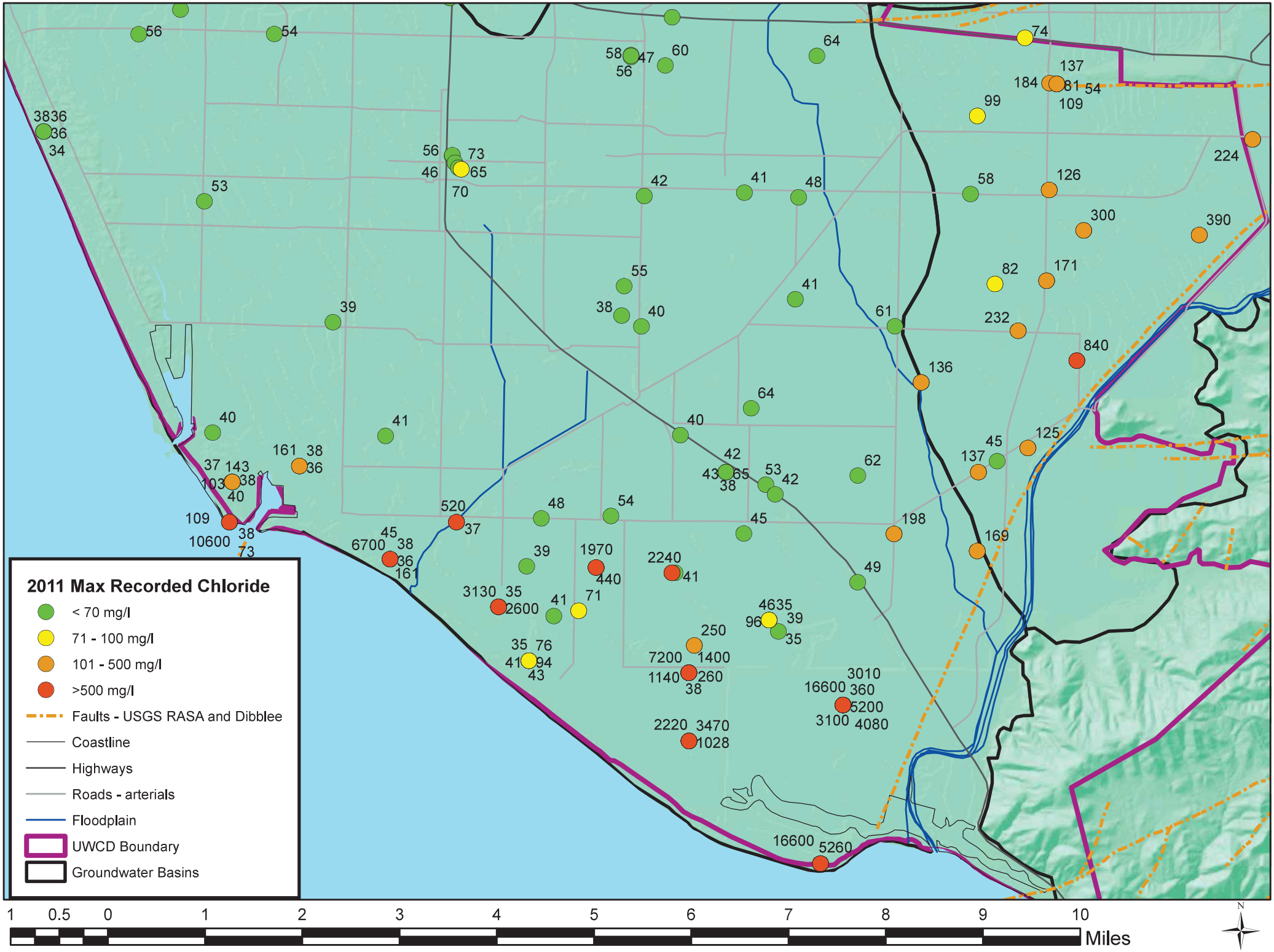


Figure 4.3-34. Maximum recorded chloride for Oxnard Plain and Pleasant Valley Basin wells, 2011

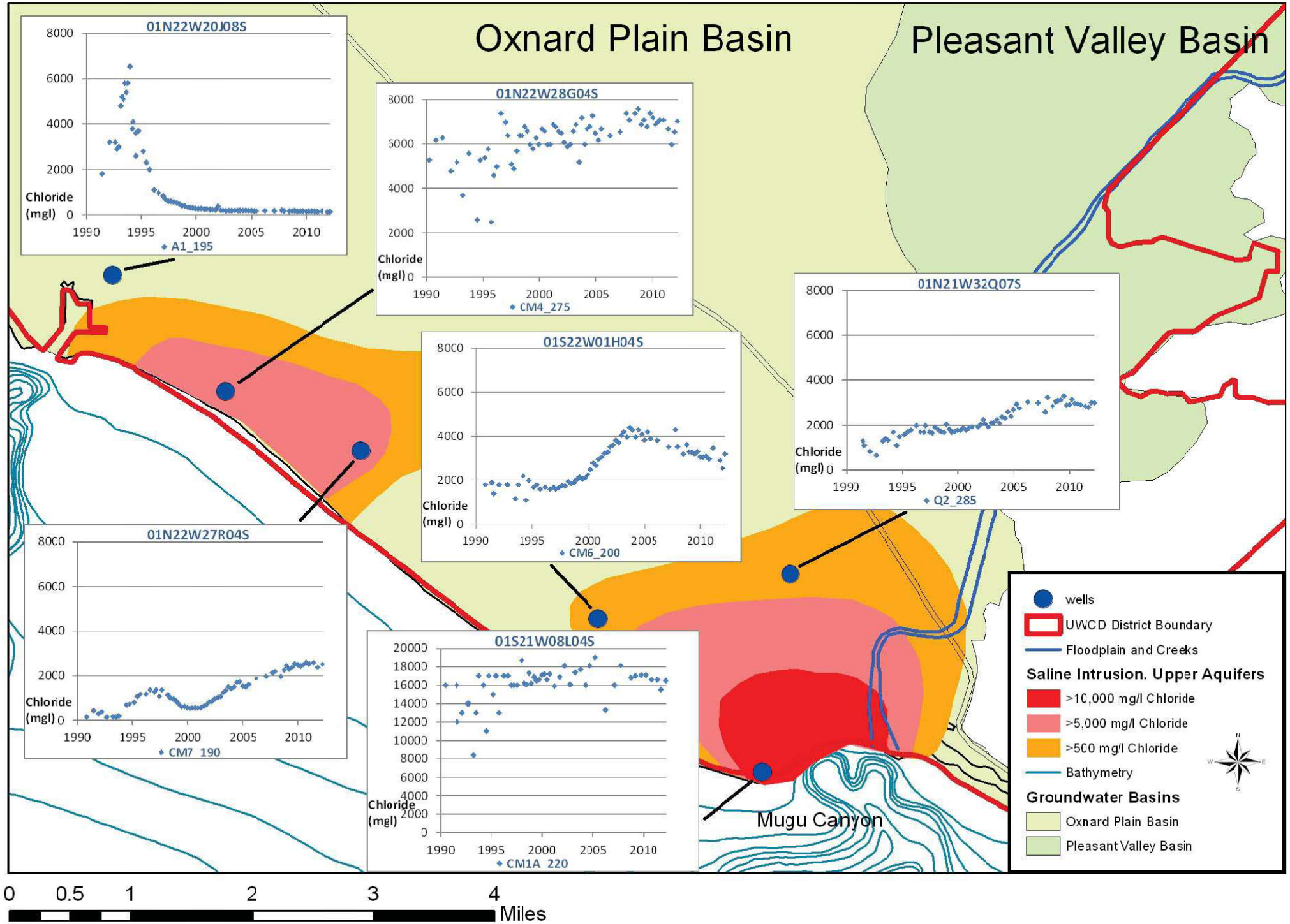


Figure 4.3-35. Chloride time series for selected Upper Aquifer System (UAS) wells, southern Oxnard Plain

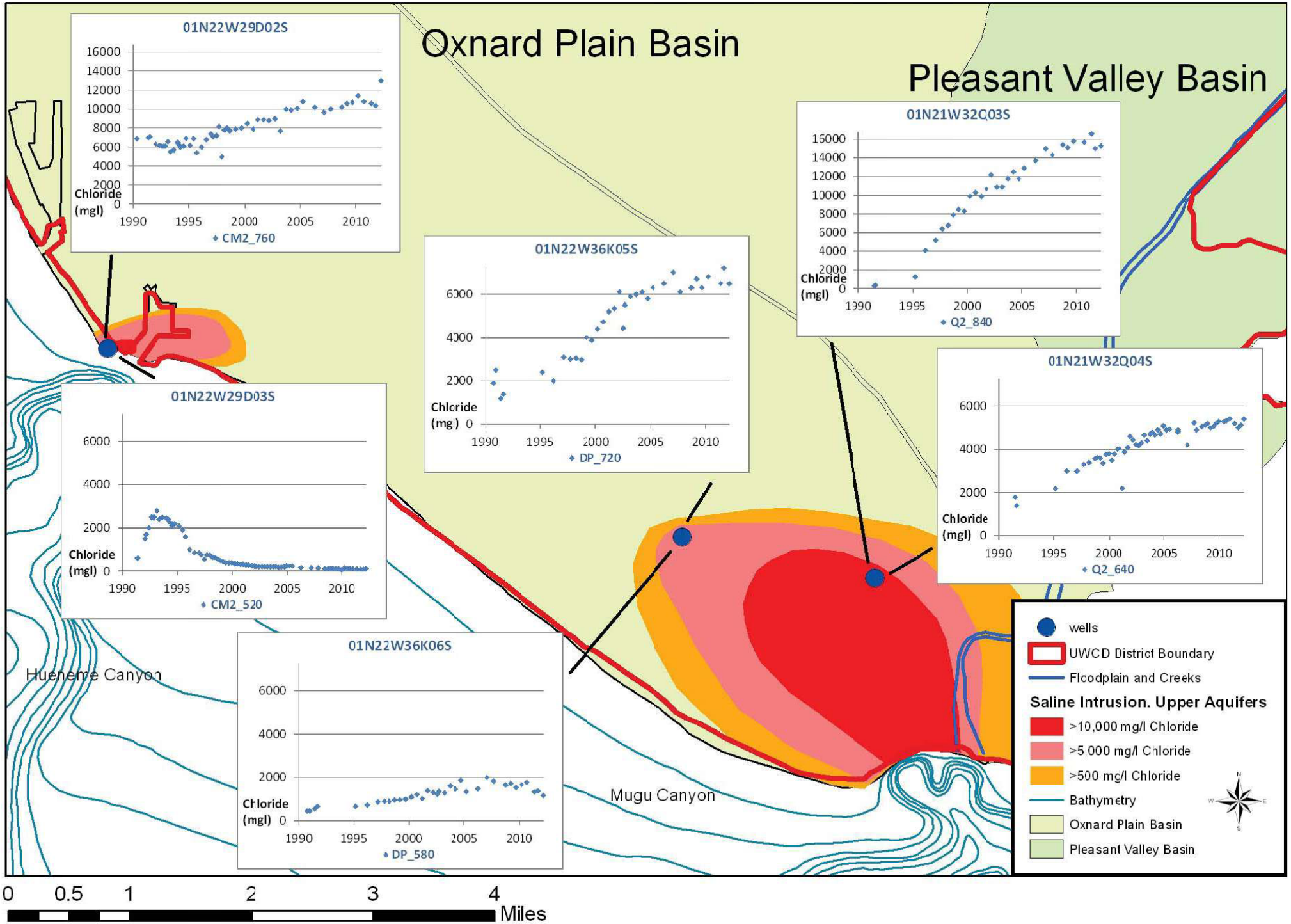


Figure 4.3-36. Chloride time series for selected Lower Aquifer System (LAS) wells, southern Oxnard Plain

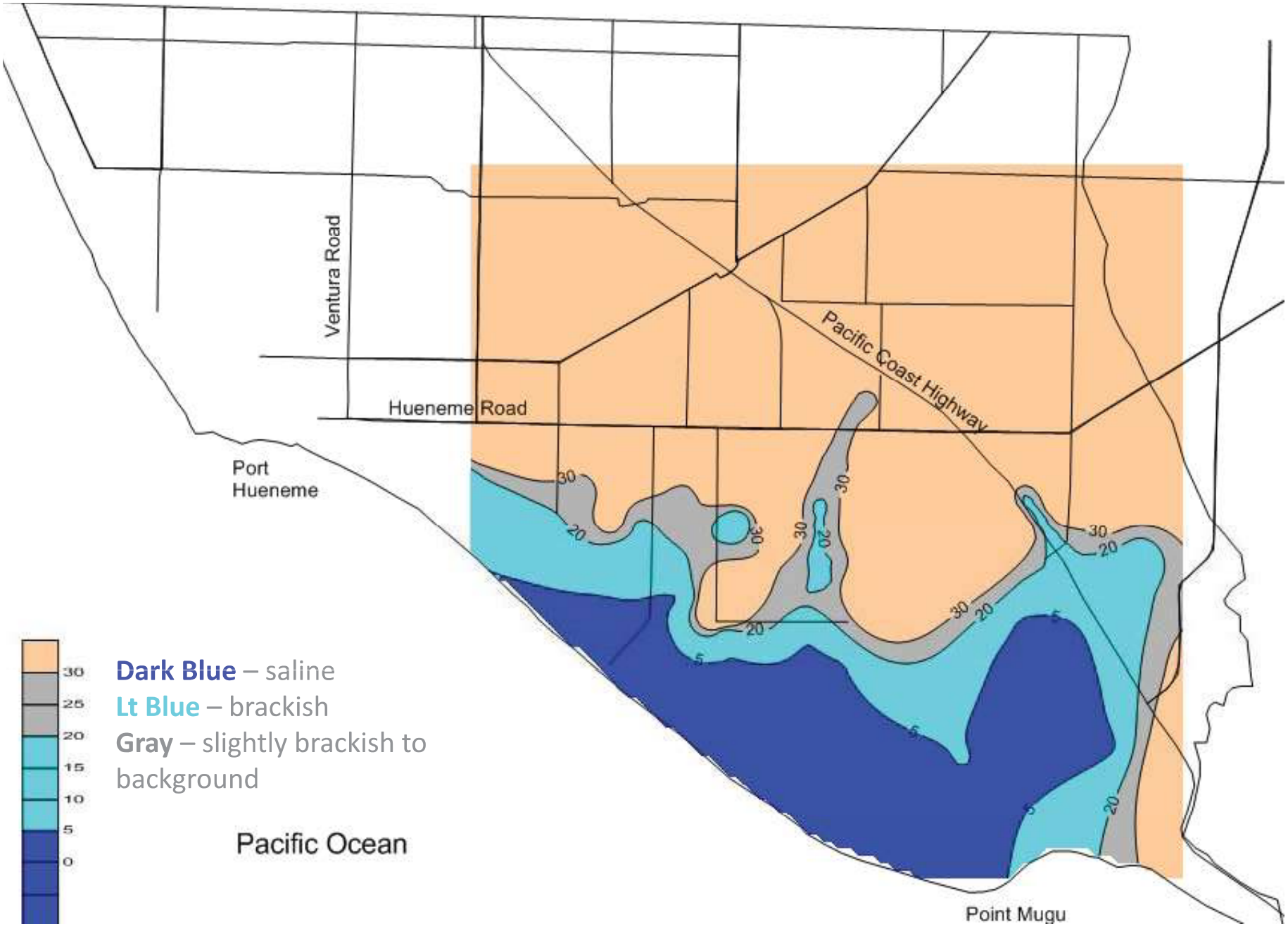


Figure 4.3-37. Geophysical survey (TDEM) of deep Upper Aquifer System (UAS) salinity, southern Oxnard Plain

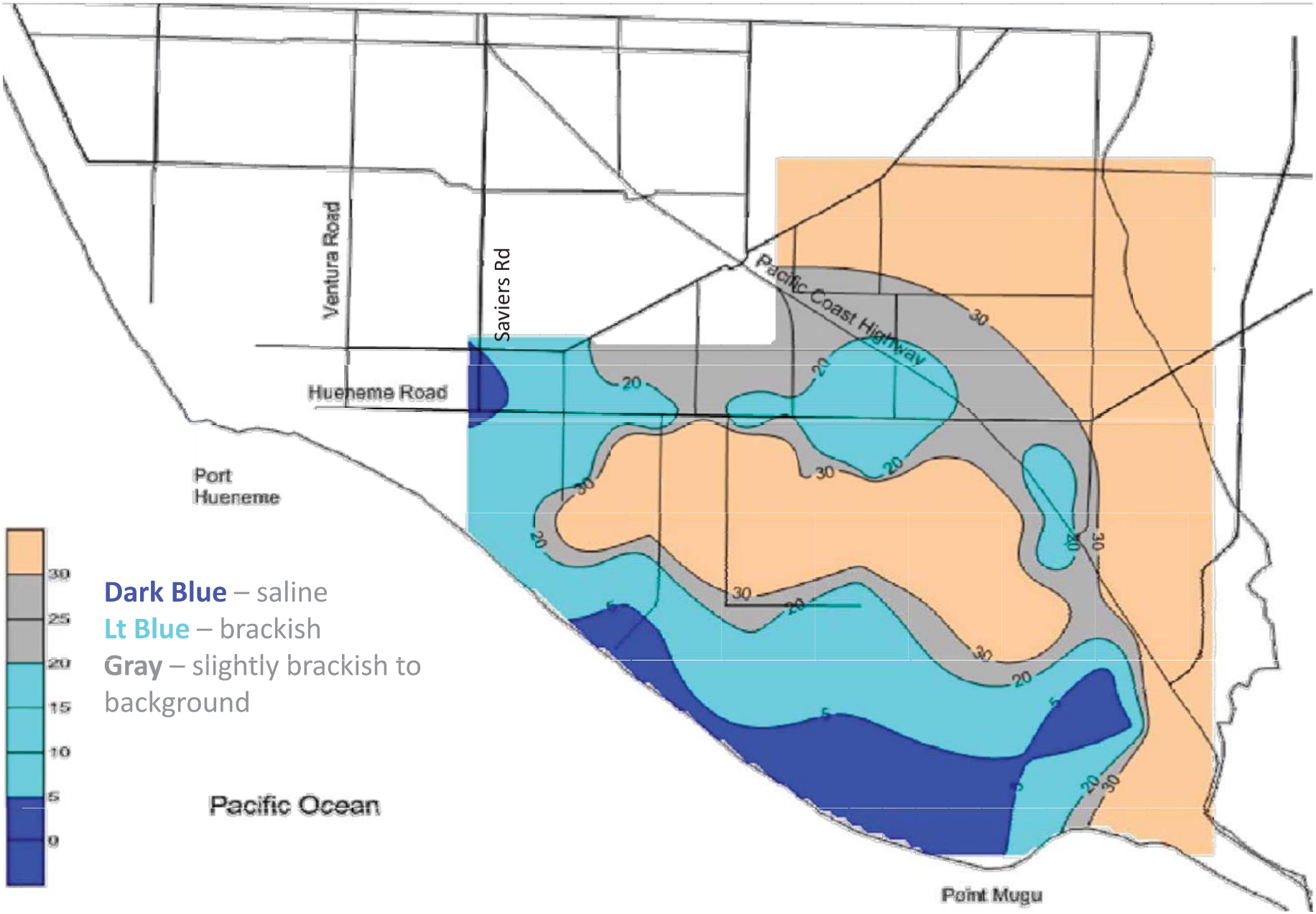


Figure 4.3-38. Geophysical survey (TDEM) of shallow Lower Aquifer System (LAS) salinity, southern Oxnard Plain

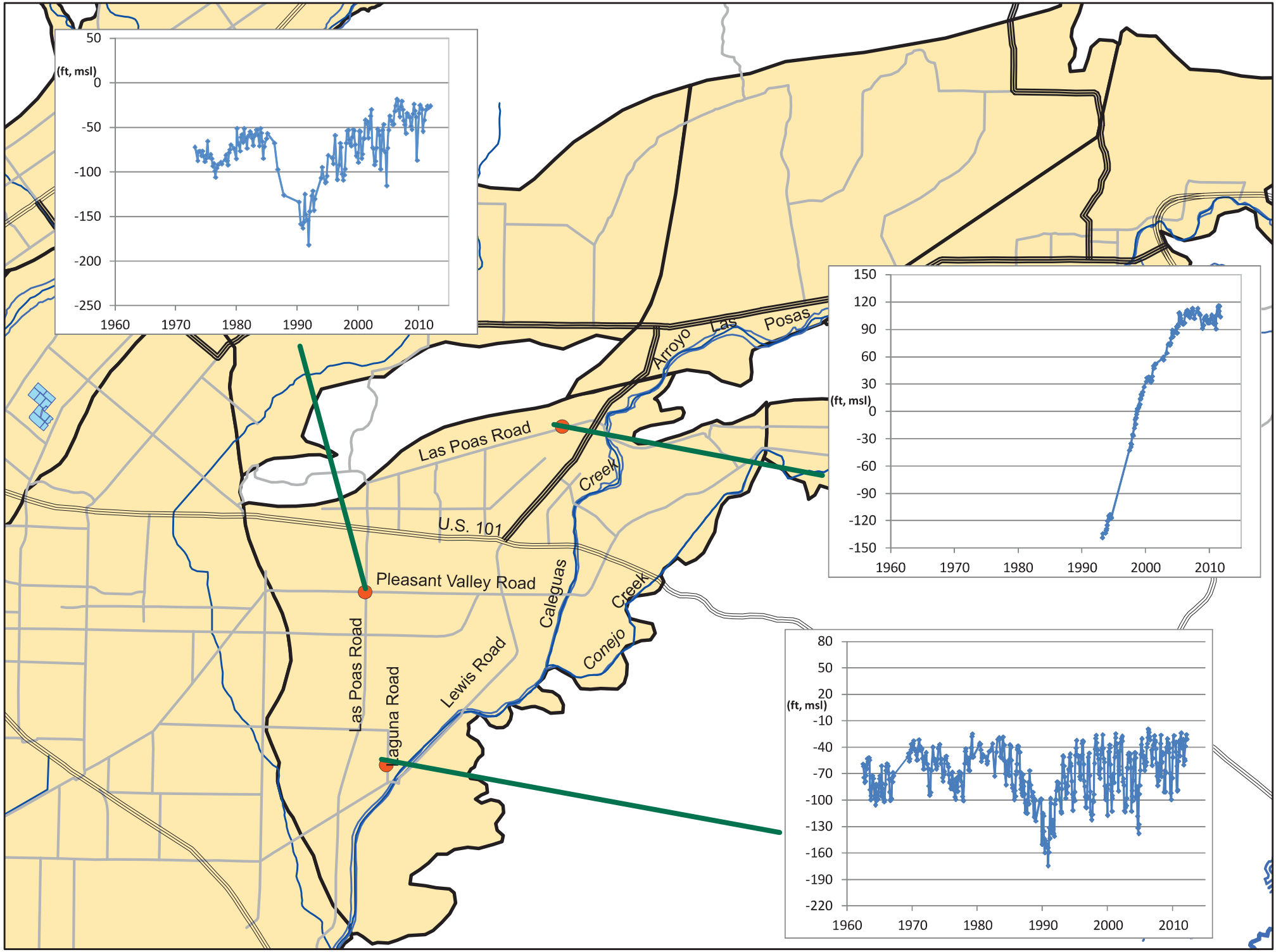


Figure 4.3-39. Pleasant Valley Basin Lower Aquifer System (LAS) groundwater elevation hydrographs, selected wells

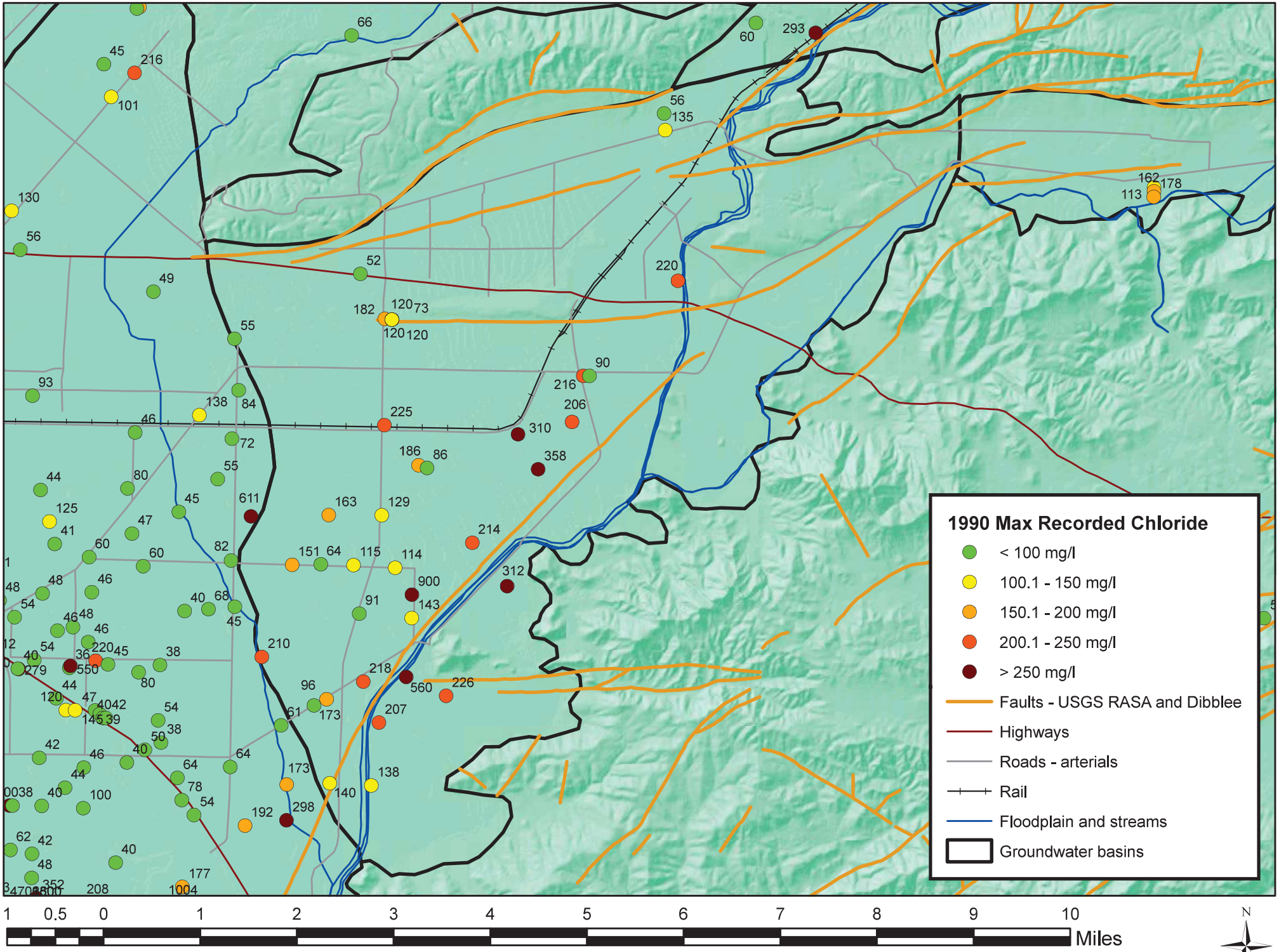


Figure 4.3-40. Maximum recorded chloride in Pleasant Valley Basin wells, 1990

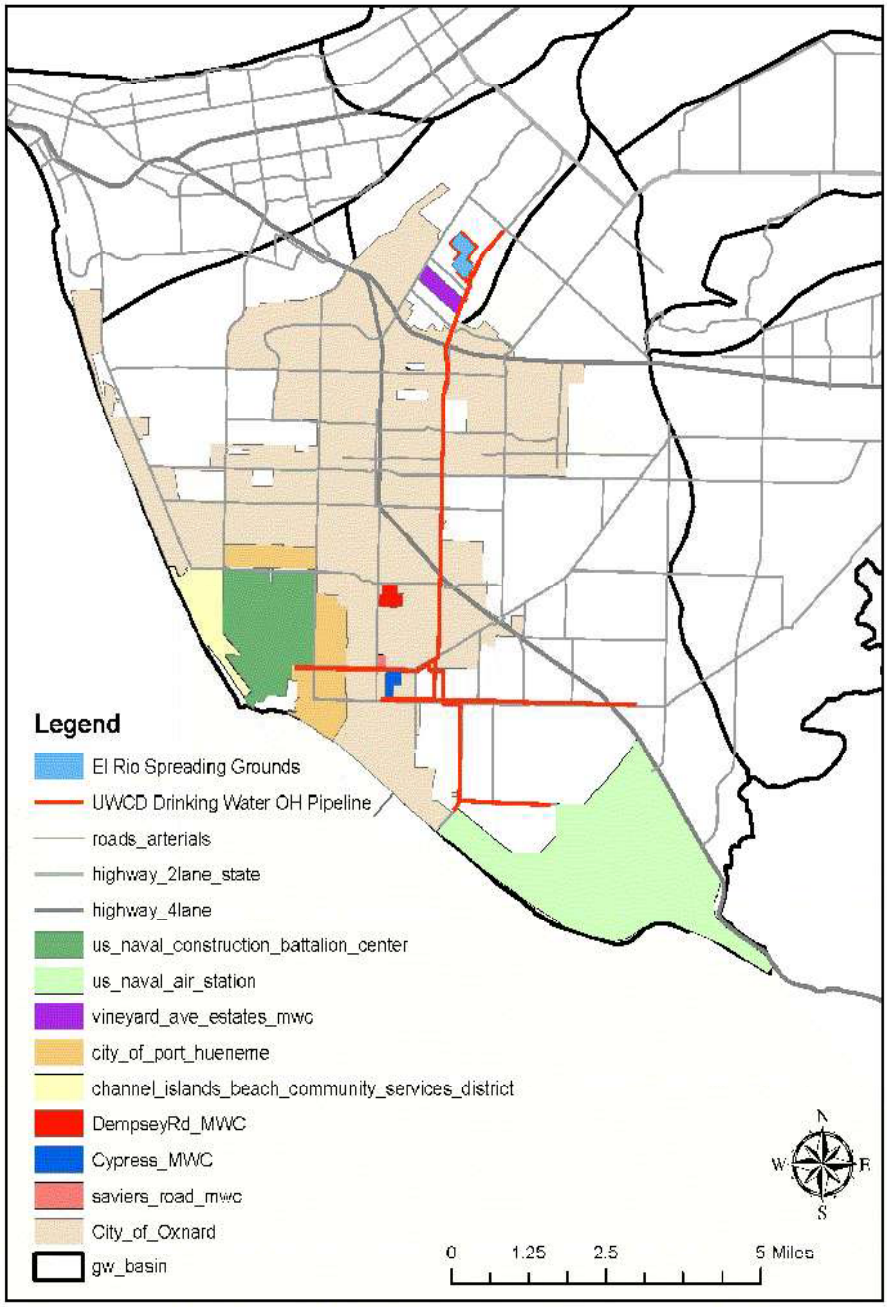
8 APPENDIX A. 2011 CONSUMER CONFIDENCE REPORT, O-H SYSTEM

United Water Conservation District

Oxnard-Hueneme Water Delivery System

2011 Consumer Confidence Report

UWCD Drinking Water Customer Service Area



Testing and Results

Last year we conducted thousands of tests for over 180 chemicals and contaminants that could be found in your drinking water. We did not detect any contaminants that would make the water unsafe to drink. This report highlights the quality of water we delivered to our customers last year. Included are details about where your water comes from, what it contains, and how it compares to State standards. For more information about your water, please call our Operations & Maintenance Manager, Mike Ellis at (805) 485-5114.

Public Meetings

Our monthly Board meetings are usually held on the second Wednesday of every month at 1:00 PM in our board room at 106 North 8th Street in Santa Paula. Our meetings are open to the public and we would welcome your questions and comments.

About Your Water Supply

United Water's Oxnard-Hueneme Delivery System supplies about 15,000 acre-feet of water per year to several agencies in the Oxnard Plain, including the cities of Oxnard and Port Hueneme, two Naval bases, and several smaller water companies. Those agencies supply our water to over 222,000 people, most of it treated or blended with other supplies. Our water source is 100% local groundwater, pumped from wells near El Rio, north of Oxnard. Water from those wells has its origin in the mountains and valleys of the 1,600 square mile Santa Clara River watershed. The wells are in an aquifer called the Oxnard Forebay. Our water is naturally high in minerals that affect its taste, but is safe to drink. Our groundwater is considered to be "under the influence of surface water," which means we do extensive monitoring of turbidity and other parameters to meet health regulations.

United Water Conservation District
106 North 8th Street
Santa Paula, CA 93060
805/525-4431 Fax 805/525-2661
www.unitedwater.org

Water produced by our wells is naturally filtered through the ground. We use chlorine as a disinfectant to kill bacteria, parasites, and viruses. Then we add chloramines to provide a long-lasting disinfection residual to keep the water safe until it reaches our customers. Due to the longer-lasting residual of chloramines, owners of pet fish must treat their tap water before putting it into aquariums or ponds.

Types of Potential Contamination

In general, sources of drinking water (both tap water and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves, naturally-occurring minerals and, in some cases, radioactive material can pick up substances resulting from the presence of animals or from human activity. Contaminants that may be present in source water include:

Microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife.

Inorganic contaminants, such as salts and metals, which can be naturally-occurring or result from urban stormwater runoff, industrial or domestic wastewater discharges, oil and gas production, mining, or farming

Organic chemical contamination, including synthetic and volatile organic chemicals, which are by-products of industrial processes and petroleum production, and can also come from gas stations, urban stormwater runoff, agricultural application, and septic systems.

Pesticides and herbicides, which may come from a variety of sources such as agriculture, urban stormwater runoff, and residential uses.

Radioactive contaminants, which can be naturally-occurring or be the result of oil and gas production and mining activities.

In order to ensure that tap is safe to drink USEPA and the California Department of Public Health prescribes regulations that limit the amount of certain contaminants in public drinking water. We treat our water to meet these health regulations. The Department's regulations also establish limits for contaminants in bottled water, which must provide the same protection for public health. Scientists and health experts are continually studying the effects of various chemicals in drinking water to make sure the public water supply is safe.

Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the USEPA's Safe Drinking Water Hotline (1-800-426-4791).

Definitions

Public Health Goal (PHG): The level of a contaminant in drinking water below which there is no known or expected risk to health. PHGs are set by the California Environmental Protection Agency.

Maximum Contaminant Level Goal (MCLG): The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs are set by the U.S. Environmental Protection Agency.

Maximum Contaminant Level (MCL): The highest level of a contaminant that is allowed in drinking water. Primary MCLs are set as close to the PHGs (or MCLGs) as is economically and technologically feasible. Secondary MCLs are set to protect to odor, taste and appearance of drinking water.

Primary Drinking Water Standard (PDWS): MCLs for contaminants that affect health along with their monitoring and reporting requirements, and water treatment requirements.

Maximum Residual Disinfectant Level (MRDL): The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

Maximum Residual Disinfectant Level Goal (MRDLG): The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLG's do not reflect the benefits of the use of disinfectants to control microbial contaminants.

Treatment Technique (TT): A required process intended to reduce the level of a contaminant in drinking water.

Detection Limit for Reporting (DLR): The level above which a chemical is to be reported.

NA: Not applicable

ppm: parts per million, or milligrams per litre

ppb: parts per billion, or micrograms per litre

ND: none detected

pCi/L: picocuries per litre (a measure of radioactivity)

Turbidity

Turbidity is a measure of the cloudiness of the water. We monitor it because it is a good indicator of the effectiveness of our water treatment. Turbidity is measured in units called NTUs. We achieved 100% compliance with turbidity standards in 2011.

Contaminants Detected in 2011

Chemical	State MCL MRDL	State DLR	PHG MCLG MRDLG	Units	Range	Avg	Date	Major Sources in Drinking Water
Primary Standards - Clarity								
Delivered water turbidity	TT	N/A	N/A	NTU	0.14 - 0.04	0.07	2011	Well corrosion byproducts. Microscopic soil particles.
Primary Standards - Radioactivity Contaminants								
Gross Alpha	15	3	NA	pCi/L	6.68 - 4.30	5.29	2011	Decay of natural and man-made deposits.
Uranium	20	1	0.43	pCi/L	8.41 - 4.63	6.64	2011	Erosion of natural deposits.
Radon	N/A	100	NA	pCi/L	364 - 129	273.25	2011	Decay of natural deposits.
Primary Standards - Inorganic Contaminants								
Arsenic	10	2	0.04	ppb	3 - ND	1.5	2011	Erosion of natural deposits.
Fluoride	2	0.1	1	ppm	0.8 - 0.7	0.75	2011	Erosion of natural deposits.
Nitrate (as NO_3)	45	2	45	ppm	9.5 - 4.7	6.72	2011	Leaching from fertilizers and septic systems.
Selenium	50	5	30	ppb	9 - 5	7	2011	Erosion of natural deposits. Discharge from mines, runoff from livestock lots.
Primary Standards - Disinfection								
Chloramine Residual (as Cl_2)	4	4	4	ppm	2.4 - 1.3	1.91	2011	Drinking water disinfectant added for treatment.
Total Haloacetic Acids	60	NA	NA	ppb	6 - 1	4.06	2011	By-product of drinking water disinfection.
Dibromoacetic Acid	N/A	2	NA	ppb	6 - 4	5.45	2011	By-product of drinking water disinfection.
Monobromoacetic Acid	none	1		ppb	1 - 1	1	2011	By-product of drinking water disinfection.
Trichloeoacetictic Acid	none	1		ppb	1 - 1	1	2011	By-product of drinking water disinfection.
Primary Standards - Disinfection By-Products								
Total Trihalomethanes	80	N/A	1.8	ppb	49.8 - 19.8	30.3	2011	By-product of drinking water disinfection.
Bromodichloromethane	N/A	1	NA	ppb	6.2 - 3.3	4.5	2011	By-product of drinking water disinfection.
Bromoform	N/A	1	NA	ppb	23.7 - 7.8	12.5	2011	By-product of drinking water disinfection.
Chloroform	N/A	1	NA	ppb	1.3 - 0.6	1	2011	By-product of drinking water disinfection.
Dibromochloromethane	N/A	1	NA	ppb	19.1 - 8.0	12.4	2011	By-product of drinking water disinfection.
Microbiological Contaminants								
Total Coliform bacteria	Systems that collect <40 samples/month: no more than 1 positive		0	Absense/ Presence/ 100ml	Absent	Absent	2011	Naturally present in the environment.
Fecal Coliform bacteria and E.*coli*	A routine and repeat sample are total coli-form positive, and one of these is fecal or E.coli positive		0	Absense/ Presence/ 100ml	Absent	Absent	2011	Human and animal fecal waste.
Secondary Standards								
Sodium	N/A	N/A	N/A	ppm	79 - 71	75	2011	Leaching from natural mineral deposits.
Sulfate	500	0.5	N/A	ppm	420 - 308	374.31	2011	Runoff/leaching from natural deposits.
Total Dissolved Solids, TDS	1,000	NA	N/A	ppm	900 - 670	803.85	2011	Leaching from natural mineral deposits.
Total Hardness	N/A	N/A	N/A	ppm	467 - 400	433.5	2011	Leaching from natural mineral deposits.
Total Organic Carbon (TOC)	N/A	0.3	N/A	ppb	1.3 - 0.8	1.03	2011	Naturally present in the environment.
Unregulated Chemicals								
Boron	N/A	100	N/A	ppb	600 - 500	550	2011	Erosion of natural deposits.

Water Quality Data

The table on page 3 lists all of the drinking water contaminants that we detected during the 2011 calendar year. The presence of these contaminants in the water does not indicate that the water poses a health risk. In addition to the contaminants on the table, we tested for many other chemicals which were not detected at significant levels. Please call us if you would like a copy of the complete list of chemicals we tested for and the test results.

Total Dissolved Solids and Sulfate

Total Dissolved Solids, or TDS, is a measure of the total mineral content of the water. TDS and sulfate are secondary standards related to the taste of the water, and water exceeding the MCL is generally safe for human consumption. Our water exceeds the secondary standards for TDS and sulfate because of naturally occurring minerals in the water.

Source Water Assessment

United Water completed a Source Water Assessment for its drinking water wells in October 2001. The current report is available for public review at our office in Santa Paula. The assessment provides a survey of potential sources of contamination of the groundwater that supplies our wells. Activities that constitute the highest risk to our water are the following: petroleum storage tanks and fueling operations, septic systems, and animal feed lots that are no longer in use. The most recent update for the Surface Water Sanitary Survey was completed in January of 2011 and was submitted to the Department of Health Services.

Cryptosporidium

Cryptosporidium is a microbial pathogen found in surface water throughout the U.S. Although filtration removes Cryptosporidium, the most commonly-used filtration methods cannot guarantee 100 percent removal. Our monitoring indicates the presence of these organisms in our source water and/or finished water. Current test methods do not allow us to determine if the organisms are dead or if they are capable of causing disease. Ingestion of Cryptosporidium may cause cryptosporidiosis, an abdominal infection. Symptoms of infection include nausea, diarrhea, and abdominal cramps. Most healthy individuals can overcome the disease within a few weeks. However, immuno-compromised people are at greater risk of developing life-threatening illness. We encourage immuno-compromised individuals to consult with their doctor regarding appropriate precautions to take to avoid infection. Cryptosporidium must be digested to cause disease, and it may be spread through means other than drinking water.

Radon

Radon is a radioactive gas that you cannot see, taste or smell. It is found throughout the U.S. Radon can move up through the ground and into a home through cracks and holes in the foundation. Radon can build up to high levels in all types of homes. Radon can also get into indoor air when released from tap water from showering, washing dishes and other household activities. Compared to radon entering the home through soil, radon entering the home through tap water will be a small source of radon in indoor air. Radon is a known human carcinogen. Breathing air containing radon can lead to lung cancer. Drinking water containing radon may also cause increased risk of stomach cancer. If you are concerned about radon in your home, you may test the air in your home. There are simple ways to fix a radon problem that are not too costly. For additional information, call the National Safety Council's Radon Hotline (800-SOS-RADON).

About Nitrate

Nitrate in drinking water at levels above 45 ppm is a health risk for infants of less than six months of age. High nitrate levels in drinking water can interfere with the capacity of the infant's blood to carry oxygen, resulting in a serious illness. Symptoms include shortness of breath and blueness of the skin. High nitrate levels may also affect the ability of the blood to carry oxygen in some individuals, such as pregnant women and those with certain specific enzyme deficiencies. Nitrate levels may rise quickly because of rainfall or agricultural activity and groundwater movement. If you are caring for an infant, or are pregnant, you should ask advice from your doctor, or choose to use bottled water for drinking and for mixing formula and juice for your baby.

Immuno-compromised Persons

Some people may be more vulnerable to contaminants in drinking water than the general population. Immune-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly and infants, can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. USEPA/Centers for Disease Control (CDC) guidelines on appropriate means to lessen the risk of infection by *Cryptosporidium* and other microbial contaminants are available from the Safe Drinking Water Hotline (1-800-426-4791).

Security of your Water

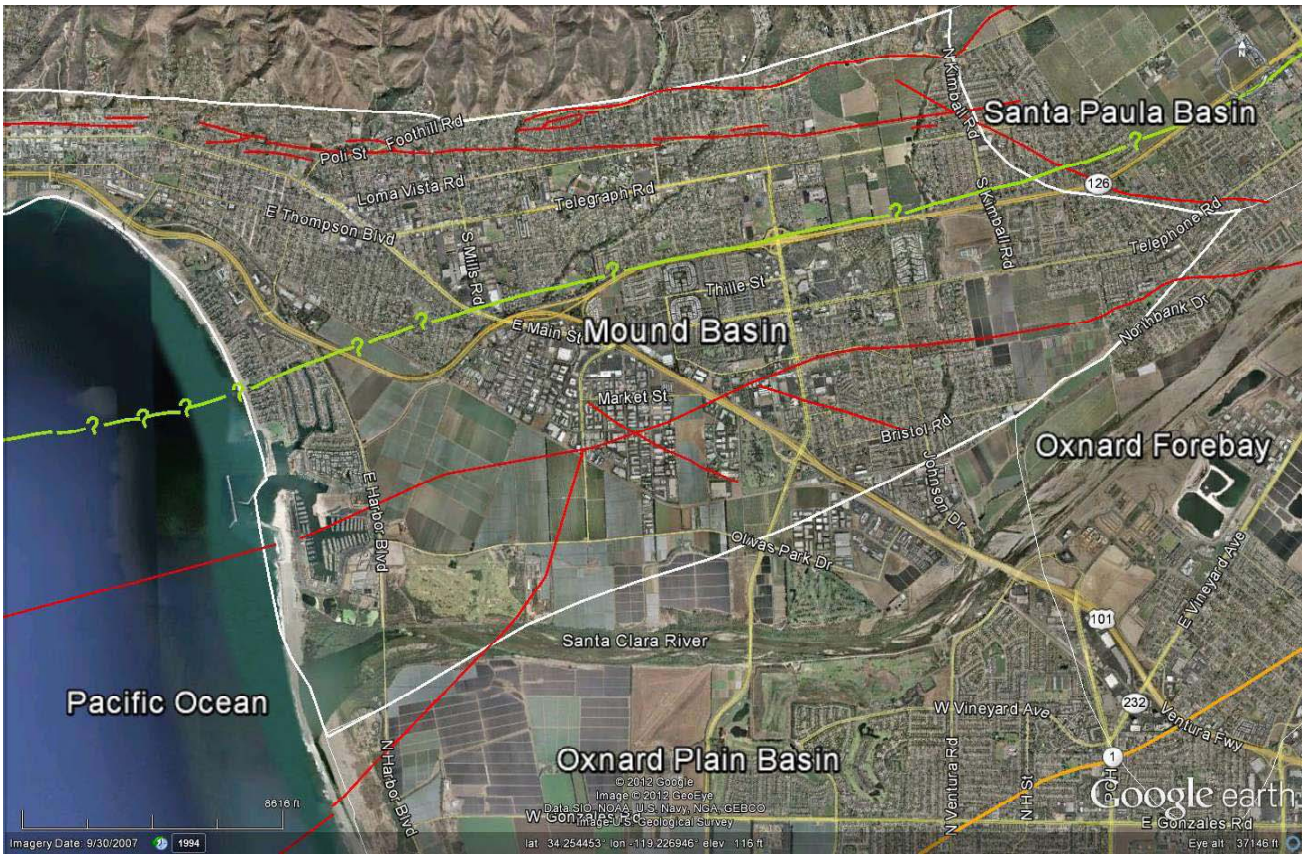
We have completed a Vulnerability Assessment of our OH water facilities. This work, funded by an EPA grant, has improved the security and safety of our water supply.

Hablamos Español

Para información en español llámenos al (805) 525-4431.

HYDROGEOLOGIC ASSESSMENT OF THE MOUND BASIN

United Water Conservation District
Open-File Report 2012-01
May 2012



THIS REPORT IS PRELIMINARY AND IS SUBJECT TO MODIFICATION BASED UPON FUTURE ANALYSIS AND EVALUATION

PREPARED BY:

GROUNDWATER DEPARTMENT

UNITED WATER CONSERVATION DISTRICT

HYDROGEOLOGIC ASSESSMENT OF THE MOUND BASIN

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HYDROGEOLOGIC ASSESSMENT OF THE MOUND BASIN

UWCD OPEN-FILE REPORT 2012-001

EXECUTIVE SUMMARY / ABSTRACT

This open file report addresses the hydrogeologic and geologic conditions of the Mound Basin in Ventura County, California. The United Water Conservation District (United Water) manages the surface water and groundwater resources for either all or part of eight groundwater basins. United Water manages the most significant portion of the Mound Basin. Much of the Mound Basin lies within the boundaries of the City of Ventura. The downtown, midtown, and west side areas of the city fall within the boundaries of the Casitas Municipal Water District. Areas south and east of midtown Ventura fall within the United Water Conservation District.

The Mound Basin has a limited amount of data for characterization of the conditions within the basin. However, the purpose of this report is to assess and outline the hydrogeologic conditions of the Mound Basin with the data that are available. This includes the geology, hydrogeology and groundwater dynamics within the basin as they relate to water supply issues. This was completed by compiling United Water's direct technical data and information from previous works related to the Mound Basin. This information can potentially be used for establishing a basis for further development and management of the groundwater resources of the basin. The scope of work included:

- Assessing the geology and hydrogeology which characterizes the Mound Basin;
- Assessing recharge characteristics and mechanisms for the basin;
- Assessing water level hydrograph records for key wells;
- Assessing water quality data for the basin;
- Assessing changes in well status throughout the basin; and
- Assessing groundwater extractions from the basin for recent years.

The Mound Basin is essentially characterized by a low lying alluvial plain mainly occupied by the City of San Buenaventura. Much of the remainder of the basin is occupied by agricultural lands. The present day boundaries of the basin include: the Ventura fault and foothills to the north, the Country Club fault to the east, the Montalvo anticline to the south and the Pacific Ocean to the west. The Santa Paula Basin borders the Mound Basin on the east side and the Oxnard Plain Basin and Forebay Basin are adjacent to the Mound Basin on the south side.

The Mound Basin lies within the greater regional Ventura Basin which is part of the Transverse Ranges geologic province. In the Ventura Basin the total stratigraphic thickness of upper Cretaceous, Tertiary, and Quaternary strata exceeds 55,000 feet

The Mound Basin is characterized by a significant east-west trending fold axis (Ventura syncline) and a significant amount of faulting. This study conducted a thorough review of geologic articles and reports, which covered 87 years of information, to generate the Mound Basin conceptual geologic model. The Mound Basin water-bearing sediments are generally Pleistocene (San Pedro formation) and Holocene (alluvium) deposits. These deposits are limited to approximately the upper 3,000 feet. The faulting is primarily reverse faulting, with some strike-slip movement, on the north (Ventura and Foothill faults), south (Oak Ridge, McGrath faults, Mound NW 3, and Mound NW 2 faults), and east (Country Club fault) sides of the basin. The Ventura and Oak Ridge faults contribute to the structural boundaries on the north and south side of the basin. The Montalvo anticline located south of the Oak Ridge fault is the present day southern boundary of the basin. However, some researchers suggest that the Oak Ridge fault may be a more appropriate southern structural boundary of the basin, as it forms the southern structural fault and uplift on the south side of the basin.

Aquifer materials and sediments within the adjacent Oxnard Plain and Forebay Basins extend into the Mound Basin. However, the sediments change in character. Some of the shallow alluvium is dominated by clays in the Mound Basin. In addition, the Fox Canyon aquifer zone becomes much more lenticular in nature on the northern side of the Mound Basin. Water level records suggest groundwater likely flows from the Oxnard Plain Basin, Forebay Basin, and Santa Paula Basin into the Mound Basin. Although there are some appreciable offsets on the faults bounding the Mound Basin, the low-permeability Santa Barbara formation does not extend to sufficiently shallow depths to impede groundwater flow. In most cases, there is a significant thickness of the San Pedro formation (aquifer materials) existing above the faults, or on both sides of the faults. The nature of the faults themselves as an impedance to flow is not known. However, groundwater flow and basin recharge across these zones is most probable.

Water levels vary considerably within the Mound Basin as evidenced in the few wells that are located within the basin. Groundwater flows generally from east to west. Gradients within the basin remain fairly flat most of the time (especially during dry periods) and water levels tend to vary somewhat among nearby wells. Water levels in many wells respond in a similar fashion to wet and dry periods, although deeper wells often have lower groundwater elevations. Groundwater production is concentrated in several areas within and around the basin, creating the potential for pumping interference in some water-level measurements.

Agricultural pumping has been the main water user in the Mound Basin (approximately 70 percent). Since the mid-1980s agricultural pumping has averaged nearly 4,200 acre-feet per year with a peak annual production of 5,850 acre-feet recorded in 1990. The City of Ventura's pumping generally increased through the 1980s, and was variable in the 1990s. Municipal pumping peaked in 2003 and has declined fairly steadily in recent years.

While the quality of the groundwater produced by most wells within the Mound Basin is suitable for municipal and agricultural uses, the basin is not known for the high quality of its groundwater. In addition, the lenticular nature of many San Pedro formation sediments within the basin, and their suggested connate waters that likely remain in this setting, impair water quality in many zones. Although groundwater flow likely occurs through areas where interconnected or continuous aquifer materials exist, the less-continuous nature of some highly permeable deposits within the basin (compared to nearby basins) have likely inhibited the flushing of poor-quality waters from the basin. Water quality is variable between wells, and many records indicate somewhat elevated concentrations of TDS, sulfate, hardness and other analytes. Water quality appears to be relatively stable among many of the Mound Basin wells having long-term water quality records. Available records from wells near the coast do not show evidence of saline intrusion.

1 INTRODUCTION AND BACKGROUND

United Water Conservation District (United Water) is a public agency within Ventura County, California that is charged with conserving the water of the Santa Clara Rivers and tributaries. United Water works to manage the surface water and groundwater resources within all or part of eight groundwater basins. These basins include the Piru, Fillmore, Santa Paula, Oxnard Forebay, Oxnard Plain, Pleasant Valley, and parts of the west Las Posas and Mound basins. Figure 1-1 shows the locations of the basins relative to each other.

United Water stores surface water in a surface reservoir (Lake Piru impounded by Santa Felicia Dam), replenishes the groundwater aquifers along the Santa Clara River, diverts natural and reservoir released water, replenishes groundwater through percolation ponds, and delivers both diverted surface water and pumped water to those areas vulnerable to overdraft and saline water intrusion. Since the 1950s, United Water has been studying means to improve groundwater management throughout the District. Projects for improved conservation of water and groundwater management have been executed since the 1950s and these efforts continue to the present day.

During the 1990s and up to the present represents a period of more detailed studies by United Water to improve the understanding of the hydrogeology, basin yields, additional water quality issues, river dynamics, and impacts of the continued high demand for water resources. These studies progressively became more fine-tuned to address more localized issues. One major issue is to actively assess and outline the hydrogeologic conditions of the Mound Basin. This includes understanding the geology, hydrogeology and groundwater dynamics within the basin. The purpose of this study is to establish a basis for planned development and management of the groundwater resources of the Mound Basin.

1.1 OBJECTIVE AND PURPOSE

The objective of this report is to investigate and compile direct technical data and other information from previous works related to the Mound Basin. This information is required to manage the

groundwater resources of the basin to maximize its long-term supply, protect the groundwater quality of the basin, and balance long-term average annual water replenishment and extractions. The direct technical data are data that United Water has had direct access or has developed from its own efforts. A review of previous work, spanning eighty-seven years of available literature related to the Mound Basin, was also conducted.

The scope of this report includes the following tasks:

- Assess geology and hydrogeology which characterizes the Mound Basin;
- Assess recharge characteristics and mechanisms for the basin;
- Assess water level hydrograph records for key wells;
- Assess water quality data for the basin;
- Assess changes in well status throughout the basin; and
- Assess groundwater extractions from the basin for recent years.

Since this report is intended to be a tool for the management of the groundwater resources of the Mound Basin it relies heavily on basic hydrogeologic and GIS data from United Water, as well as data obtained from the City of San Buenaventura and the County of Ventura.

1.2 PHYSICAL SETTING

The Mound Basin is located in Ventura County, California, and has been an important source of water supply to both agricultural and municipal users since at least the 1920s. The basin is characterized by a low-lying alluvial plain which gently rises in a northerly direction. It is the westernmost basin within the Santa Clara River Valley drainage. The basin is approximately 7 miles long and 4 miles wide and contains approximately 10,000 acres. The majority of the Mound Basin is occupied by the city/suburban environment of San Buenaventura (Ventura), California. The remainder of the basin is occupied by agricultural lands.

The present day mapped boundaries of the Mound Basin are indicated on Figure 1-2. The southern boundary extends from approximately the mouth of the Santa Clara River and trends northeastward toward South Mountain. This boundary approximately coincides with the axis of the subsurface structure consisting of the Montalvo anticline. The northern boundary consists of the Ventura Foothills north of the City of Ventura with the approximate trace of the Country Club fault forming the eastern boundary. The Country Club fault does not have a surface expression and is considered to be a concealed fault. The Pacific Ocean borders the basin to the west. The Oxnard Forebay Basin and Oxnard Plain Basin are directly adjacent to the Mound Basin on the south side and the Santa Paula Basin is directly adjacent on the eastern side.

As evidenced in Figure 1-2, most of the Mound Basin is occupied by the City of San Buenaventura. The city streets and structures occupy approximately 70 percent of the basin. The remainder of the

basin is occupied by agricultural lands. Generally, the main crops in the agricultural fields consist of citrus, avocadoes, berries, and row crops. Occasionally celery is grown during the offseason of berry crops. Highway 101 cuts through the Mound Basin in a northwest-southeast direction. One other major highway (Highway 126) cuts through the basin and runs generally east-west.

2 GENERAL GEOLOGY

The groundwater basins managed by United Water are part of the Transverse Ranges geologic province where the mountain ranges and basins are oriented east-west rather than the typical northwest-southeast trend over much of California. These basins are located within the more regional Ventura Basin, which is an elongate east-to-west trending structurally complex syncline within the Transverse Range province (Yeats, et. al., 1981). The Santa Clara River Valley occupies the Ventura Basin, which is one of the major sedimentary basins in the geomorphic province. The total stratigraphic thickness of upper Cretaceous, Tertiary, and Quaternary strata exceeds 55,000 feet (Sylvester and Brown, 1988).

Active thrust/reverse faults border the basins of the Santa Clara River Valley contributing to the uplift of the adjacent mountains and down-dropping of the basins. This configuration creates the elongate mountains and valleys that dominate Santa Barbara and Ventura Counties. The basins are filled with sediments that were deposited in both marine and terrestrial settings. The basins on the coast, including the Mound Basin, are filled with recent sediments deposited on a wide delta complex that formed at the terminus of the Santa Clara River. Figure 2-1 is a regional geologic map showing the general geology of the region. Figure 2-1 shows the local formations which form the mountain ranges, surface geology, and the major faulting in relation to the United Water basins.

As discussed above, the geology associated with the Transverse Ranges is primarily east to west trending folds and faulting (fold axes trend east-west). As per the regional geology, the Mound Basin is characterized by a prominent syncline (Ventura syncline) whose axis trends east-west and plunges to the west.

The surface and shallow materials in the Mound Basin are characterized by Quaternary alluvium (Holocene and late Pleistocene). These are composed of lagoonal, beach, river/flood plain, alluvial fan, terrace, and marine terrace deposits. Underlying the Quaternary alluvium are the upper Pleistocene San Pedro formation (marine and continental clays, silts, sands and gravels) which hosts most of the aquifers in the area; the lower Pleistocene Santa Barbara formation (mudstone, shale and minor sandstone); and the lower Pleistocene Pico formation (marine mudstones, siltstones, sandstones, and conglomerates) (Mukae and Turner, 1975). The Pleistocene deposits outcrop in the hills bordering the Mound Basin to the north. The two mounds located in the south-central part of the basin, the namesake of the basin, are characterized by outcrops of the San Pedro formation.

2.1 MOUND BASIN FOLDING

Figure 2-2 is a generalized geology map of the Mound Basin. The geology as shown in Figure 2-2 is discussed in this section of this report. The Ventura syncline (called the Santa Clara River syncline by some researchers) axis trends through the Mound Basin in an east-west direction and the approximate location of the axis is indicated on Figure 2-2. The syncline plunges gradually to the west. The Montalvo anticline is approximately parallel to the Ventura syncline and is located south of the syncline near the present day southern structural boundary of the Mound Basin (Geotechnical Consultants, Inc., 1972). The southern leg of the Ventura syncline forms the northern leg of the Montalvo anticline. Some workers also place a parallel fault at the location of the Montalvo anticline (Mann, 1959; Fugro West, Inc., 1996). Seismic reflection data from Fisher et al (2005) does confirm that an anticline exists at that location. It is unlikely that the Montalvo anticline is a simple fold. Some faulting is involved on the northern flank of the Montalvo anticline (McGrath fault, Mound NW 3 fault, Mound NW 2 fault, Oak Ridge Fault).

2.2 MOUND BASIN FAULTING

The Mound Basin is characterized by several faults. The faults are discussed in the following sections.

2.2.1 VENTURA AND FOOTHILL FAULTS

The Ventura fault (Figure 2-2) is located in the northern section of the basin and trends east-west. It is a reverse fault that dips to the north at a high angle, with the up-thrown side on the north contributing to the Ventura foothills (Yerkes et al, 1987). Figure 2-3 is a cross-section interpretation showing the Ventura fault. The fault was mapped by the United States Geological Survey (USGS) near the base of the Ventura Foothills. The Ventura fault extends offshore where it is referred to as the Pitas Point fault by Greene et al (1978), however, the USGS and other workers still refer to it as the Ventura fault. The Foothill fault is also mapped as an east-west trending fault in the northeast section of the Mound Basin. It is not referenced in most publications for the geology of the area. However, it was included in the GIS coverage from the USGS website (United States Geological Survey, 2011). Yerkes et al (1987) do show an inferred fault at the approximate location of the Foothill fault where it is shown in Figure 2-2. However it is not shown on Figure 2-3. The assumed motion along the fault is that of a reverse fault with the up-thrown side to the north.

2.2.2 COUNTRY CLUB FAULT

The Country Club fault is an arc shaped fault that trends northwesterly along the eastern edge of the Mound Basin and mainly forms the structural boundary between the Mound Basin and the Santa Paula Basin to the east (Figure 2-2). It is a steeply dipping (almost vertical) reverse fault with some appreciable left-lateral displacement (Turner, 1975). United Water's inspection of oil well data indicate a displacement of 1,600 to 1,800, feet with the south side of the fault displaced

upward relative to the northern side which is consistent with the offset reported by other investigators [Fugro West (1996) indicates approximately 2,000 feet of offset; Geotechnical Consultants, Inc. (1972) shows approximately 1,700 feet of offset].

2.2.3 Oak Ridge fault/McGrath fault/Mound NW faults

An understanding of the location (Figure 2-3) and nature of the Oak Ridge fault, McGrath fault, Mound NW 2 fault and Mound NW 3 fault share a more complex development in historical literature. The Mound NW 2 fault and Mound NW 3 fault both are located adjacent to a topographic mound referred to as “pressure ridges”.

U.S. Geological Survey Bulletin 753 (USGS, 1924) does not extend the overall fault coverage map to the Mound Basin, although they produced a geology map of Los Angeles and Ventura Counties. This suggests that the Mound Basin was not studied at that time. In 1933 the Division of Water Resources Bulletin 46 (California Department of Water Resources, 1933) presents the results of a geological investigation of Ventura County, however, the Oak Ridge fault, McGrath fault, Mound NW 2 fault, or Mound NW 3 fault are not shown pertaining to the Mound Basin. In addition, the Ventura and Montalvo anticlines are not shown. The California State Water Resources Board Bulletin No. 12 (California State Water Resources Board, 1953) contains a geologic map which shows the Oak Ridge fault in the Santa Paula Basin only. It extends to another fault referred to as the Saticoy fault (predecessor in study of the modern Oak Ridge fault) partially extending into the Mound Basin (Figure 2-4). The Saticoy fault is mapped to the east side of the Mound Basin, however, if projected to the west it would trend through or just north of the Mound NW 2 and Mound NW 3 faults (and pressure ridges). The McGrath fault is not shown. The map does show the Montalvo anticline which is depicted as partially coincident with the Santa Clara River.

John F. Mann Jr. and Associates (1959) appears to replace the Montalvo anticline with the “Montalvo fault” on his map. However, he does refer to the Montalvo anticline in his text. The Saticoy fault, as per Bulletin 12, is included in this publication. The McGrath fault or the Mound NW 2 and Mound NW 3 faults (and pressure ridges) are not shown on maps or included in the text. His cross-section shows the Montalvo fault extending to the surface with the up-thrown side to the southeast (Figure 2-5). In 1972 Geotechnical Consultants, Inc. show the Oak Ridge fault extending in a general east-west direction across the entire Mound Basin. It is depicted as touching one Mound NW fault and pressure ridge. There is only one Mound NW fault and pressure ridge shown. The Montalvo anticline is also shown. In map view, they show the McGrath fault approximately coincident with the Montalvo anticline trending approximately parallel to the Oak Ridge fault. GTC’s McGrath fault is very similar to the Montalvo fault shown in Mann (1959). No Saticoy fault, or McGrath fault as shown in Figure 2-2, is included. In cross-section, the Oak Ridge fault is shown to partially extend upward into the San Pedro Formation and displaces less than 200 feet of the Santa Barbara formation adjacent to the San Pedro formation at a depth of 2,300 feet.

Turner and Mukae (1975) have the Oak Ridge fault extending through the Mound Basin in a general east-northeast orientation north of the pressure ridges (Figure 2-6). They show the

McGrath fault extending from the main part of the Oak Ridge fault. It connects with the Oak Ridge fault east of the pressure ridges. The McGrath fault section is north of the Santa Clara River for its entire length. The Montalvo anticline merges with the McGrath fault in the western portion of the Mound Basin. The Country Club fault also merges with the Oak Ridge fault. In cross-section, both the Oak Ridge and McGrath faults extend into the alluvial deposits in the area (Figure 2-7) with the southern side up-thrown for both faults. The Santa Barbara formation is not shown on their cross-sections as they only address the effective base of fresh water. However, the San Pedro formation and overlying alluvium are shown to extend across both faults for thicknesses between 1,000 and 1,600 feet according to the cross-sections.

Yerkes et al (1987) map the Oak Ridge fault extending through the Mound Basin in a general east-northeast orientation located north of the pressure ridges. They also show the McGrath fault as an unnamed fault which connects to the Oak Ridge fault west of the pressure ridges and curves westward extending south of the Santa Clara River (Figure 2-8). An oversize plate from Yerkes et al (1987) also shows the Oak Ridge fault at a different scale. From that scale it can be observed that the Oak Ridge fault is located directly north of the two pressure ridges located adjacent to the Mound NW 3 and Mound NW 2 faults. In fact the Oak Ridge fault actually "touches" the mound (pressure ridge) adjacent to Mound NW 2. Yerkes et al (1987) state that the Oak Ridge is a zone of faulting that forms the southern boundary of the Ventura synclinal trough in the western Ventura Basin (Mound structural basin) rather than the Montalvo anticline as mapped by earlier researchers. They state that the faults in the area are buried and known only from subsurface data. They describe the Oak Ridge as a steeply dipping reverse fault with stratigraphic separation of about 350 meters (1150 feet) at the base of the San Pedro formation. Yerkes et al describe the pressure ridges as two isolated, elongate northwest trending structural uplifts. They are described as compressional features and are compatible with left-lateral slip along the adjacent Oak Ridge fault. It suggests a significant strike-slip component along the Oak Ridge fault as well as a reverse fault uplift on the south side.

Yeats (1988) maps the Oak Ridge fault extending through the Mound Basin in a general east-northeast orientation north of the pressure ridges (Figure 2-9). He refers to the McGrath fault as the "Montalvo" fault and shows the fault extending southwestward in an arcuate shape extending from the Oak Ridge fault. It connects with the Oak Ridge fault west of the pressure ridges and trends south of the Santa Clara River where it goes out to sea. Both faults are mapped as concealed. The Yeats configuration of the Oak Ridge fault and McGrath fault (Yeats' Montalvo fault) agrees with the Yerkes et al (1987) which is used for Figure 2-2. United Water uses that configuration. Yeats contains two cross-sections (A-A' and B-B') over the Oak Ridge fault and McGrath fault (Montalvo fault) (Figure 2-10). Cross-section A-A' is oriented north-northwest and crosses both the Oak Ridge fault and the McGrath fault. Cross-section B-B' is also oriented north-northwest and crosses the Oak Ridge fault in the vicinity of the pressure ridges. Cross-section A-A' shows that the McGrath ("Montalvo") fault actually merges with the Oakridge fault at a depth of approximately 2 kilometers (6,562 feet) (Figure 2-11). The Oak Ridge fault is shown as a reverse fault with the up-thrown side on the south side. The McGrath fault is also a reverse fault with the up-thrown side on the south side. Therefore, the area between faults as they appear in map view is actually up-

thrown in whole. Both cross-sections indicate that the top of the Oak Ridge fault exists at a depth of 1.0 to 1.5 kilometers bgs (3,300 feet to 4,900 feet). Yeats et al (1982) contends that the upper edge of the Oak ridge fault is buried by Quaternary sediment 1,250 meters thick (4,100 feet) in the Ventura Basin near Ventura, California. This is much deeper than the aquifer systems in the San Pedro formation.

Fisher et al (2005) conducted a high resolution and medium resolution marine seismic reflection survey over the Oak Ridge fault and the McGrath fault offshore south of Ventura, California. Using data from Huftile and Yeats (1995), Fisher et al show the Oak Ridge fault upper edge greater than a kilometer (3,300 feet) deep as measured under the continental shoreline where it goes out to sea. Seismic reflection data obtained from approximately 6 kilometers (~19,700 feet or 3.7 miles) as well as 9 kilometers (~29,500 feet or 5.6 miles) offshore image the Oak Ridge fault. These data are interpreted to image an unconformity, at a depth estimated to be approximately 80 meters (265 feet) below the sea floor that is probably at the base of the upper Pleistocene and Holocene strata which is not offset by the Oak Ridge fault. The upper edge of the Oak Ridge fault extends to the unconformity, however, the unconformity and strata above it are not offset. The McGrath (Montalvo) fault is also interpreted by Fisher et al (2005) to be truncated by an unconformity below the sea floor approximately 3 kilometers (9,850 feet or 1.9 miles) offshore.

3 HYDROSTRATIGRAPHY

In the Mound Basin, alluvial deposits and the San Pedro formation represent the principal water bearing strata. Underlying deposits, which include the Santa Barbara and Pico formations, are considered non-water bearing in the Mound Basin area even though they yield a limited amount of water for domestic wells elsewhere in Ventura County.

Figure 3-1 is a schematic cross-section of the Mound Basin taken from Greene (1978). Although the faulting may not be consistent with the latest understanding of the basin, it shows the general formations within the basin discussed in the following paragraphs of this report. It also shows the Montalvo anticline on the right hand side of the figure. Figure 3-2 shows the relationship between the major hydrostratigraphic units (i.e., aquifers and aquifer systems) and the geologic formations and their ages as typically defined for the region. In general the Oxnard aquifer and Mugu aquifer zones comprise the Upper Aquifer System (UAS) with the Lower Aquifer System (LAS) containing the Hueneme, Fox Canyon, and Grimes aquifers. These hydrostratigraphic units extend into the Mound Basin from adjacent basins, however, they change character (e.g., lithology, thickness, degree of interbedding) in places. Generalized conceptual groundwater flow paths are depicted in Figure 3-3. Figure 3-4 is a southwest to northeast cross-section, across the Oxnard Plain, located southeast and adjacent to the Mound Basin. The Grimes Canyon aquifer is not shown on the cross-section.

3.1 UPPER AQUIFER SYSTEM

The UAS is composed of Holocene (Oxnard aquifer) and late Pleistocene (Mugu aquifer) alluvium separated by an unconformity that functions as a clay aquitard (Figure 3-2). The boundary between the UAS and LAS is an unconformity.

Undifferentiated younger alluvium (Holocene Oxnard aquifer zone) and older alluvium (late Pleistocene Mugu aquifer zone) comprise the water bearing alluvial deposits in the UAS in the Mound Basin. The younger alluvium in the Mound Basin is composed of flood plain and active river deposits in the vicinity of the Santa Clara River, and fan deposits which mantle much of the remaining portion of the basin. These deposits are predominately interbedded, lenticular clays with some silts, sands, and gravels. Geotechnical Consultants, Inc. (1972) report a maximum thickness of approximately 290 feet near the southwest corner of the Mound Basin. These deposits unconformably overlie the older, late Pleistocene alluvium. In the nearby Oxnard Plain Basin, the younger alluvium is reportedly nearly 250 feet thick on average (Turner, 1975) and contains a permeable coarse-grained unit at its base (Oxnard aquifer). As the Oxnard aquifer zone in the Mound Basin is dominated by clay deposits, the coarse grained units tend to be more sparse and lenticular in nature.

Undifferentiated older alluvium (late Pleistocene) unconformably overlies the late Pleistocene San Pedro formation. Older alluvium can be divided into an upper and lower portion. The upper portion consists mainly of confining zones (clay and silty clay) with minor amounts of sand and gravel. Interstratified sand and gravel, with variable amounts of clay, comprise the lower portion of these deposits. In the Mound Basin this coarse-grained portion is thickest near the Santa Clara River and becomes generally thinner to the north toward the foothills. The coarse grained strata at the base of the older alluvium in the Mound Basin are considered equivalent to the Mugu Aquifer, which has been traced into the Mound Basin from the Oxnard Plain Basin. Most wells in the Mound Basin contain perforations in the Mugu Aquifer. Older alluvium reported thicknesses are variable ranging from approximately 125 feet (Geotechnical Consultants, Inc., 1972) in the eastern part of the basin to about 450 feet (Turner, 1975) near the coast. Borehole geophysical logs reviewed for this investigation (Figures 3-5, 3-6, and 3-7) suggest Mugu hydrostratigraphic unit thicknesses up to about 425 ft.

3.2 LOWER AQUIFER SYSTEM

The Hueneme and Fox Canyon aquifers are part of the late Pleistocene San Pedro formation with the Grimes Canyon aquifer being part of the early Pleistocene Santa Barbara formation.

The San Pedro formation deposits are upper Pleistocene in age and underlie the alluvial deposits in the Mound Basin along a marked angular unconformity. Exposures of the San Pedro formation occur in the foothills which form the northern boundary of the basin. They attain a maximum thickness of 2,300 feet in this region (Geotechnical Consultants, Inc., 1972). The thickness of the San Pedro formation is considerably less at the southern edge of the Mound Basin as a result of

complex folding and faulting and subsequent erosion in that area (Montalvo anticline). This is evidenced in oil well geophysical logs inspected by United Water. The maximum thickness of the San Pedro formation occurs at the axis of the Ventura syncline near the center of the basin. Oil well data show that the maximum thickness is approximately 4,500 feet (Yerkes et al, 1987; Fugro West, 1996).

Upper portions of the San Pedro formation contain variable amounts of clay, silty clay, and sand. A series of interbedded water-bearing sands in this section form the time equivalent of the Hueneme aquifer in the Oxnard Plain Basin. Structural complexities and erosion have removed a portion of these beds in the southern part of the Mound Basin. In the central and northern part of the basin e-log signatures indicate changes in the aquifer units compared to the Oxnard Plain. However, thick sections of the Hueneme aquifer (or its time equivalent) do occur in the Mound Basin, as oil well e-logs interpreted by United Water indicate variable amounts of aquifer materials. Some areas appear to be characterized by significant clays. Most of the deeper wells in the Mound Basin are perforated in the Hueneme aquifer.

Lower portions of the San Pedro formation consist principally of sand and gravel zones with variable thicknesses of interstratified clay and silt. In a northerly direction across the Mound Basin these coarser grained water bearing strata are somewhat lenticular and generally become thinner (Mann, 1959, Geotechnical Consultants, Inc., 1972). This predominantly sand and gravel zone located at or near the base of the San Pedro formation is known as the Fox Canyon Aquifer in the Oxnard Plain Basin and extends into the Mound Basin. These deposits occur at great depths in the Mound Basin and are generally not targeted for water production.

The Fox Canyon Aquifer is continuous and traceable across the Oxnard Plain. As discussed above these beds apparently partially pinch out and become more lenticular in a northerly direction across the Mound Basin. Exposures near the base of the San Pedro formation in the foothills on the north side of the Mound Basin do not indicate the same aquifer thickness, or sediment coarseness, as at the type location of the Fox Canyon zone on the south flank of South Mountain, located several miles southeast of the basin. Nevertheless, in the Mound Basin (and surrounding areas) the distinct borehole geophysical log signature of the Fox Canyon Aquifer can be used as an aid in defining the base of the San Pedro formation.

United Water created several cross-sections by correlating borehole geophysical data from oil wells and some water wells. Figure 3-5 is a location map for two cross-sections that cross the Mound Basin in a general southwest-northeast (Cross-section J-J'; Figure 3-6) and north-south orientation (Cross-section P-P'; Figure 3-7). Both cross-sections illustrate the spatial relationships between the hydrostratigraphic units in the Mound Basin. On Section J-J' the large stratigraphic offset between the second and third well on the southwest side of the profile likely represents the McGrath fault. At that location, there appears to be approximately 700 feet of throw on the top of the Santa Barbara formation with the up-thrown side on the south. It has put some Santa Barbara formation in contact with the San Pedro formation. However, there is still approximately 1,200 feet of San Pedro formation and alluvium above the Santa Barbara formation. Interestingly, offset across the Oak

Ridge fault is not readily apparent which may be a function, at least in part, of the log spacing (i.e., wells are far apart). The Oxnard and Mugu alluvial aquifers do not appear to have been offset by either the McGrath or Oak Ridge faults. Overall, the UAS and a significant portion of the LAS hydrostratigraphic units are continuous across these faults.

On the northeast half of Cross-section J-J', the depth to the bottom of the Hueneme aquifer zone and Fox Canyon aquifer zone (San Pedro formation) in the Ventura syncline are not resolved by the well data (the wells are not deep enough). The Hueneme and Fox Canyon aquifer zones are deeper than the available well log data. The northern leg of the Ventura syncline is very steep on the northeast side of the profile as it extends upward to form the foothills.

On the southern portion of Cross-section P-P' the Fox Canyon aquifer zone extends upward and is in contact with the Mugu aquifer. This is likely the expression of the Montalvo anticline. Part of the extreme upward extension of the Fox Canyon aquifer zone in that area may be due to the Oak Ridge fault. There is approximately 200 feet of offset in the Mugu aquifer zone between wells 02N22W08L01S and 02N22W08P04S which may be caused by the Oak Ridge fault or related splays. Typically the UAS aquifers are not offset by the fault except for this location. The Hueneme aquifer zone is missing between Wells 2N22W17G01S and 2N22W17Q04S. Geotechnical Consultants Inc. (1972) also indicate that structural complexities and erosion have removed the Hueneme aquifer zone in the southern part of the Mound Basin. However, it is present further to the south. The contact between the Fox Canyon aquifer (beneath the Oxnard Plain) and the thick section of Mugu aquifer might serve a source of recharge to LAS aquifers in the Mound Basin.

3.3 IMPACT OF STRUCTURAL FEATURES ON HYDROSTRATIGRAPHY

The hydrostratigraphy of the Mound Basin has been impacted by the development of the structural features such as folding (e.g., Venture syncline, Montalvo anticline) and/or faulting (e.g., Country Club fault, Oak Ridge fault, McGrath fault) that created the Mound structural basin. Some researchers have suggested that the major faults within the basin or basin bounding faults function as impediments to groundwater flow and in some cases as barriers to flow. In most cases, researchers have proposed that low permeability geologic deposits have been uplifted into a juxtaposed position with the aquifers. Review of the readily available literature (Section 2) on the structural geology provided insight into data used to develop the historical perspectives.

The top of the Montalvo anticline has been eroded and the truncated edges of the Hueneme aquifers may be in hydraulic communication with the shallower aquifer zones in that area. Such a contact likely serves as a source of recharge to aquifers in the Mound Basin under certain water level conditions (Fugro West, 1996).

No readily available research on the influence the faults themselves have on groundwater flow has been identified. Their impact on groundwater has not been quantified.

3.3.1 Country Club fault

The Country Club fault has been speculated to be significant barrier to groundwater flow on the eastern boundary of the Mound Basin. However, it only displaces a portion of the low permeability Santa Barbara formation against the aquifer rich San Pedro formation. GTC (1972) shows approximately 1,300 feet of the San Pedro formation and alluvium exists above the up thrown Santa Barbara formation at that location. Fugro West (1996) shows approximately 1,500 feet of San Pedro formation and alluvium on top of the up thrown Santa Barbara formation at that location.

With the San Pedro formation on both sides of the Country Club fault above the displaced Santa Barbara formation, the Country Club fault zone likely conducts groundwater flow. Approximately 1,500 feet of San Pedro formation and younger Quaternary alluvium is continuous across the top of the Country Club fault forming a section that is possible for groundwater flow and recharge to the Mound Basin. The deeper section of the fault where the Santa Barbara formation is in contact with the San Pedro formation may act as a groundwater flow barrier only at depths below a minimum of 1,500 feet. The fault is not considered to extend upward through the alluvium (GTC, 1972).

3.3.2 Oak Ridge fault / McGrath fault / Mound WN faults

Mann (1959) depicts (Figure 2-5) the low-permeability Santa Barbara formation plotted adjacent to the San Pedro formation for approximately 500 feet, at a depth of 900 feet below ground surface (bgs). Therefore, there would be some hydraulic connection in the San Pedro formation (aquifers of the San Pedro formation) for water to recharge or flow on both sides of the “Montalvo fault” for a thickness of 900 feet.

GTC (1972) shows that hydraulic connection could occur for a significant thickness (~2,300 feet) on both sides of the Oak Ridge fault. GTC’s McGrath fault extends upward through the San Pedro formation however it does not penetrate the 400 feet of alluvium above it. The fault does displace 500 to 600 feet of Santa Barbara formation adjacent to the San Pedro formation at a depth of 800 to 1,100 feet (depending on which of the cross-sections used). Accordingly, there may be significant hydraulic connection between the aquifers of the San Pedro formation across GTC’s McGrath fault. There is a thickness of 800 feet to 1,100 feet of San Pedro formation and alluvium overlying the highest up-thrown section of Santa Barbara formation. Therefore it is likely that there is flow in that zone and recharge to the Mound Basin.

Turner and Mukae (1975) cross sections show the San Pedro formation and overlying alluvium extending across both the Oak Ridge and McGrath faults for thicknesses of between 1,000 and 1,600 feet. Therefore there could be hydraulic connection between the aquifers of the San Pedro formation across both faults. Mapping in the California DMG Open File Report 76-5 (California Division of Mines and Geology, 1975) is very similar to Turner and Mukae (1975) as far as the surface mapping of the faults is concerned. However, the western section of the McGrath fault is located south of the Santa Clara River. In addition, the eastern section of the McGrath fault does not connect with the Oak Ridge fault. It is mapped to end before it merges with the Oak Ridge fault.

Cross-Section D-D' from Yerkes et al (1987) (Figure 2-3) is a full cross-section that extends north-south from the Ventura foothills past the Oak Ridge fault and shows insignificant stratigraphic offset along the Oak Ridge fault (approximately 100 feet). The cross-section shows the San Pedro formation as having a thickness of approximately 1,500 feet on both sides of the Oak Ridge fault overlying the low permeability Santa Barbara formation. This is a significant thickness for possible groundwater flow and recharge.

Yeats et al (1982) depict the San Pedro formation and most of its aquifers as continuous across the top of the Oak Ridge fault and extending between the Oxnard Plain Basin and the Mound Basin unimpeded by the Oak Ridge fault along the southern boundary of the basin. The McGrath fault (Yeats Montalvo fault) extends upward to shallower depths close to the land surface. However, the McGrath fault only traverses a small portion of the southern boundary of the Mound Basin. The shallower aquifer systems of the Oxnard Plain and Forebay Basins extend between the basins across the top of the fault. This configuration, for both faults, suggests hydraulic connection and flow to the Mound Basin from the Oxnard Plain Basin and Forebay Basin.

The seismic data presented in Fisher (2005) suggests that a 265 feet thickness of aquifer materials (below the sea floor) exist continuously across the top of the Oak Ridge fault several miles offshore (3.7 and 5.6 miles).

4 WATER LEVELS

Groundwater elevation records exist for nearly sixty wells located within the Mound Basin. A number of key wells have water levels dating to the late 1920s, allowing an evaluation of long-term water level trends within the basin. However, the distribution of wells is heavily skewed towards the southern half of the basin, with relatively few wells existing north of Telephone Road. In the western portion of the basin wells are concentrated along Olivas Park Drive and near the railroad tracks south of Highway 101. This distribution of active and historic wells complicates the assessment of potential mountain-front recharge to the basin from the north. The southern and eastern boundaries of the basin are defined by structural features, and water level records from adjacent areas help assess the nature of the basin boundaries in these areas. Water level trends for many wells within the basin are similar, with evidence of recharge from adjacent basins to the east and south. The main groundwater flow pattern is down the axis of the basin from east to west. The slope of the potentiometric surface within the basin is quite flat during dry periods and the gradient increases somewhat following periods of above-average rainfall. During dry periods, groundwater elevations in many wells fall below sea level.

A major structural feature of the Mound Basin is the Ventura syncline, with the axis following an alignment similar to that of Highway 126. Several wells are located near the axis of this syncline, providing water level information in the center of the basin. Recharge on the north flank of the structure is believed by some to be likely, where the San Pedro formation crops out in the foothills (Geotechnical Consultants, Inc., 1972). The influence of faulting along the northern margin of the basin is undetermined, but may limit the potential for recharge from the adjacent uplands. Water

level records are known to exist for only one well in the northern portion of the Mound Basin (well 02N23W01P01S, total depth 300 feet). Water level records are only available for the mid-1970s, when recorded water levels were about 100 feet higher than in other wells from the central portion of the basin. Monitoring well 02N22W07M03S was constructed in 1995, located near the intersection of Highways 101 and 126, and screened from 210-270 feet below grade. Groundwater elevations in this well are similar to those recorded earlier in well 02N23W01P01S, and show very little seasonal or annual variability (Figures 4-1 and 4-2). Samples from the monitoring well show water quality to be consistently very poor, supporting the water level record as evidence of a perched groundwater system (of unknown extent) in this vicinity. Water levels in the aquifer units that may exist on the north flank of the Ventura syncline are not known to exist. Test holes drilled near the mouth of Lake Canyon (near Foothill Road and Victoria Ave) in the early 1970s apparently did not penetrate productive aquifer units and were not completed as production wells.

The eastern boundary of the Mound Basin sits adjacent the western Santa Paula basin. This boundary between sub-basins of the Ventura Central basin is generally defined by the concealed trace of the Country Club fault (Turner, 1975 and Geotechnical Consultants, Inc. 1972). The geology of the western Santa Paula basin is structurally complex, and faulting and folding in this vicinity may complicate groundwater flow within the regional groundwater flow system down the Santa Clara River valley. Groundwater elevations in the western Santa Paula basin generally range from 80 to 140 feet above sea level, and individual wells in this area exhibit somewhat muted water level variability, common to groundwater discharge areas of the other sub-basins of the valley. Groundwater elevations in three wells (02N22W09K05S, -09L03S and -09L04S) near Kimball Road in the eastern Mound Basin are similar to those recorded in the western Santa Paula basin, and are some 40 to 80 feet higher than other nearby wells (Figure 4-4). The high heads in these three deep wells may suggest some aquifer zones have a better connection to the Santa Paula basin. A fourth well located south of the Oak Ridge fault and in section 02N22W09 has a record of groundwater elevations in the 1970s approximately 20 to 30 feet higher than nearby wells. However, recorded groundwater elevations in shallower wells in the eastern Mound Basin are often 80 to more than 100 feet lower than those in western Santa Paula. This differential in head produces a large hydraulic gradient across the basin boundary, and likely results in groundwater flow from the Santa Paula to the Mound Basin. The magnitude of this flow, however, remains unquantified.

Along its southern margin, the Mound Basin sits adjacent to the Oxnard Forebay in the east and the Oxnard Plain to the west. A number of past researchers adopted the Montalvo anticline as the southern boundary of the Mound Basin, and this same feature has been mapped by others as the Montalvo fault or McGrath fault (Mann, 1959 and Geotechnical Consultants, Inc. 1972). More recently, others have refined the existence and location of the Oak Ridge fault about 4,000 feet to the north (Figure 2-2 geology section), and argue this is a more appropriate southern boundary for the Mound “structural” basin (Yerkes et al, 1987, Yeats et al, 1988). This more northern interpretation of the basin structural boundary leaves few production wells in the central portion of the Mound Basin. Historic water level records exist for a few wells located in the area north of the Oak Ridge fault, but the amount of water produced from these older wells is unknown. In the early

1980s municipal pumping in section 02N22W08 increased rapidly, reaching 3,000 acre-feet in 1984 and averaging slightly more than this amount annually through the end of 2010. Groundwater elevations around 40 feet above sea level were common in this area throughout the 1970s, but rare in years since (Figure 4-1). Regardless of this change in pumping in the area, a long-term profile of groundwater elevations from selected wells located near the axis of the basin shows a fairly consistent and gradual decline in heads from east to west [from the Kimball Road area to the coast near Ventura Harbor (Figures 4-5 and 4-6)]. Significant agricultural pumping also exists in the areas east and northeast of the harbor.

The annual water level responses for the wells located south of the Oak Ridge fault are similar, with the more eastern wells (up-gradient wells) having higher heads than the wells closer to the coast (Figures 4-7 and 4-8). Deeper wells throughout the basin tend to have lower groundwater elevations, but recorded water levels in most Mound Basin wells tend to converge during dry periods. In periods of drought, water elevations in many wells in the central portion of the basin fall below sea level. Contouring of water levels in the central portion of the basin is difficult given the poor distribution of wells and a common variability in water levels among nearby wells of up to 20 feet.

Comparison of water level records from the northern Forebay/Oxnard Plain and the area between the Montalvo Anticline and the Oak Ridge fault of Yerkes and Yeats appear to support the appropriateness of the more-northern boundary. Contouring of available groundwater elevations from wells south of the Oak Ridge fault generally show a relationship with those from adjacent areas to the south, namely, the former “Zone C” area north of the Santa Clara River and the northern Oxnard Plain in areas south of the Santa Clara River (Figures 4-7 and 4-8; Appendix B). Wells located north of the Montalvo anticline and closest to the Forebay (e.g., well 02N22W16K01S) predictably exhibit the greatest annual variability, but the range of recorded water levels is less than that in wells in the main recharge areas of the Forebay. Groundwater flow to the Mound basin from the Forebay and northern Oxnard Plain has been noted in older reports, but also noted was reduced opportunity for recharge north across the Montalvo anticline during times of depressed groundwater elevations on the Oxnard Plain (GTC, 1972; Fugro, 1996). United Water’s contouring of water levels north of the Montalvo anticline support these prior findings, showing good agreement with water levels in the northern Forebay and Oxnard Plain in the spring of some recent wet years (e.g., 2001, 2005). Contouring also suggests that during drier periods the southern strip of the Mound basin (located south of the Oak Ridge fault and north of the Montalvo anticline) exhibits heads that are commonly 5 to 15 feet lower than those to the south, with the head differential between the basins increasing towards the coast.

The contouring of past water level conditions is complicated at times by sparse data. Increased collection of water level records is recommended in this greater area in order to better define groundwater gradients between these adjacent basins. The recent installation of monitoring wells north of the Santa Clara River near the northwestern margin of the Forebay should be helpful in better defining the flow of groundwater from the Oxnard Forebay to areas north of the Montalvo anticline. However, relatively few wells exist along the southeastern portion of the Mound basin, an

area of sparse well records and known structural complexity. In recent times no active production wells have been located within a mile of the coast, so in 1995 United Water and the City of Ventura jointly funded the installation of three monitoring wells at Marina Park near the north side of Ventura Harbor to assess groundwater conditions near the ocean. Artesian conditions are common in the shallowest of these wells, screened 170 to 240 feet below the land surface. Heads 20 feet above the land surface are commonly recorded, suggesting recharge from the Ventura foothills to the north. In fall 2004 water levels in most wells in the western Mound Basin were below sea level, but heads in this well remained high. No active wells in the area are screened in this shallow aquifer zone. A deeper well at Marina Park (screened 480-660' deep) commonly displays weak artesian conditions, and recorded heads six feet below sea level in 2004. The deepest well at this site rarely has artesian flow, but often has groundwater elevations above sea level. In the agricultural area east of Ventura Harbor, production wells record water levels below sea level in dry periods (Figure s 4-9 and 4-10). Heads of 25 feet below sea level were recorded here in 1991, and 14 feet below sea level in 2004.

As discussed in this chapter and the hydrostratigraphy chapter (Section 3), the Mound Basin is structurally complex. The current distribution of wells and water level records within and surrounding the basin allows an imperfect understanding of groundwater source and movement in some locations. Available information indicates the Mound Basin receives groundwater recharge from both the Santa Paula basin to the east and the Oxnard Forebay/ Oxnard Plain to the south. Overall, water levels in many wells respond in similar fashion to wet and dry periods. Gradients within the basin remain fairly flat most of the time. Water levels tend to vary among nearby wells, with deeper wells often having lower groundwater elevations. Groundwater production is concentrated in several areas with the basin, creating the potential for pumping interference in some water level measurements. In some production wells, the large distance to water may lead to occasional errors in water level measurement.

5 GROUNDWATER EXTRACTION

Much of the Mound groundwater basin lies within the boundaries of the City of Ventura. The Downtown, Midtown and West Side areas of the City fall within the boundaries of Casitas Water District, and water supplied to these areas source from Lake Casitas and various City wells located near the community of Casitas Springs. Areas south and east of Midtown Ventura fall within the boundary of United Water Conservation District. The City chose to concentrate Mound Basin pumping in the area near the Ventura County Government Center. Deep municipal wells were constructed here in 1975, 1994 and 2000, and since 1982 the great majority of municipal pumping in this central portion of the basin has been from the City's wells. The City also operates high-capacity production wells near the San Buenaventura Golf Course on the Oxnard Plain, and pumps water north to businesses and residents located in the Mound Basin. Other areas in the eastern portion of the City receive water from a production well in the Santa Paula basin.

Historically, agricultural pumping has been the majority water user in the Mound Basin, and agricultural pumping totaled nearly 70 percent of reported pumping in calendar year 2010. Agricultural pumping is concentrated in three main areas of the basin: farmland near Olivas Park Drive in the south, the agricultural areas east of Ventura Harbor, and the so-called Serra area extending southeast from the southern terminus of Kimball Avenue (Figure 5-1). A fourth agricultural area, located north of Hwy 126 and west of Kimball Avenue, is served by water imported from the Santa Paula basin. These areas of agricultural land use have not been incorporated by the City and are not served by the City's potable water system.

The distribution of historic pumping between agricultural and municipal uses in the Mound Basin is displayed in Figure 5-2. The city's pumping generally increased through the 1980s, and was variable in the 1990s. Municipal pumping peaked in 2003 at over 5,500 acre-feet, and has declined fairly steadily in recent years. Since the mid-1980s agricultural pumping has averaged nearly 4,200 acre-feet per year, with peak annual production of 5,850 AF recorded in 1990. The above pumping totals are for the Mound Basin defined as the area north of the Montalvo anticline. If the Mound Basin were defined as the area north of the Oak Ridge fault, pumping along Olivas Park Drive would be included with Oxnard Plain pumping totals. In this case, 2010 pumping would total 4,630 AF, with agricultural usage totaling 64 percent of the reported pumping.

6 WATER QUALITY

While the quality of the groundwater produced by most wells within the Mound Basin is suitable for municipal and agricultural uses, the basin is not known for the high quality of its groundwater. The Geotechnical Consultants, Inc. (1972) investigation of the Mound Basin noted structural complexity and the lenticular nature of many San Pedro Formation sediments within the basin, and suggested connate waters continue to impair water quality in many zones. Structural deformation and the less-continuous nature of highly permeable deposits within the basin (compared to nearby basins) have likely inhibited the flushing of poor-quality waters from the basin. Water quality is variable between wells, and many records indicate somewhat elevated concentrations of TDS, sulfate, hardness and other analytes. Water quality appears to be relatively stable among many of the Mound basin wells having long-term water quality records. Available records from wells near the coast do not show evidence of saline intrusion.

Relatively few dedicated monitoring wells exist in the Mound Basin. Six monitoring wells, jointly funded by United Water and the City of Ventura, were installed in 1995. One nest of wells exists at Marina Park, at the north side of the Ventura Harbor. Water quality in these three wells has been fairly stable since the wells were installed. The deepest well, screened 970 to 1070 feet bgs, routinely records TDS concentrations near 1,300 mg/l and sulfate concentrations of approximately 500 mg/l. A shallower well, screened between 480 and 660 feet below the surface, records slightly better water quality, with TDS around 900 mg/l and sulfate around 400 mg/l. The shallowest well at this location, well 02N23W15J03S, is screened from 170 to 240 feet bgs has the poorest water quality. In this shallow well TDS concentrations are above 3,000 mg/l and chloride values average

nearly 100 mg/l. As noted in the previous section on water levels, strong artesian heads are consistently recorded in this well. The high heads in this well suggest offshore groundwater gradients in this vicinity. Near-shore submarine canyons, such as those that exist near Port Hueneme and Point Mugu, do not incise the offshore portion of the Mound groundwater basin. The absence of near-shore canyons, high heads in coastal wells and the lack of active production wells near the coast results in a minimal threat of saline intrusion under current basin conditions.

A second cluster of three monitoring wells was installed at Camino Real Park in the central portion of the basin. Sampling of these wells has resulting in the only water quality records known to exist for wells located north of Highway 126. As with the Marina Park wells, mineral content is slightly higher in the deeper San Pedro unit (screened 1,200 to 1,280 feet bgs) than in a shallower zone (screened 710 to 780 feet bgs). In the deeper screened interval TDS concentrations of 1,100 mg/l are commonly recorded. TDS is generally less than 1,000 mg/l in the shallower screened well CP-780 (Figure 6-1). Sulfate anions account for about half of the total mineral content of the water as is typical for other wells in the basin.

The shallowest of the three wells at the Camino Real Park site (screened 210 to 280 feet bgs) records some of the worst groundwater quality in the basin. TDS in this well sometimes exceeds 5,000 mg/l. Chloride and nitrate are also found at high concentrations in this well. These analytes are rarely elevated in other Mound Basin wells. Groundwater elevations are very stable in this well and are also much shallower than in other nearby wells. The anomalous groundwater elevations and water quality from this well suggest perched groundwater conditions, or an aquifer zone otherwise isolated from aquifer units utilized for groundwater production elsewhere in the basin.

The two newest monitoring wells in the Mound Basin were installed near Kimball and Telegraph Roads in 2008 as part of a siting study for a potential new production well for the City of Ventura (Hopkins Groundwater Consultants, Inc., 2008). Limited samples exist for these wells to date. The shallower well (screened 480 to 510 feet bgs) records very poor water quality. A recent sample recorded TDS of 6,300 mg/l, sulfate of 3,700 mg/l and hardness of 2,650 mg/l. Nitrate and chloride concentrations were also high. The deeper well (screened 890 to 950 feet bgs) records water quality more typical of wells within the basin. Both of these wells have groundwater levels higher than some other surrounding wells. It is unclear at this time whether the higher heads are related to groundwater recharge from the nearby Santa Paula basin, or associated with aquifer zones that are poorly connected with other permeable zones within the stratigraphic section that are currently utilized for groundwater production.

Municipal pumping in the Mound basin is concentrated in section 02N22W08 with production wells located around the perimeter of the Ventura County Government Center. The City's Victoria 1 well was constructed in 1975 with five screened intervals within the depth range of 460 to 1,405 feet below ground surface. Water quality was very consistent in this well from the early 1980s through the 1990s, with TDS commonly measured near 1,500 mg/l. In the late 1990s production shifted to the new Victoria 2 well and sampling of Victoria 1 became infrequent as the well was maintained in standby status. A few samples in 2001 and 2002 did however show a distinct increase in dissolved

mineral content, with TDS peaking above 2,000 mg/l and sulfate approaching 1,200 mg/l. The nearby Victoria 2 well (02N22W08F01S) has two screened intervals (580-640 and 900-940 feet bgs). Water quality records from this well show a steady long-term decline. Early TDS concentrations of less than 1,000 mg/l slowly increased to values of 1,400 to 1,800 mg/l common to recent samples (Figure 6-2). A third well, Mound 1, was constructed in 2000 (screened 580 to 650 feet bgs) and began reporting production in 2003. Water quality records from 2006 to 2011 show fairly consistent TDS concentrations of around 1,800 mg/l, with some samples exceeding 2,000 mg/l. The cause of the water quality changes in this vicinity is not readily apparent. The multiple screened intervals in the Victoria 1 well do however provide an opportunity for depth-dependent water quality sampling. Sampling devices are now available to measure both water quality and groundwater production from various depths within an active production well. This type of information might assist the designers of future wells in this area in avoiding aquifer zones of poor water quality.

Water quality samples from wells in an area of former municipal pumping, the Montalvo area in the southern portions of Section 02N22W17, record a period of significant deterioration in water quality. Quality problems began in the early 1970s and continued through the 1980s. Pumping records are not available prior to 1980, so it is unclear if water quality changes in this vicinity were related to an increase in groundwater pumping in the 1970s. A peculiarity of these records is that chloride concentrations rose along with TDS and sulfate.

A map showing recorded TDS concentrations in Mound basin wells from 2011 is shown as Figure 6-3. The map plots TDS (by summation) from production well samples collected by the Groundwater Section of the Ventura County Watershed Protection District, as well as TDS (by residue) as sampled by United Water and the City of Ventura. It is easily seen that without the sampling by the County's Groundwater Section, coverage in the basin would be very poor. The distribution of sampled wells within the basin for 2011 is better than in most prior years. TDS in the production wells ranged from 1150 to over 2,200 mg/l. Also shown is sulfate sample results from 2011 (Figure 6-4). These two maps show that sulfate commonly contributes roughly half the TDS in these samples, and water quality results are often variable among nearby wells.

Mapping the maximum values of all available water quality samples for Mound basin wells reveals that many of the highest chloride concentrations are recorded in wells located near mapped faults in the southern portion of the basin (Figure 6-5). Many of these high values are likely associated with times of drought, but some may be outlier records from individual wells. The maximum-recorded chloride concentrations from the 2011 calendar year are shown in Figure 6-6. One production well located near the intersection of highways 101 and 126 recorded chlorides above 100 mg/l, a target water quality threshold for many agricultural operations.

Many of the active wells in the basin are operated for agricultural water supply and sampling of these wells tends to be less consistent than in the public supply wells. If samples are collected, the results often are not shared with regulators or water management agencies. A good water quality record does exist for well 02N22W16K01S. This well is located east of Harmon Barranca and just

north of the mapped location of the Montalvo anticline axis. Water quality records for this well exist for the years 1953 through 1997. The water quality record shows some variability (upward deflections) but no clear trending over the period of record. This well is screened from approximately 290 to 350 feet bgs. Water quality in this well is relatively good, with most recorded TDS concentrations less than 1,200 mg/l. In the western basin near Ventura Harbor, well 02N23W14K01S provides another example of a well with good water quality for the period of record from 1933 to 1981. Concentrations for most analytes are fairly stable, with TDS concentrations averaging less than 1,200 mg/l (Figure 6-7). This agricultural well is screened from 475 to 915 feet bgs. One outlier record of elevated chloride exists from 1962. This outlier of 376 mg/l is shown just inland of Ventura Harbor in Figure 6-5. Otherwise the records from this coastal production well show no evidence of saline intrusion.

7 DISCUSSION

There are a limited number of wells within the Mound Basin. Wells are absent along the northern portions of the basin, and the western extent of the basin also lacks wells as this area is supplied by surface water and groundwater from Ventura River valley. Some public supply wells exist in the central portion of the Mound basin but significant quantities of groundwater are imported from Oxnard Plain to the south, in part due to the better water quality associated with those wells. The amount of data available for characterization of basin conditions is somewhat limited. The water supply scenario for the Mound Basin is atypical for the region, with groundwater imports from three adjacent basins. The other basins managed by United Water are dominated by agricultural land use with some urban environment. The Mound Basin is dominated by the urban environment of the City of San Buenaventura and surrounded by some agricultural lands. Pumping records indicate that agricultural pumping often exceeds municipal pumping in the Mound basin.

The Mound basin is a complex basin due to its physical and geologic setting. Characteristics of the Mound Basin are different than most of the other basins that are managed by United Water. Despite its unique characteristics the Mound Basin shares similar hydrogeologic dynamics and processes with the other basins in the Santa Clara River Valley and Oxnard Plain.

The present day boundaries of the Mound Basin consist of: the Ventura foothills/Ventura fault to the north, the Country Club fault to the east, the Pacific Ocean to the west, and the Montalvo anticline to the south. The Oak Ridge fault runs sub-parallel to the Montalvo anticline approximately one half to one mile north of the anticline. Although the Montalvo anticline is presently used for the southern boundary it has been suggested that perhaps the Oak Ridge fault should be used for the southern basin boundary. Yerkes et al (1987) state that the Oak Ridge is a zone of faulting that forms the southern boundary of the Ventura synclinal trough in the western Ventura Basin (Mound groundwater basin) rather than the Montalvo anticline. Since the basin is characterized by faults along the northern and eastern boundaries it is arguable that the southern boundary should be defined by a fault, forming a consistent structural architecture to the basin rather than a geographical basin for groundwater management. Groundwater elevations in the zone between the

Oak Ridge fault and the Montalvo anticline are responsive to water levels in the Oxnard Forebay, especially during periods of above-average recharge in the Forebay.

There are some appreciable offsets of geologic formations across the faults bounding the Mound Basin. Several previous studies by others and recently reviewed borehole geophysical data suggest that the low-permeability Santa Barbara formation does not extend to sufficiently shallow depths to impede groundwater flow across the faults or above the faults. In most cases the faults do not extend close enough to the surface to disturb San Pedro or alluvial sediments. In those cases, there is a significant thickness of the San Pedro formation (aquifer materials) existing on both sides of the faults. The degree of aquifer offset is site-specific along the trace of the faults, however, there are significant data to suggest that the UAS and to a somewhat lesser degree the LAS, are continuous across most of the basin-bounding faults. This implies that the hydrogeological boundaries of the basin are not necessarily coincident with its' structural boundaries and that there is hydrologic connection between the Mound basin and the adjoining groundwater basins.

The nature of the faults themselves as an impedance to groundwater flow is not known. However, groundwater flow and basin recharge across these zones is most probable. Recharge from the Oxnard Plain basin, Forebay basin, and Santa Paula basin into the Mound Basin is likely occurring across the geologic features that currently delineate the Mound basin. Groundwater flow within the basin is generally east-to-west, and groundwater flows from recharge areas to surrounding down-gradient areas. These recharge and flow dynamics are consistent with the accepted and well-documented groundwater flow systems in the Oxnard Forebay/Oxnard Plain and other coastal California basins.

In the Mound Basin water levels in many wells respond in similar fashion to wet and dry periods. Gradients within the basin remain fairly flat most of the time and water levels tend to vary somewhat among nearby wells. Deeper wells often have lower groundwater elevations. Records of groundwater samples from Mound basin wells reveal that salt concentrations are somewhat elevated compared to adjacent basins, but the water is generally suitable for municipal and agricultural uses. Although groundwater flow may occur through areas where interconnected or continuous aquifer materials exist, the less-continuous lens-like nature of some highly-permeable deposits within the basin (compared to nearby basins) have likely inhibited the flushing of poor-quality waters from the basin (possible connate waters). Active production wells are not currently located near the coast, and available records from coastal wells do not show evidence of saline intrusion.

Since there is somewhat limited data for characterization of the Mound basin, it is recommended that some additional studies be performed to better define basin conditions. One study would be to assess and better characterize the Country Club fault. Geophysical surveys (TDEM) can be utilized across the assumed location of the Country Club fault. Since the Santa Barbara formation is easily recognizable in electric logs (very low resistivity), its depth along a profile or profiles extending from the Santa Paula Basin into the Mound Basin may be defined using this technique. From that data

the actual location of the Country Club fault and the throw on the fault might be resolved. This would provide information regarding the thickness of the San Pedro formation above the up-thrown Santa Barbara formation. Once those data are resolved a pump test could be conducted with a pumping well on one side of the fault and observation wells on both sides of the fault. This type of study can furnish information on flow dynamics on both sides of the fault and across and/or over the fault. A similar study could also be conducted in the vicinity of the Oak Ridge fault.

Additional study is also warranted in the southern portion of the basin, in the greater area surrounding the Montalvo anticline and the Oak Ridge fault. This area of geologic complexity likely provides significant recharge to the Mound basin. The complexity of the zone appears to influence water quality as well, with some of the basin's highest historical chloride concentrations located in this area. A number of active wells currently exist in this area, but data collection from these wells has been poor or inconsistent to date.

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9 APPENDIX A – GENERAL FIGURES

Figure 1-1: Map of Basins Managed by United Water Conservation District.

Figure 1-2: Map Showing Boundaries of the Mound Basin.

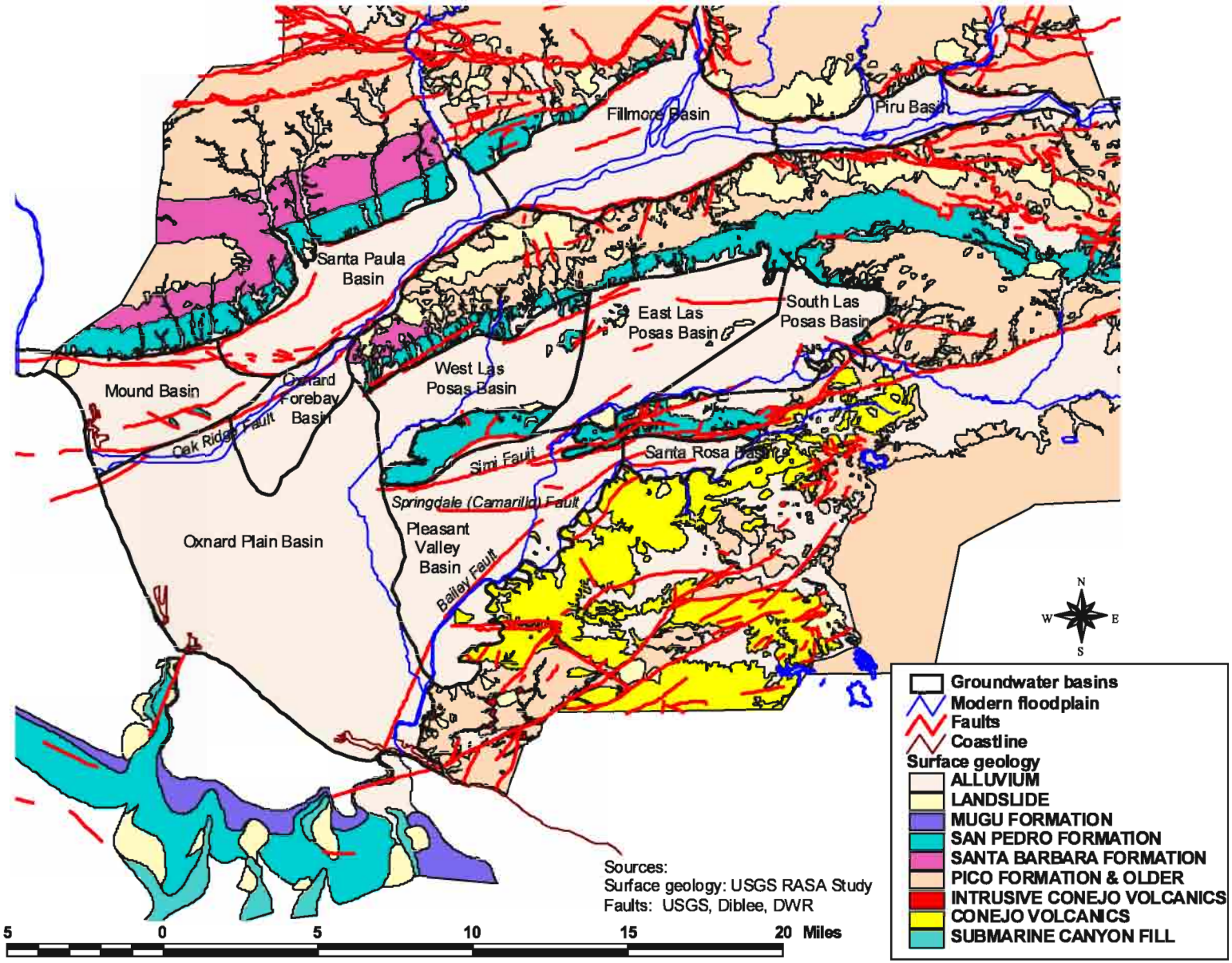


Figure 2-1: Overall geologic map showing groundwater basins including the Mound Basin.

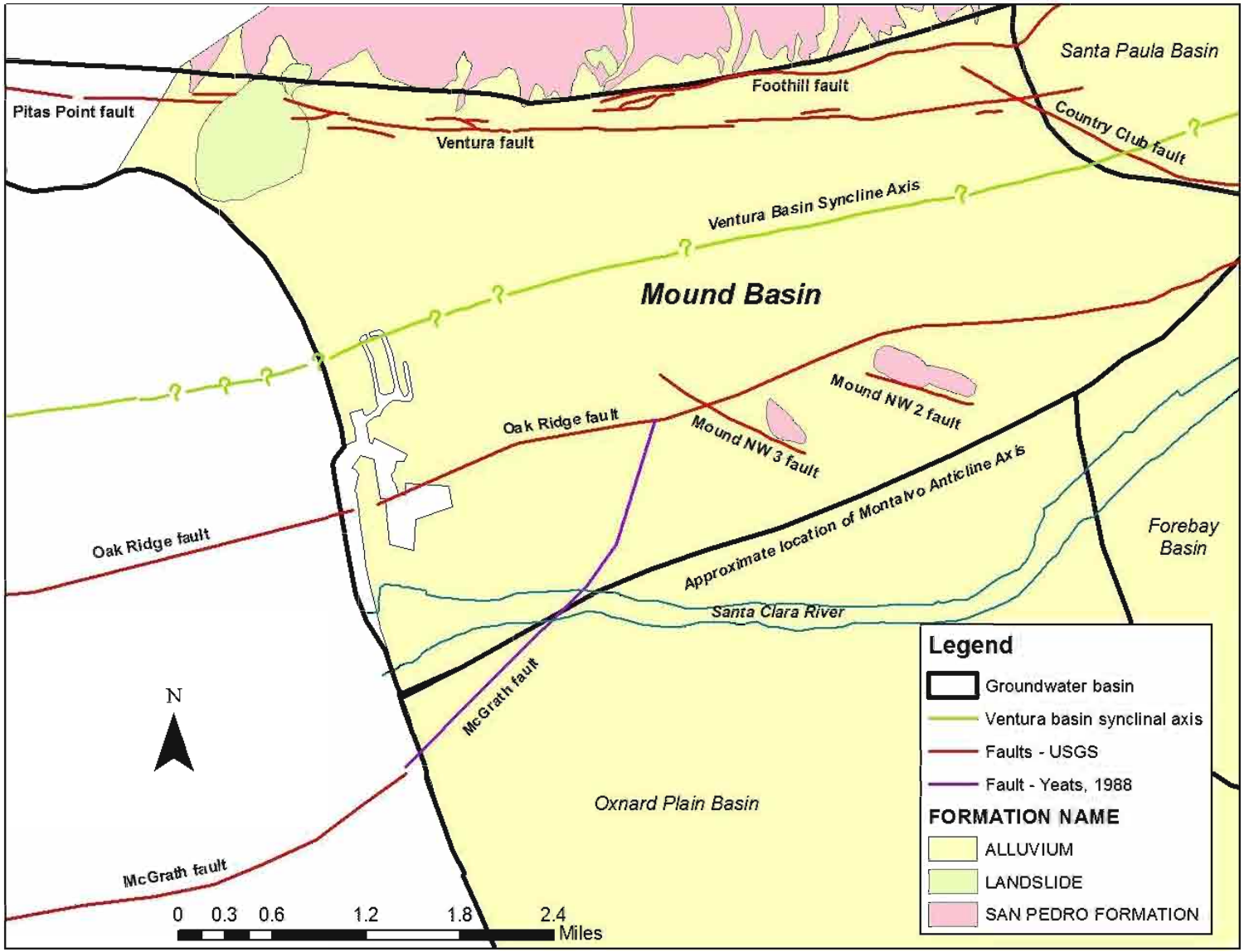


Figure 2-2: Generalized geologic map of the Mound Basin.

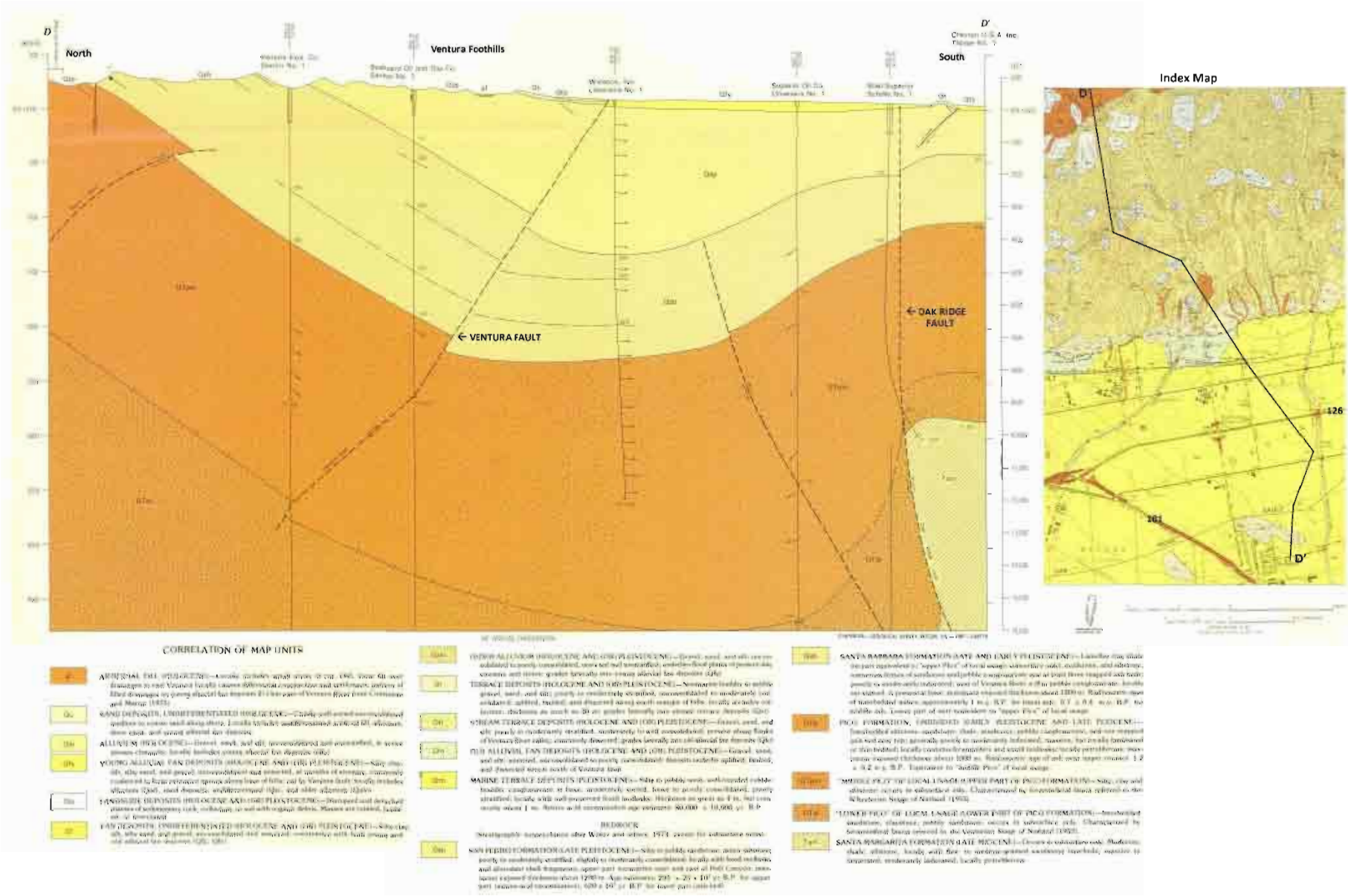


Figure 2-3: Cross-section of the Mound Basin showing the Ventura fault and Oak ridge fault interpretations (Yerkes et al, 1987).

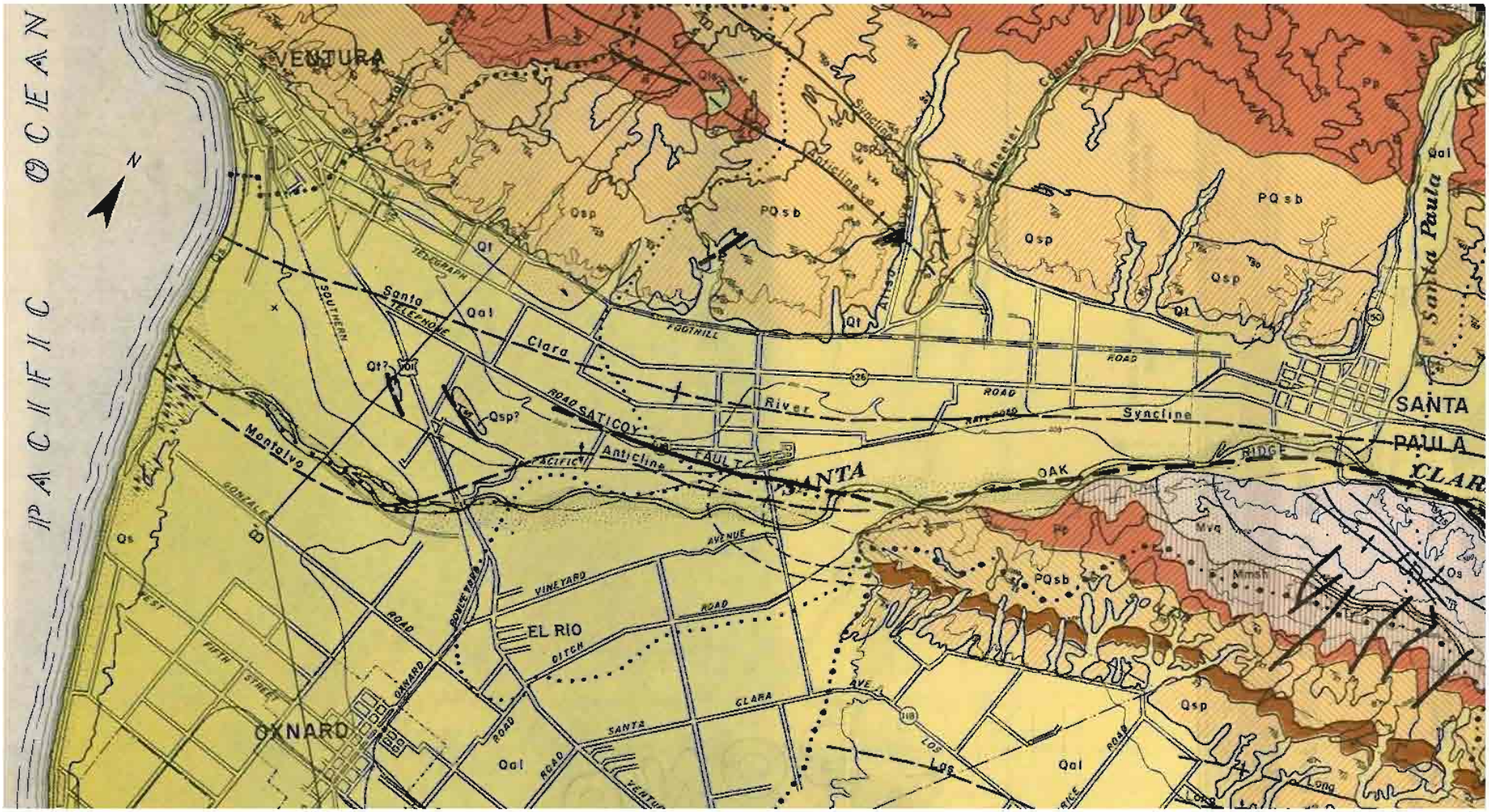
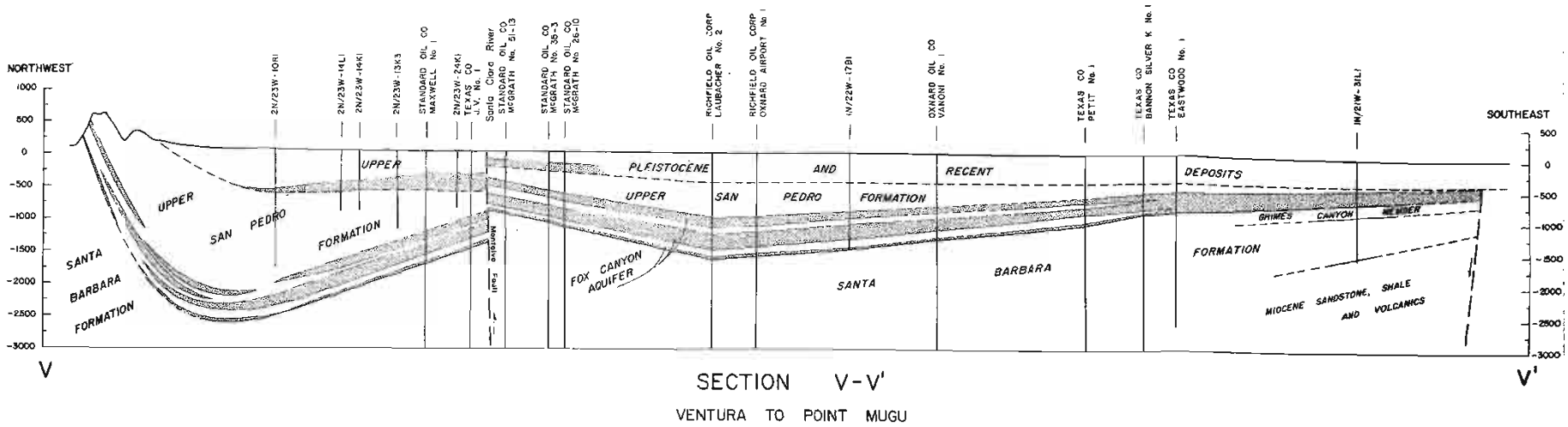


Figure 2-4: Map showing Oak Ridge fault near Santa Paula leading to the "Saticoy Fault" on the eastern side of the Mound Basin (California State Water Resources Board, 1953).



SECTION V-V'

VENTURA TO POINT MUGU

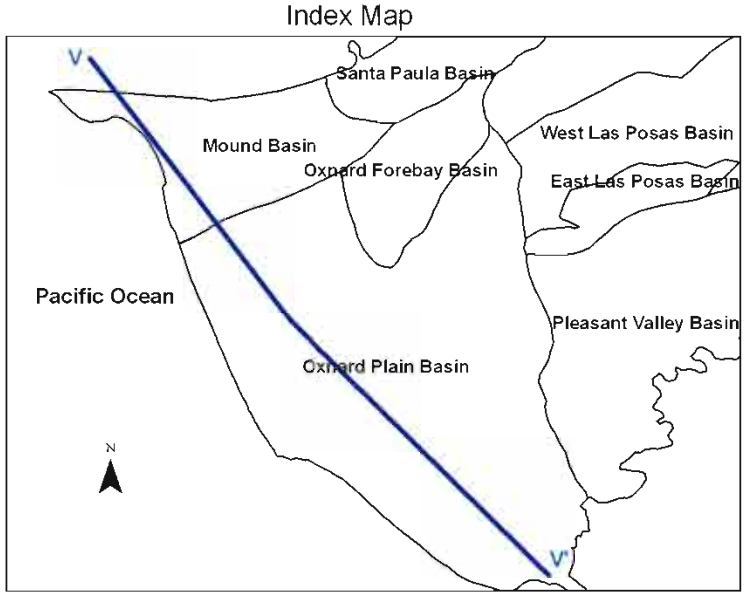


Figure 2-5: Cross-section taken from Mann (1959). The Montalvo fault is shown to form the southern boundary of the Mound Basin. Note that the Ventura fault is not shown.

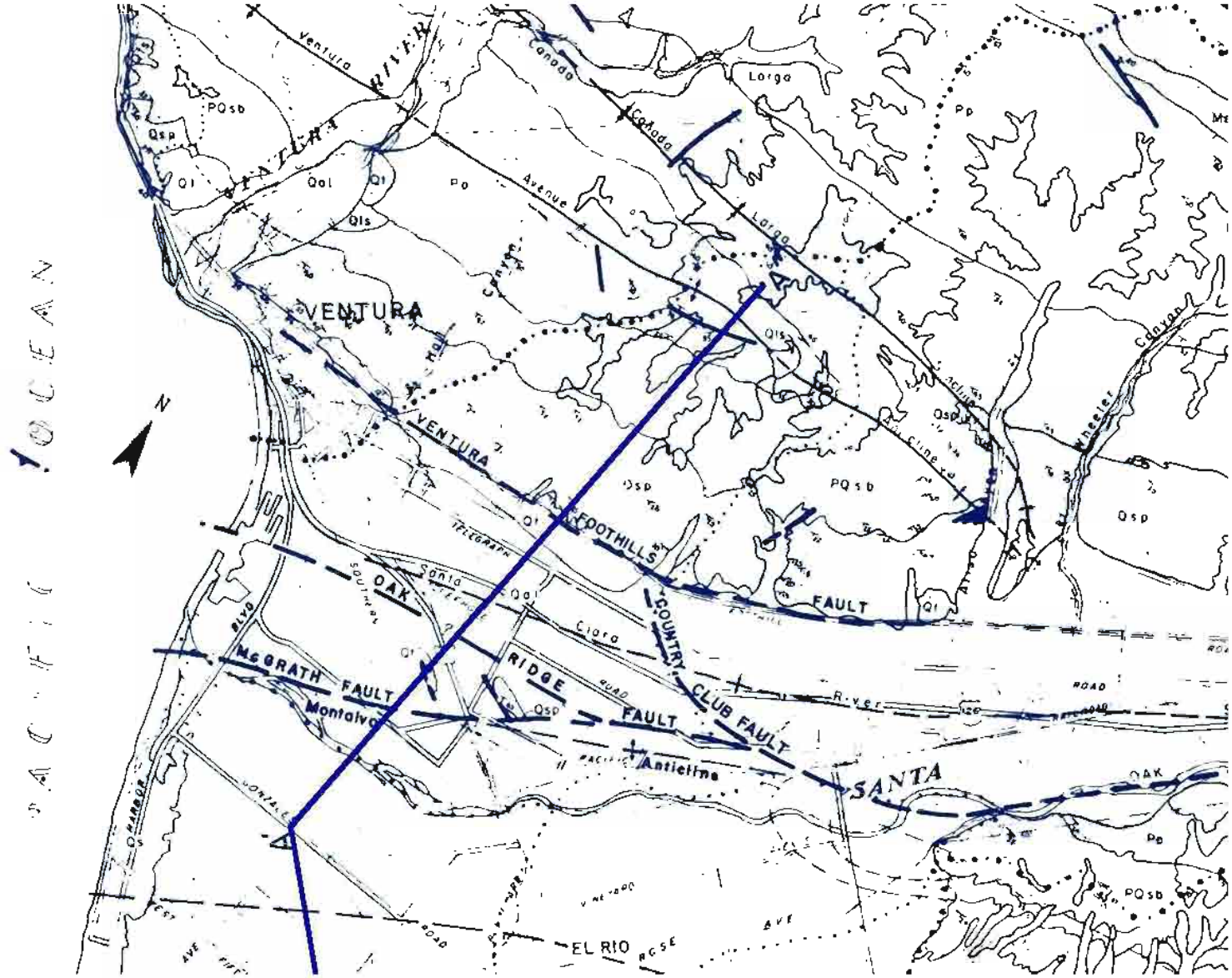


Figure 2-6: Turner and Mukae (1975) map showing Oak Ridge fault and McGrath fault. The Montalvo anticline is shown which forms the southern boundary of the Mound Basin. The location of cross-section A-A' is also shown.

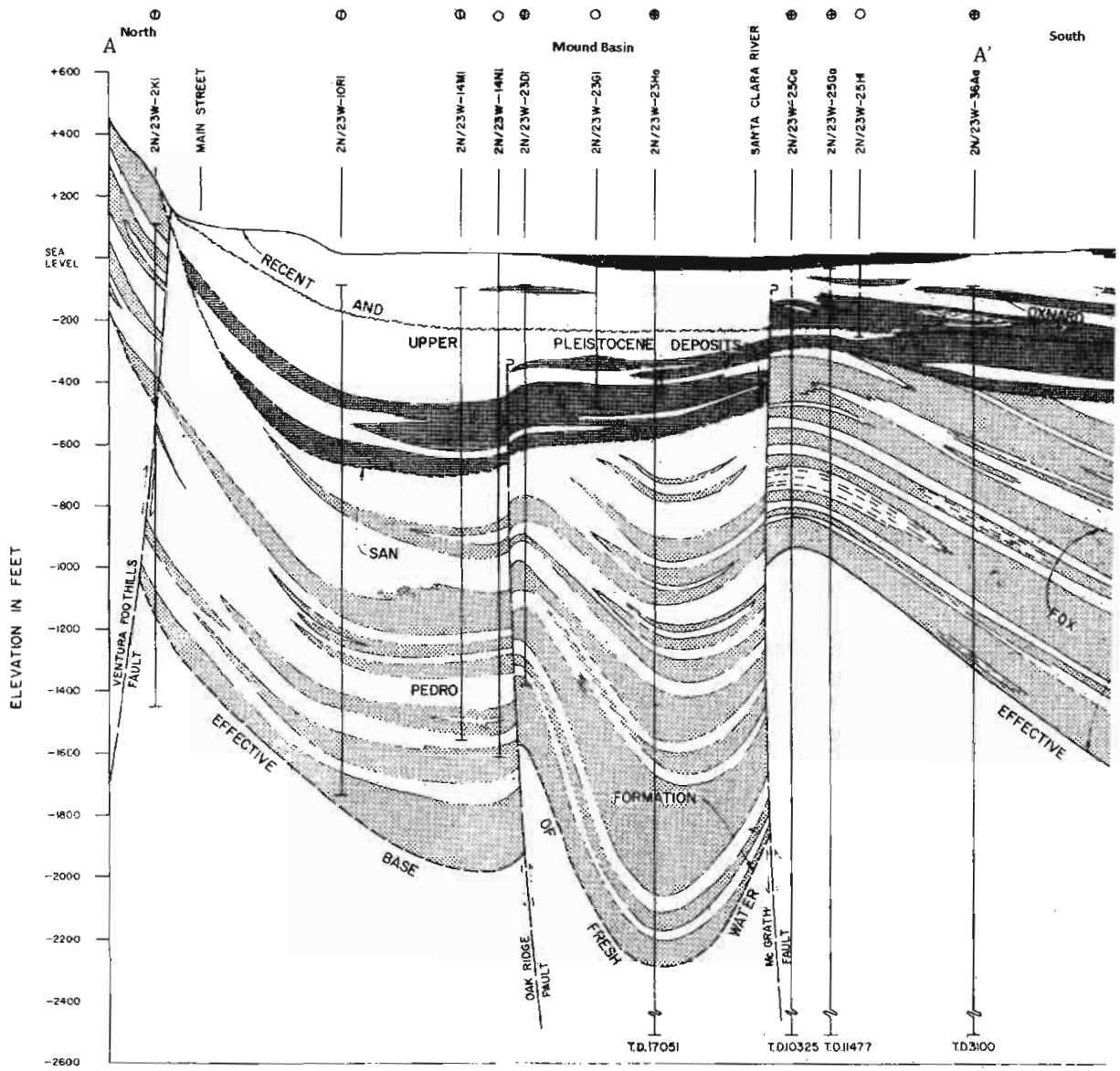


Figure 2-7: Turner and Mukae (1975) cross-section A-A' of Mound Basin near the coast showing the Oak Ridge fault and McGrath fault.

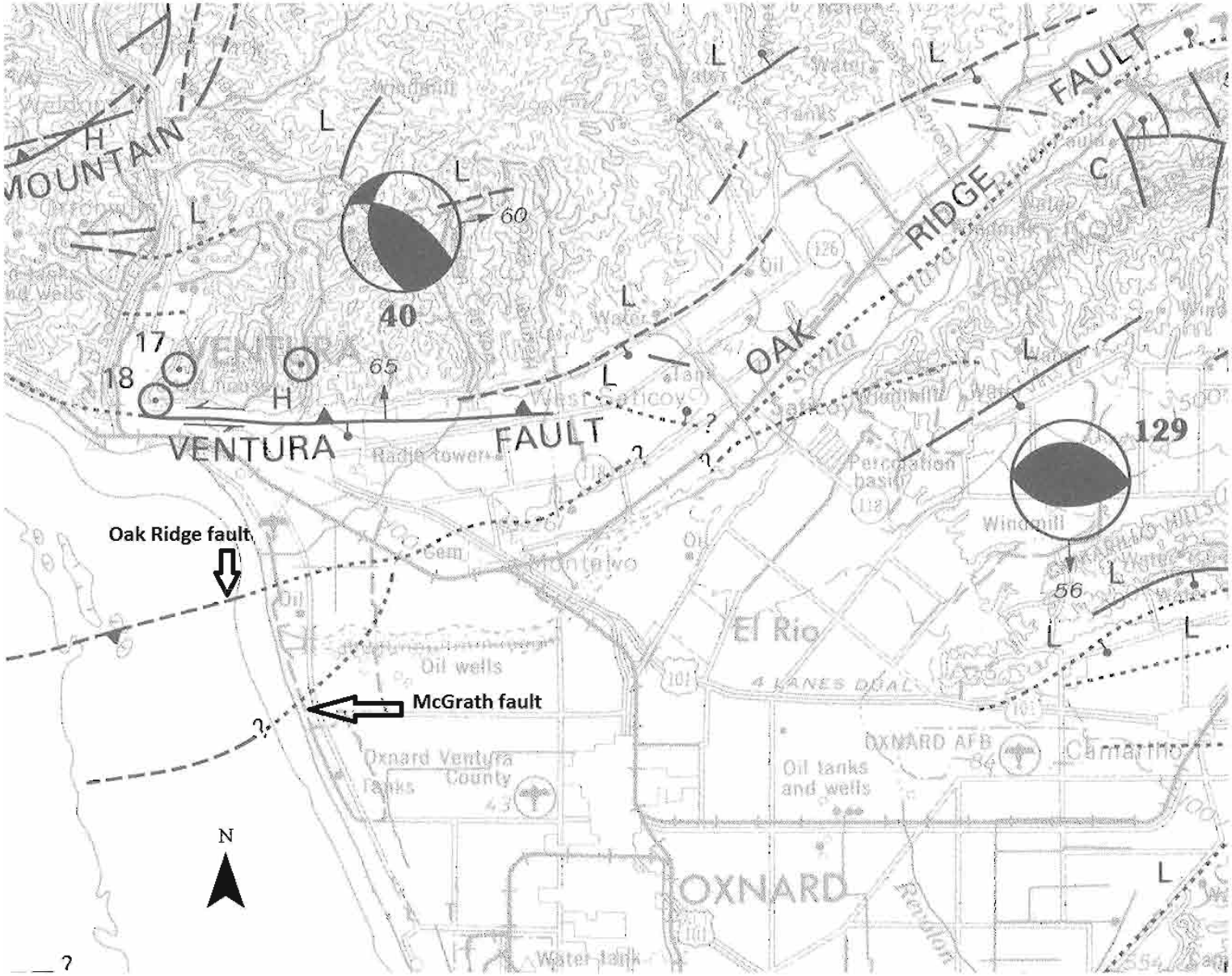


Figure 2-8: Yerkes et al (1987) map showing the Oak Ridge fault and McGrath fault.

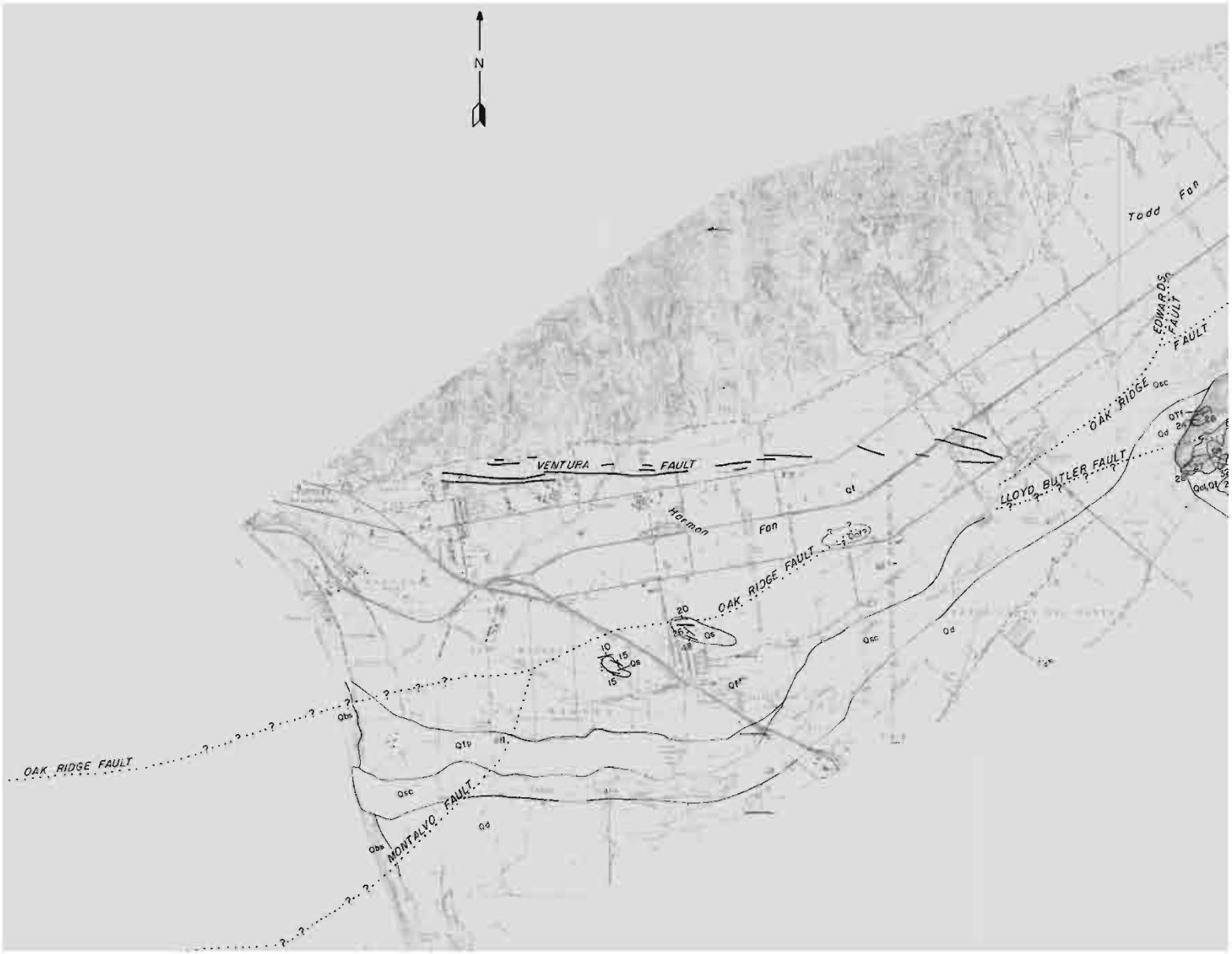


Figure 2-9: Yeats et al (1988) map showing the Oak Ridge fault and McGrath fault. Yeats refers to the McGrath fault as the "Montalvo" fault.

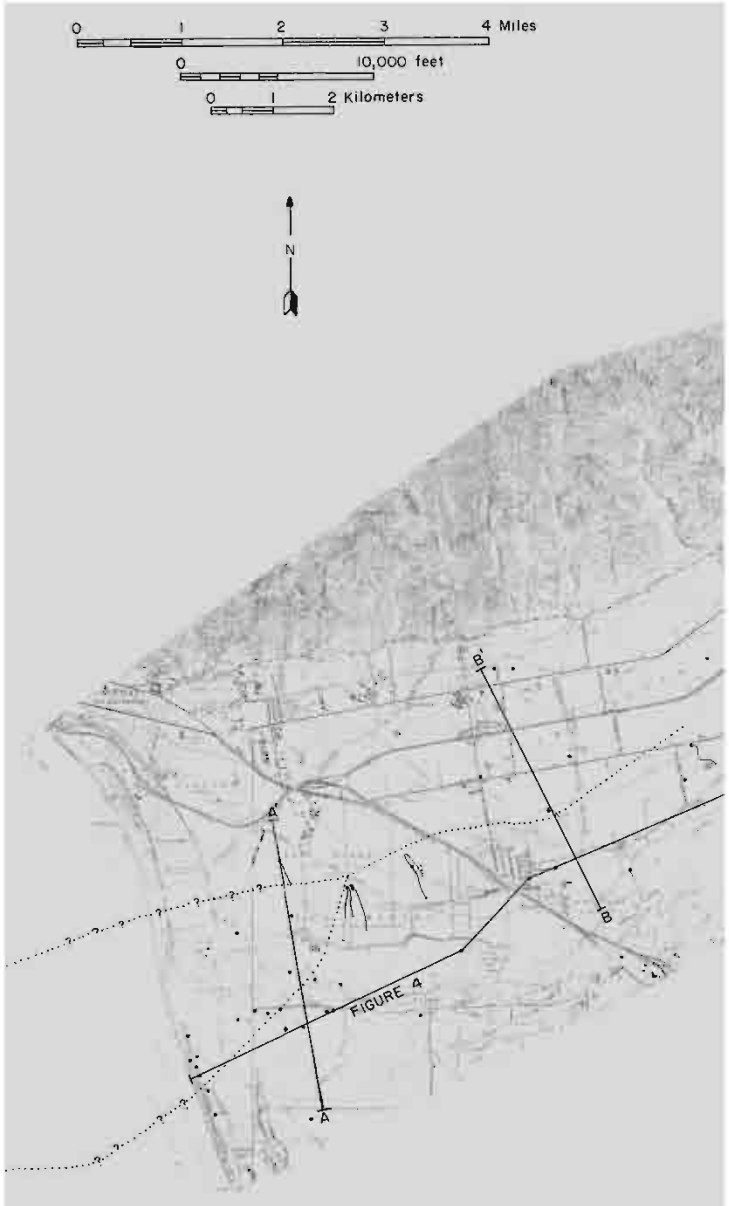


Figure 2-10: Yeats et al (1988) map showing Cross-sections A-A' and B-B' locations over the Oak Ridge fault and McGrath fault ("Montalvo" fault).

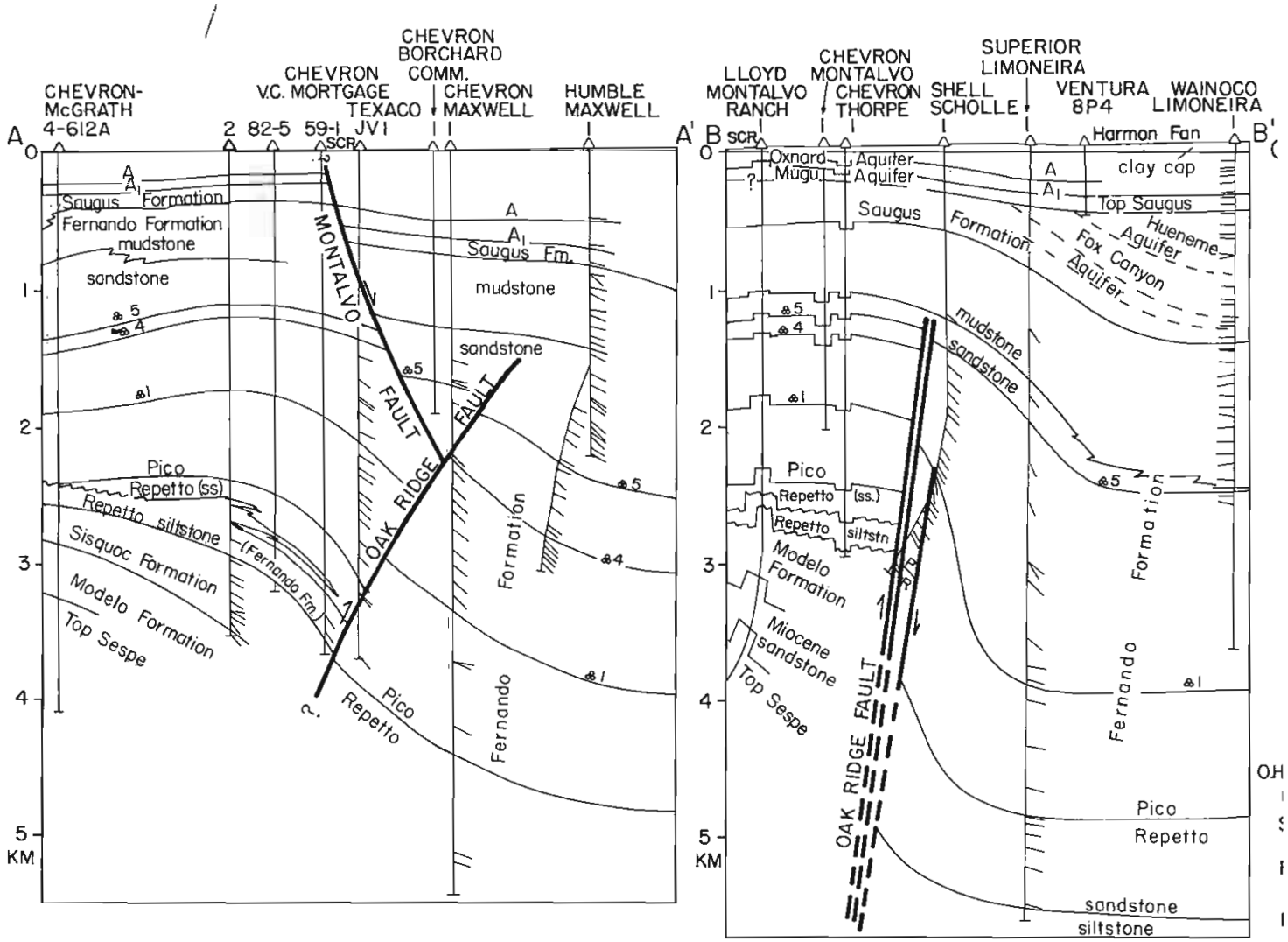
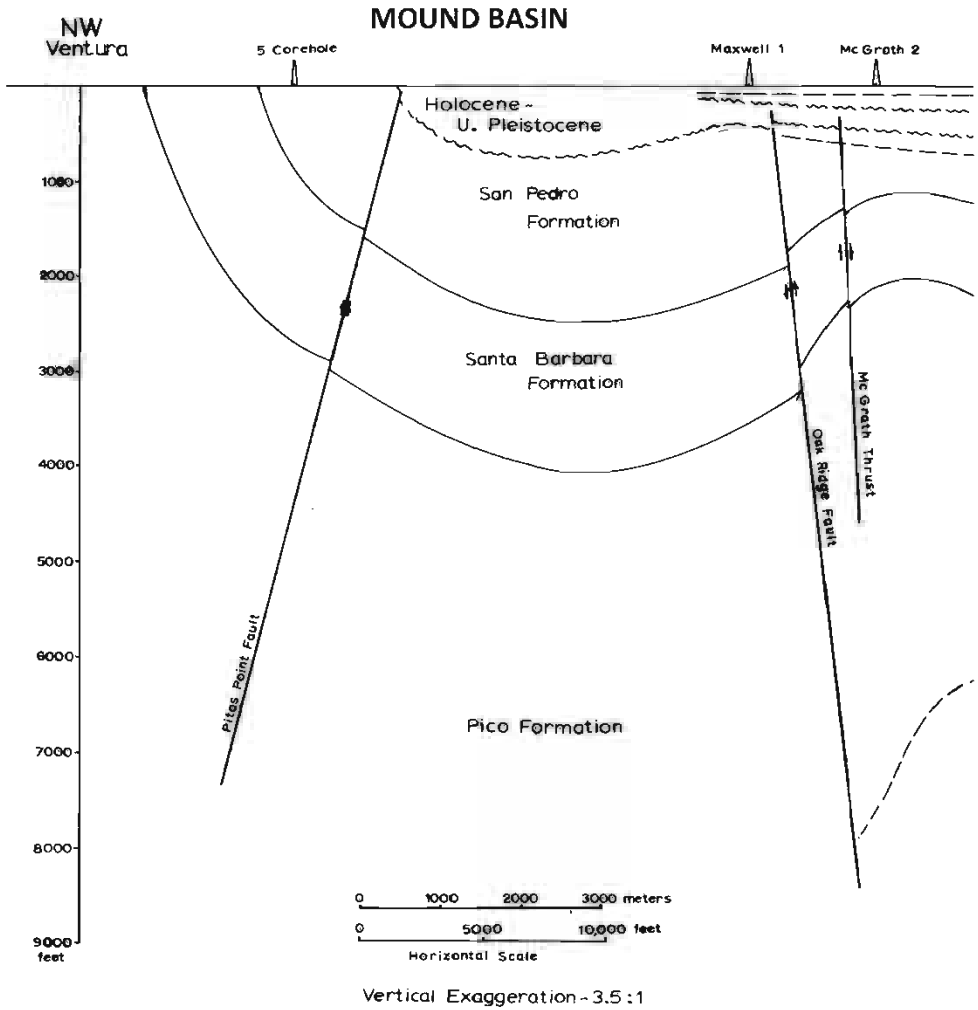
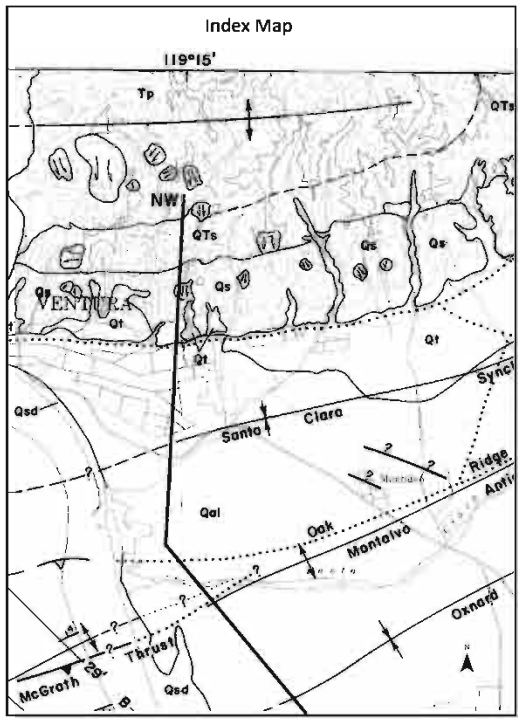


Figure 2-11: Yeats et al (1988) Cross-sections A-A' and B-B' over the Oak Ridge fault and McGrath fault ("Montalvo" fault).





Generalized onshore stratigraphic cross-section across the coastal portion of Oxnard Plain. See Plate 2 for areal extent and orientation of cross-section. (Modified after Paschall and others, 1956; State of California, 1965; Ogle, 1969; Turner, 1971, oral commun.)

Figure 3-1: Schematic Cross-Section of the Mound Basin taken from Greene et al (1978).

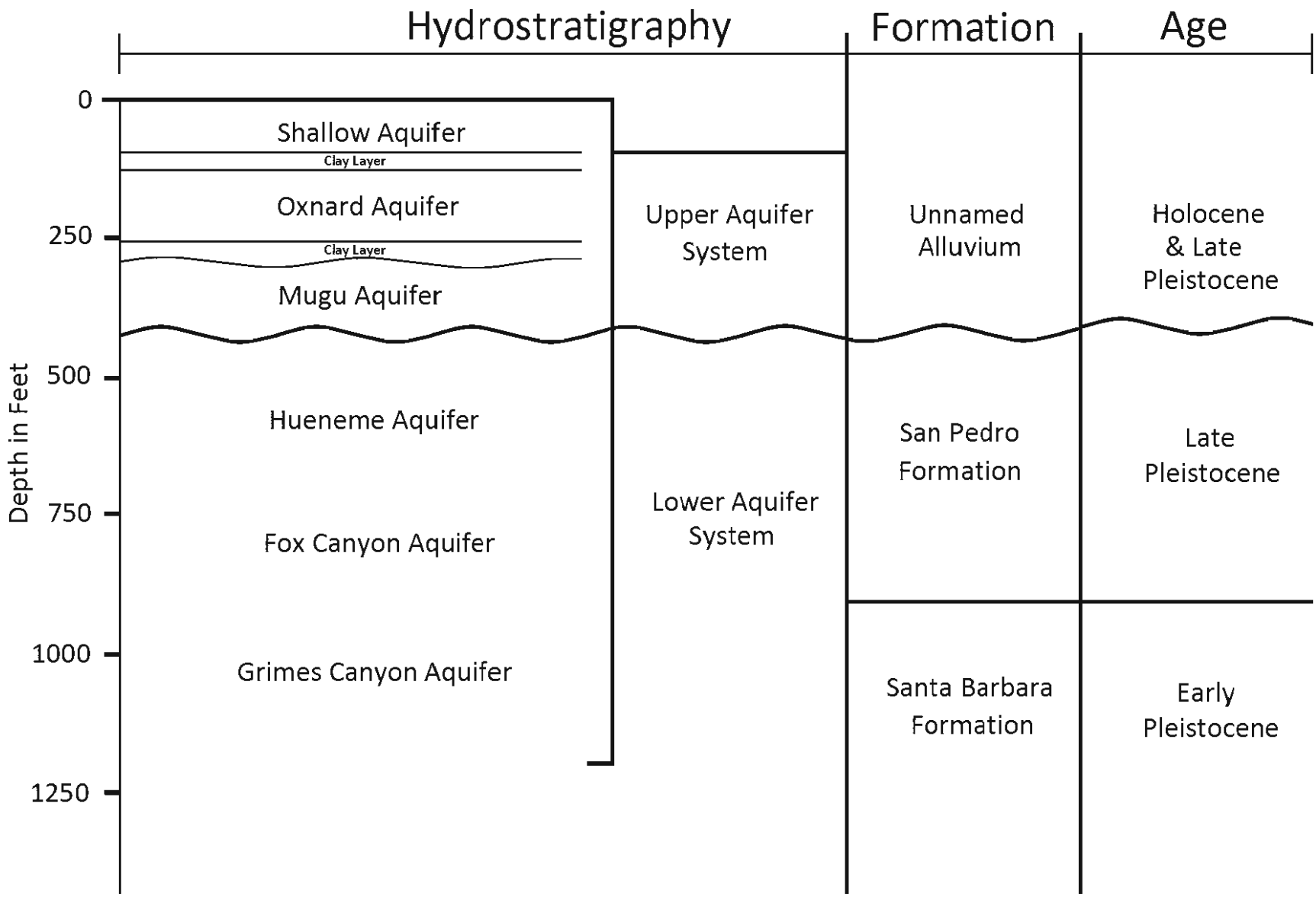


Figure 3-2: Schematic diagram of general aquifer systems.

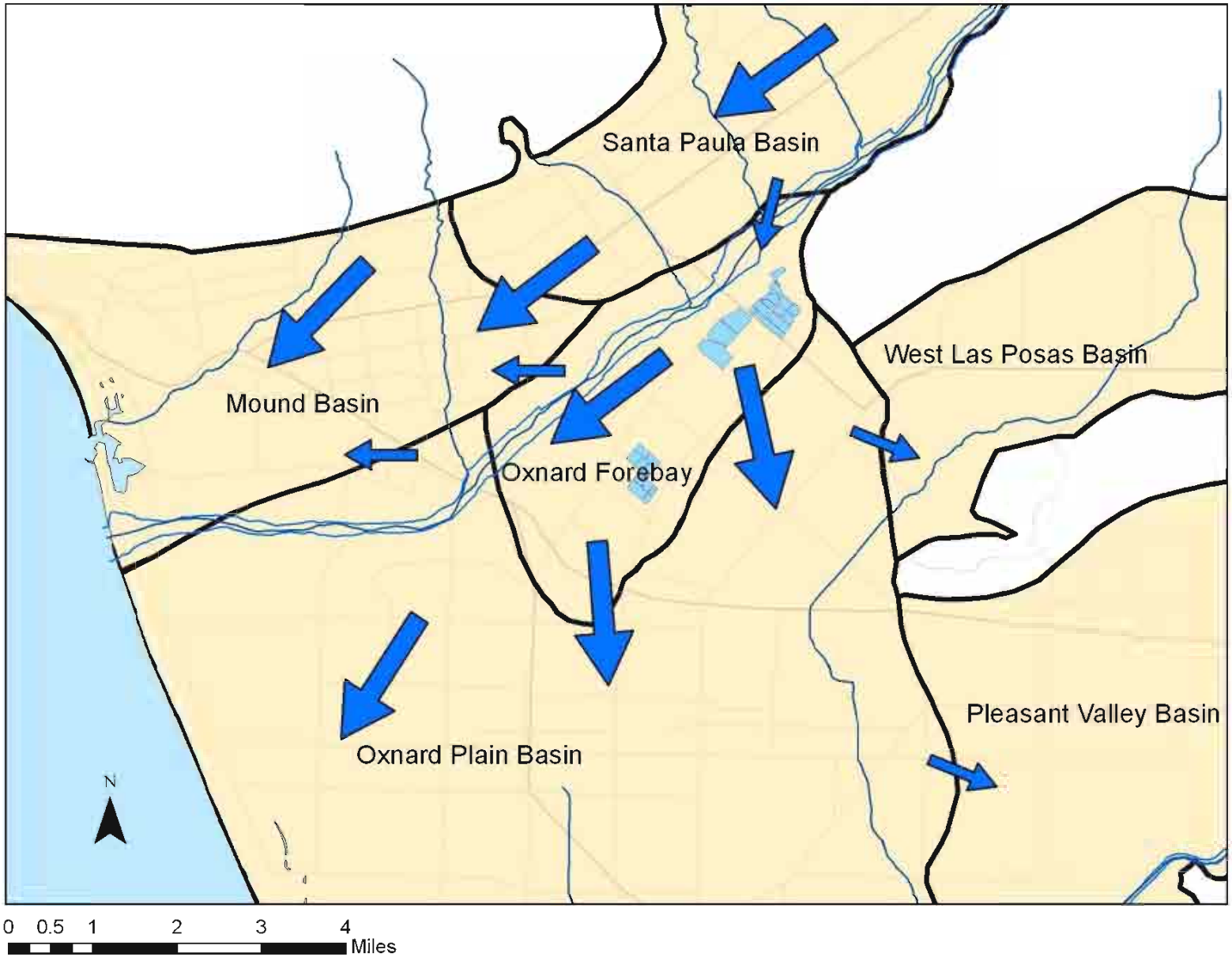


Figure 3-3. Generalized conceptual groundwater flow paths.

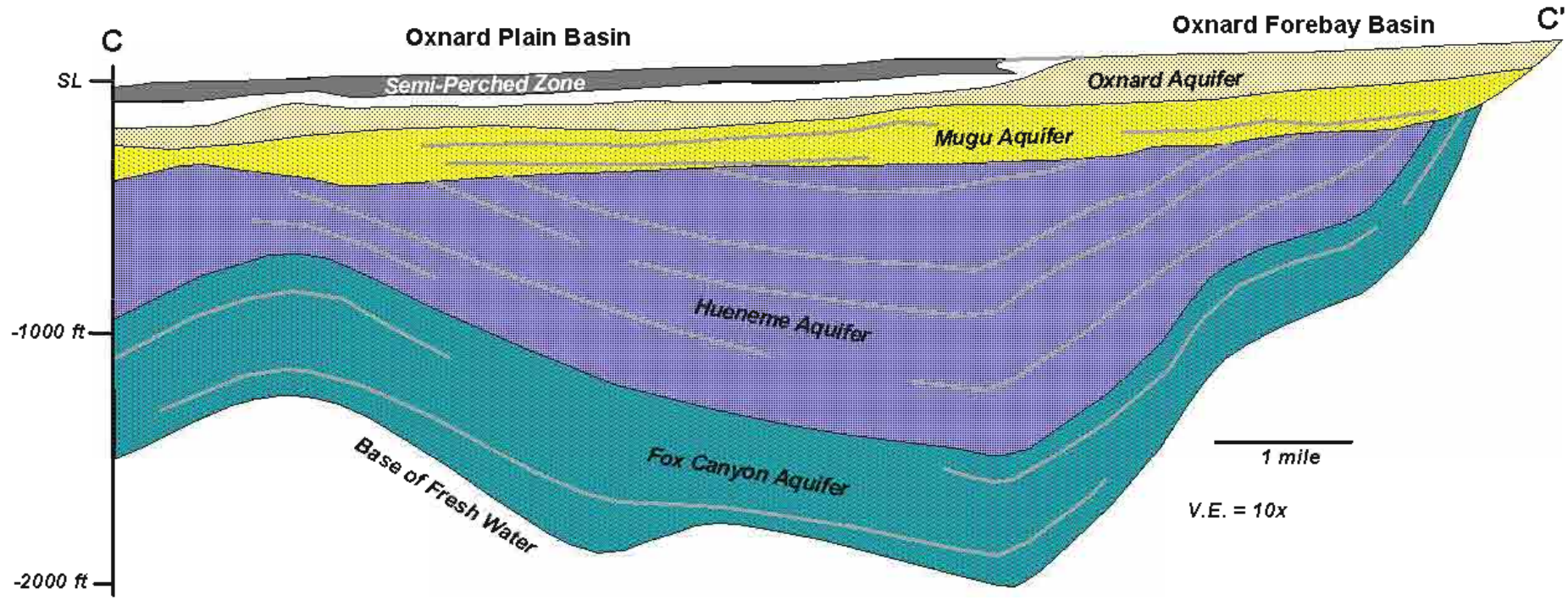


Figure 3-4: Schematic Cross-Section of Aquifer Systems in the adjacent Oxnard Plain south of the Mound Basin.

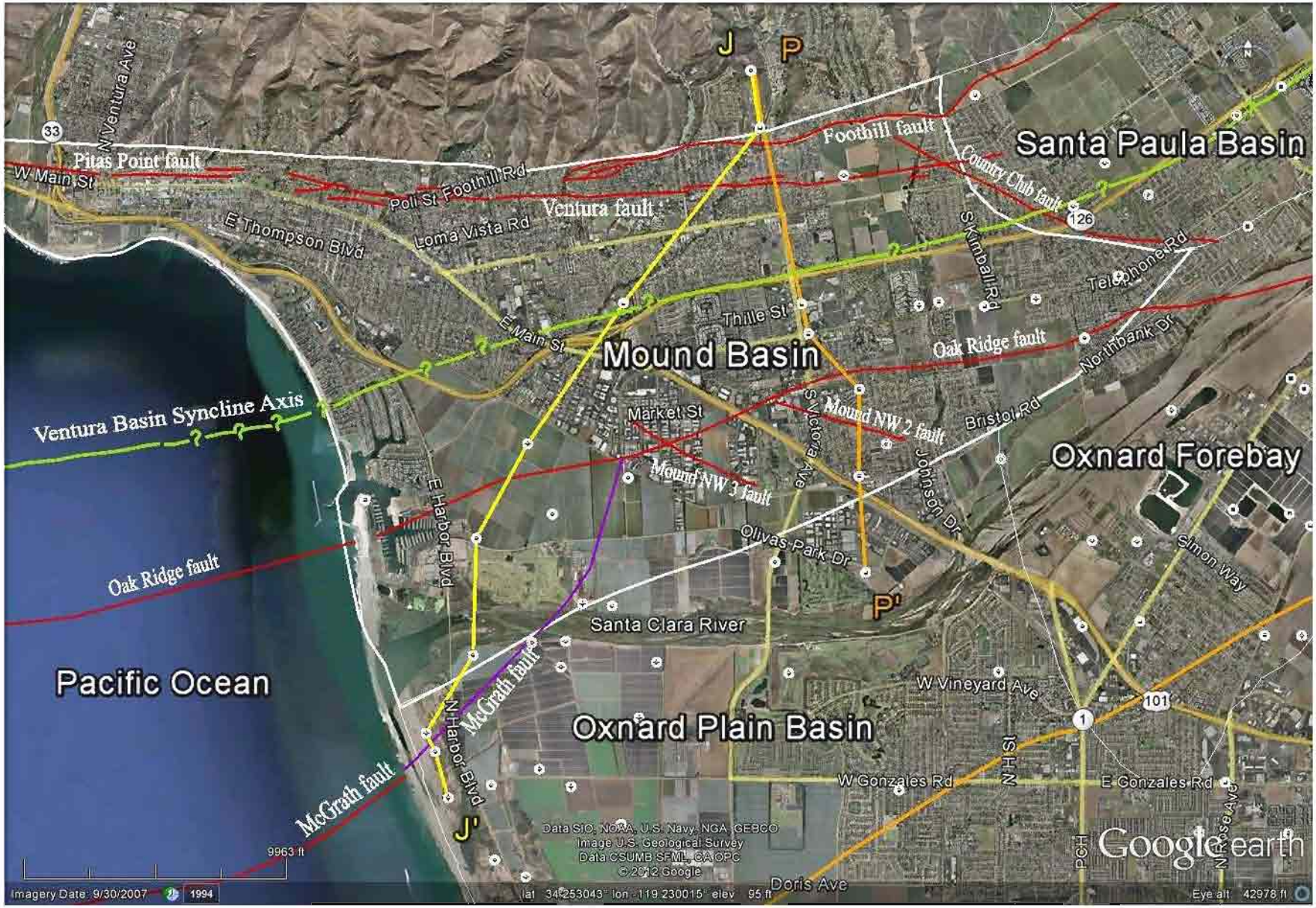


Figure 3-5: Location Map for United Water Cross-Sections J-J' and P-P'.

Cross-Section J-J'

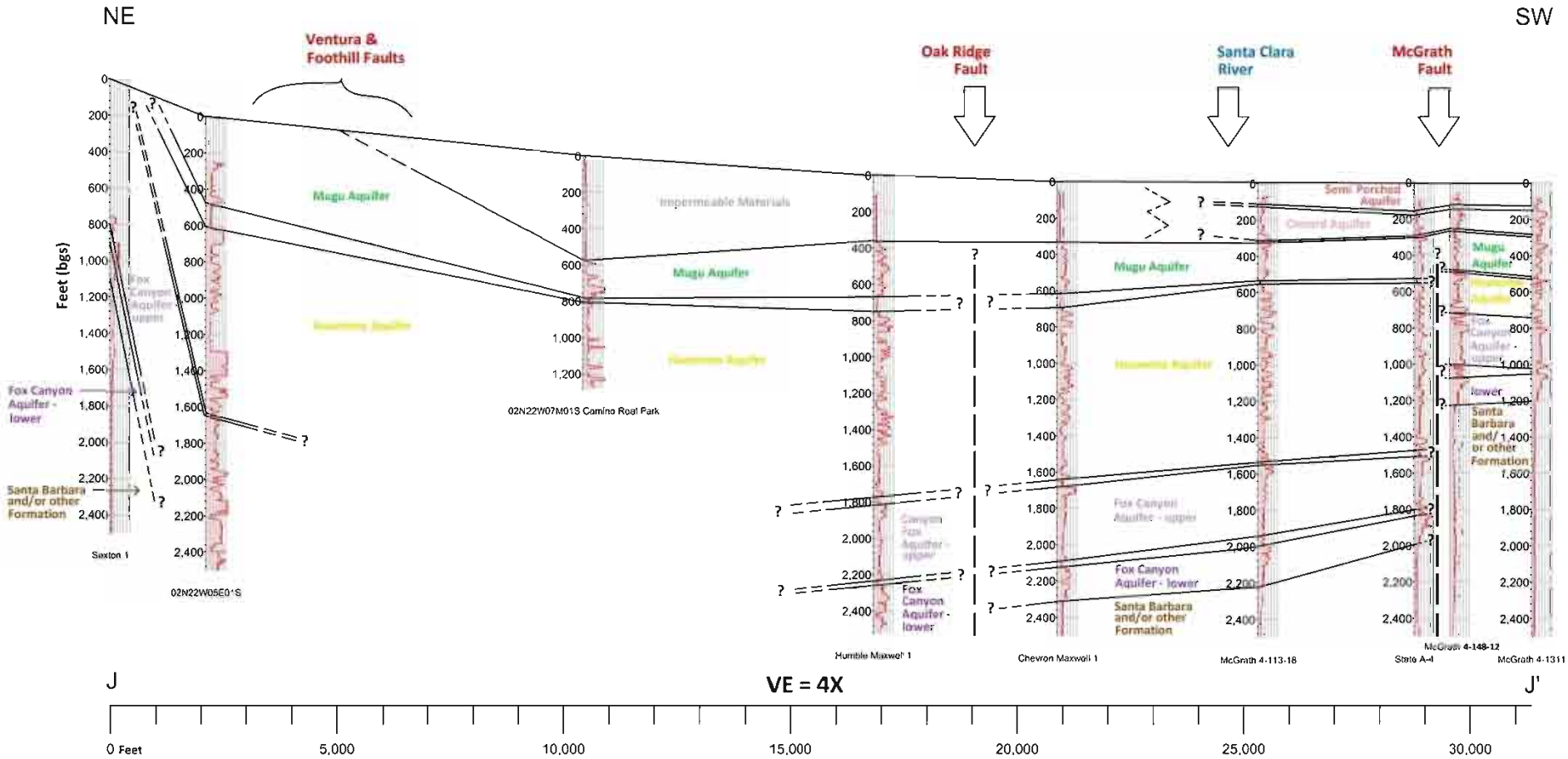


Figure 3-6: United Water Cross-Sections J-J'.

Cross-Section P-P'

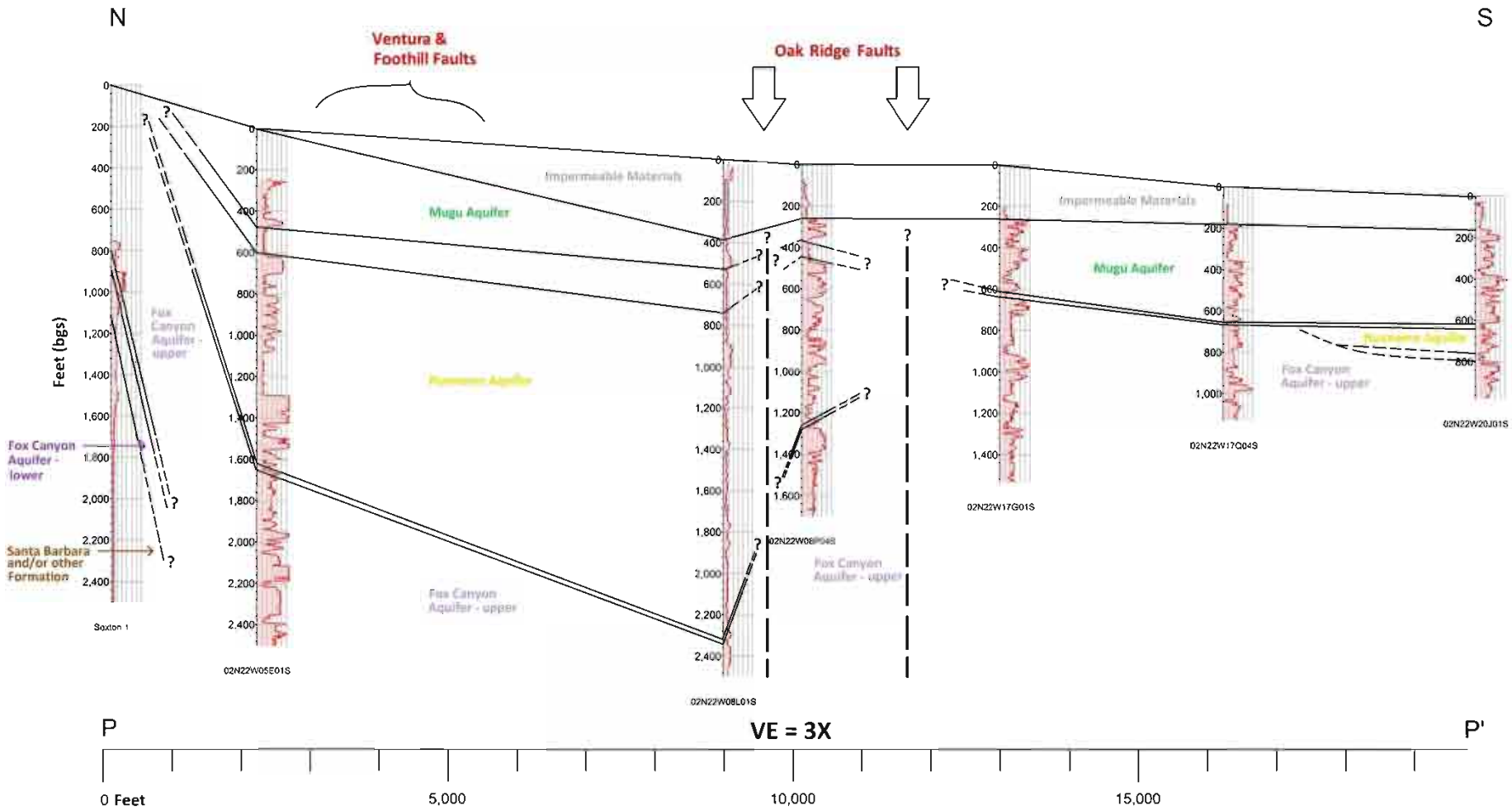


Figure 3-7: United Water Cross-Sections P-P'.

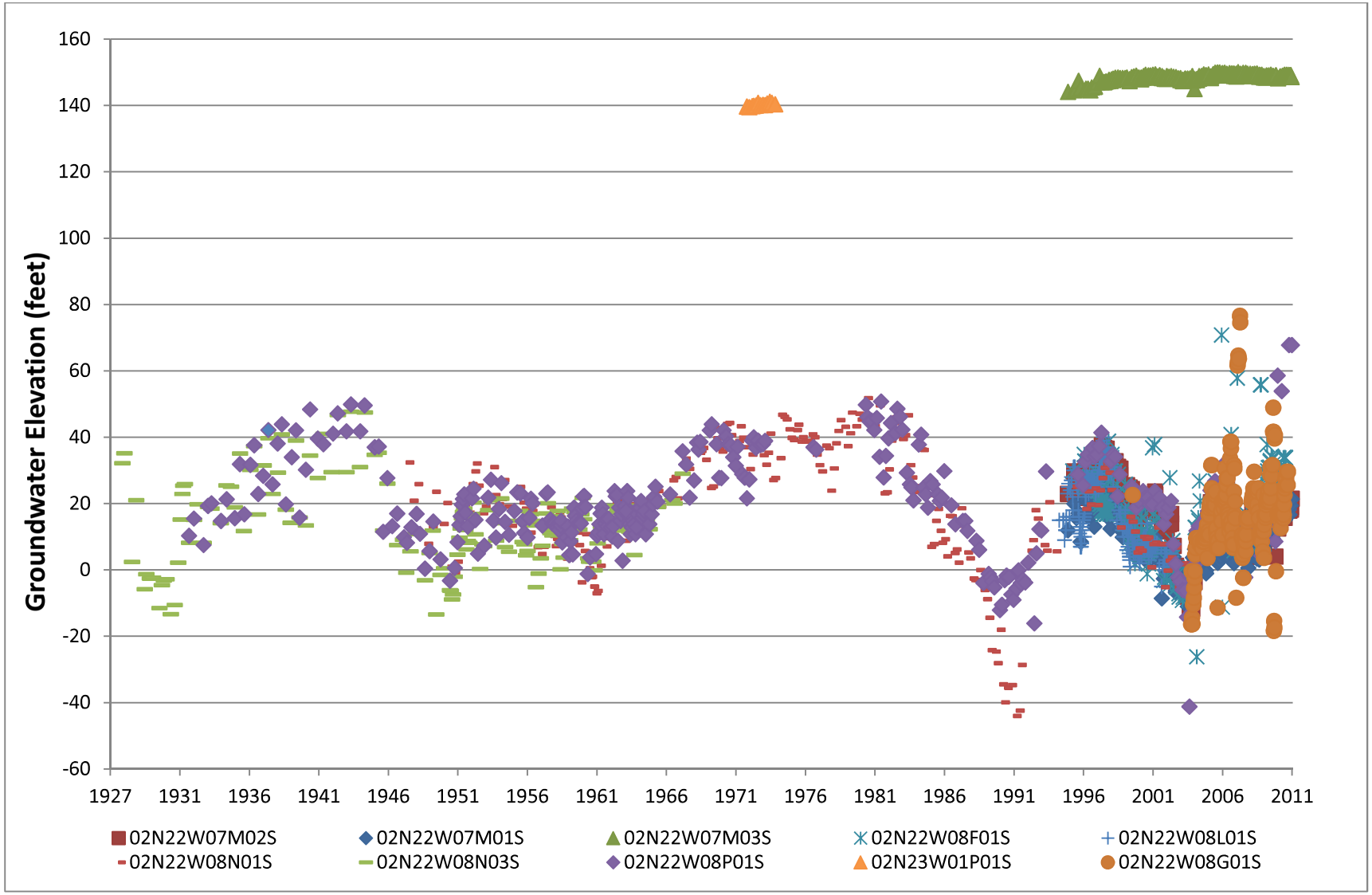


Figure 4-1. Recorded groundwater elevations, north and central Mound basin.

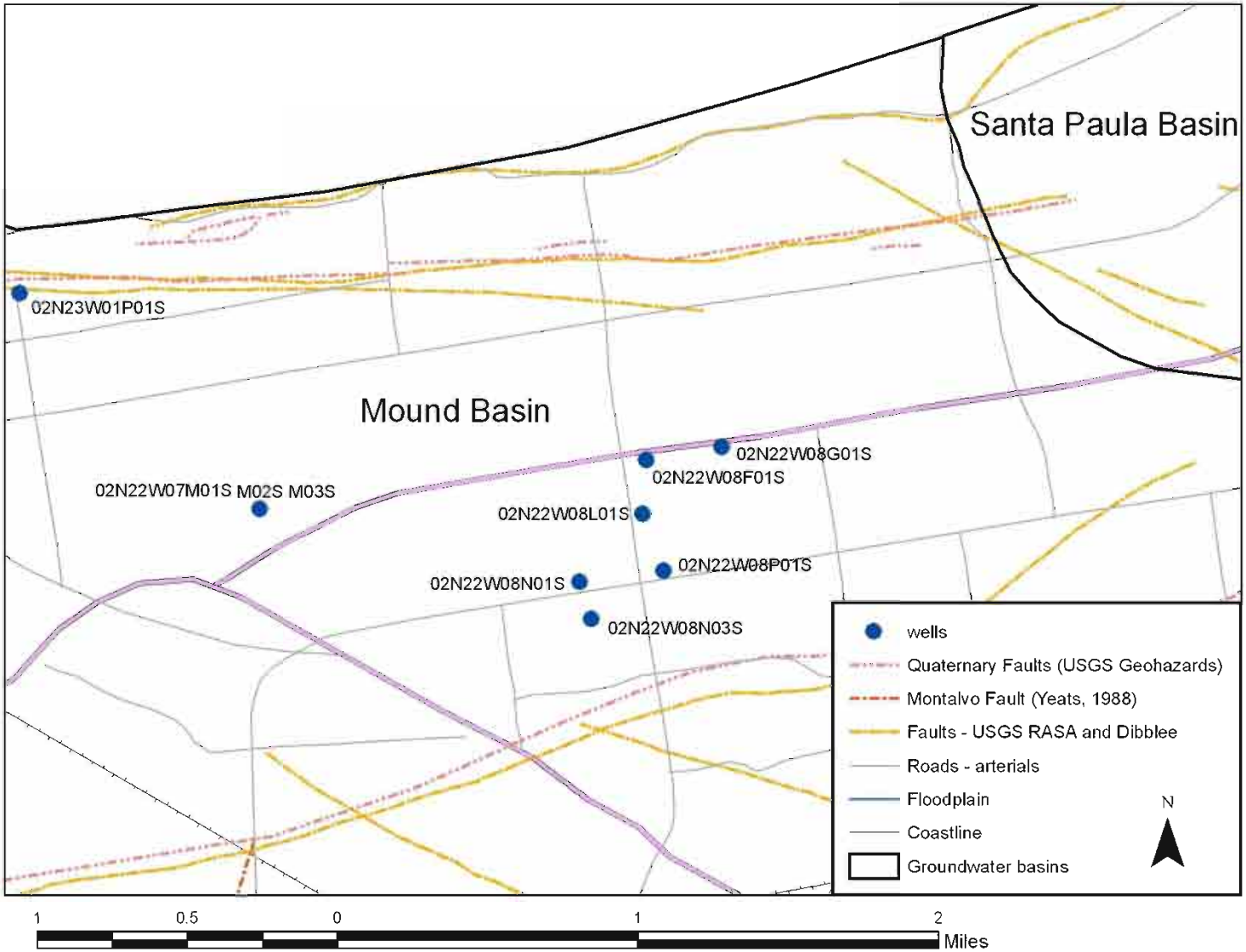


Figure 4-2. Location map for north and central Mound basin wells with WLE records.

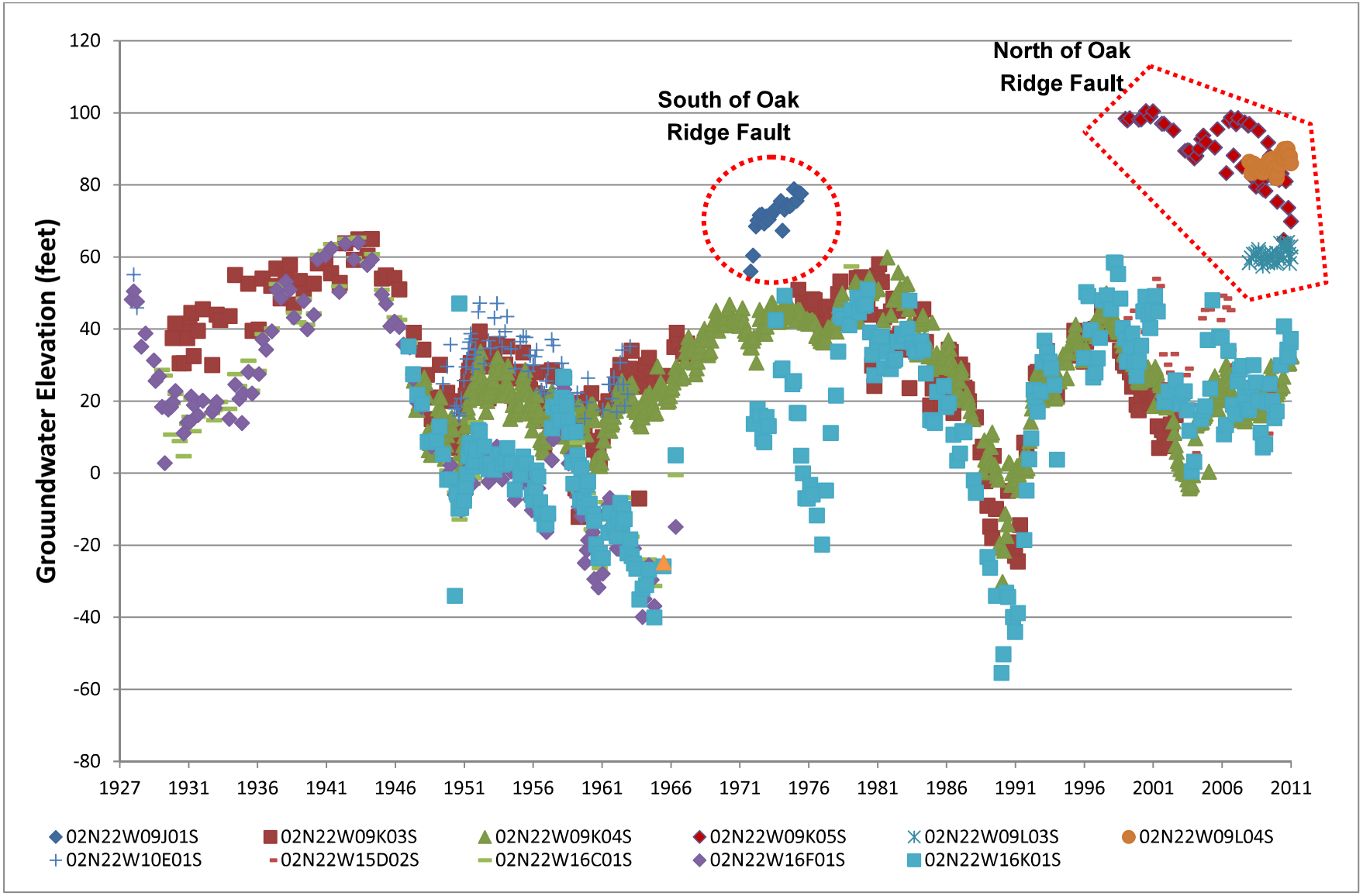


Figure 4-3. Recorded groundwater elevations, eastern Mound basin.

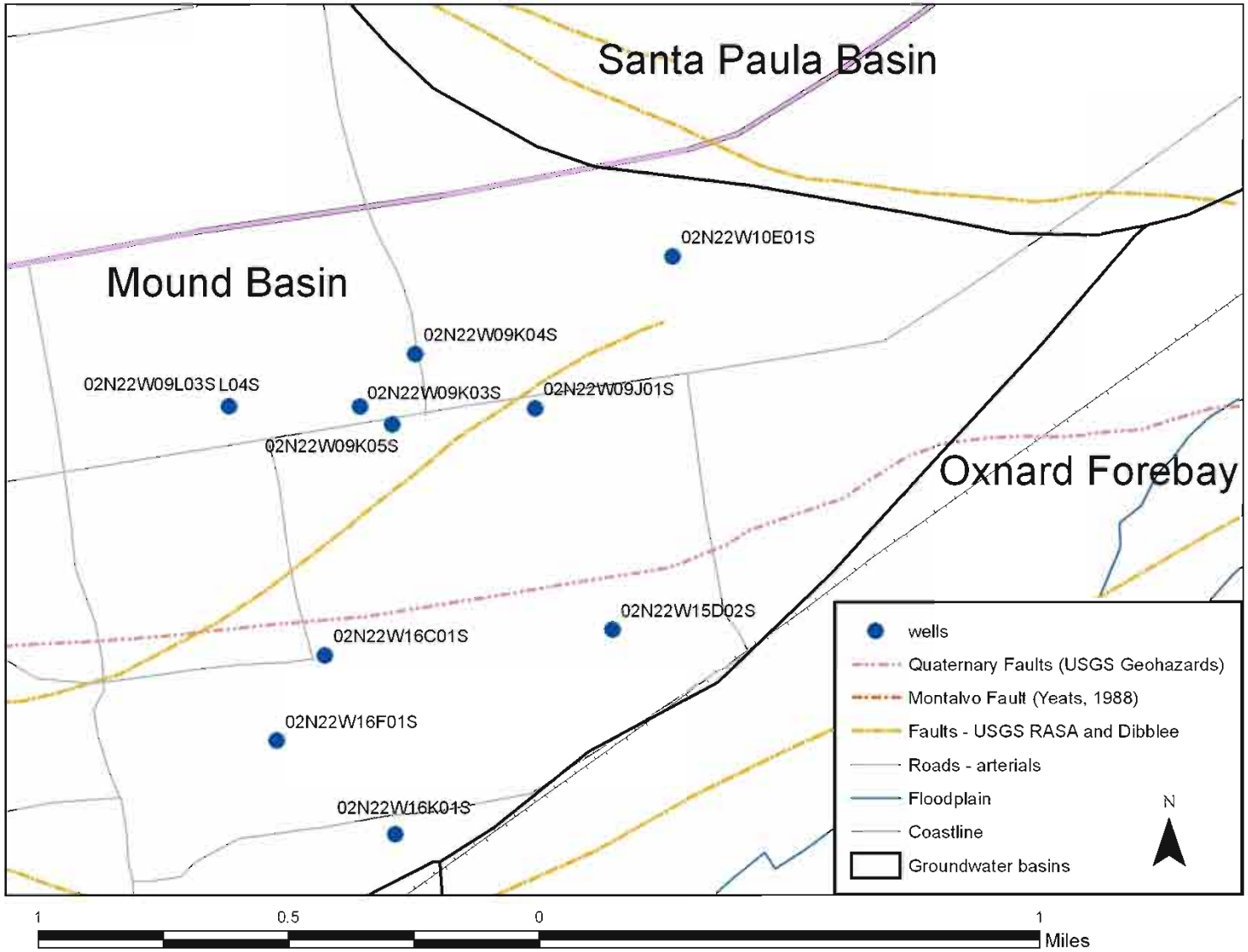


Figure 4-4. Location map for eastern Mound basin wells with WLE records.

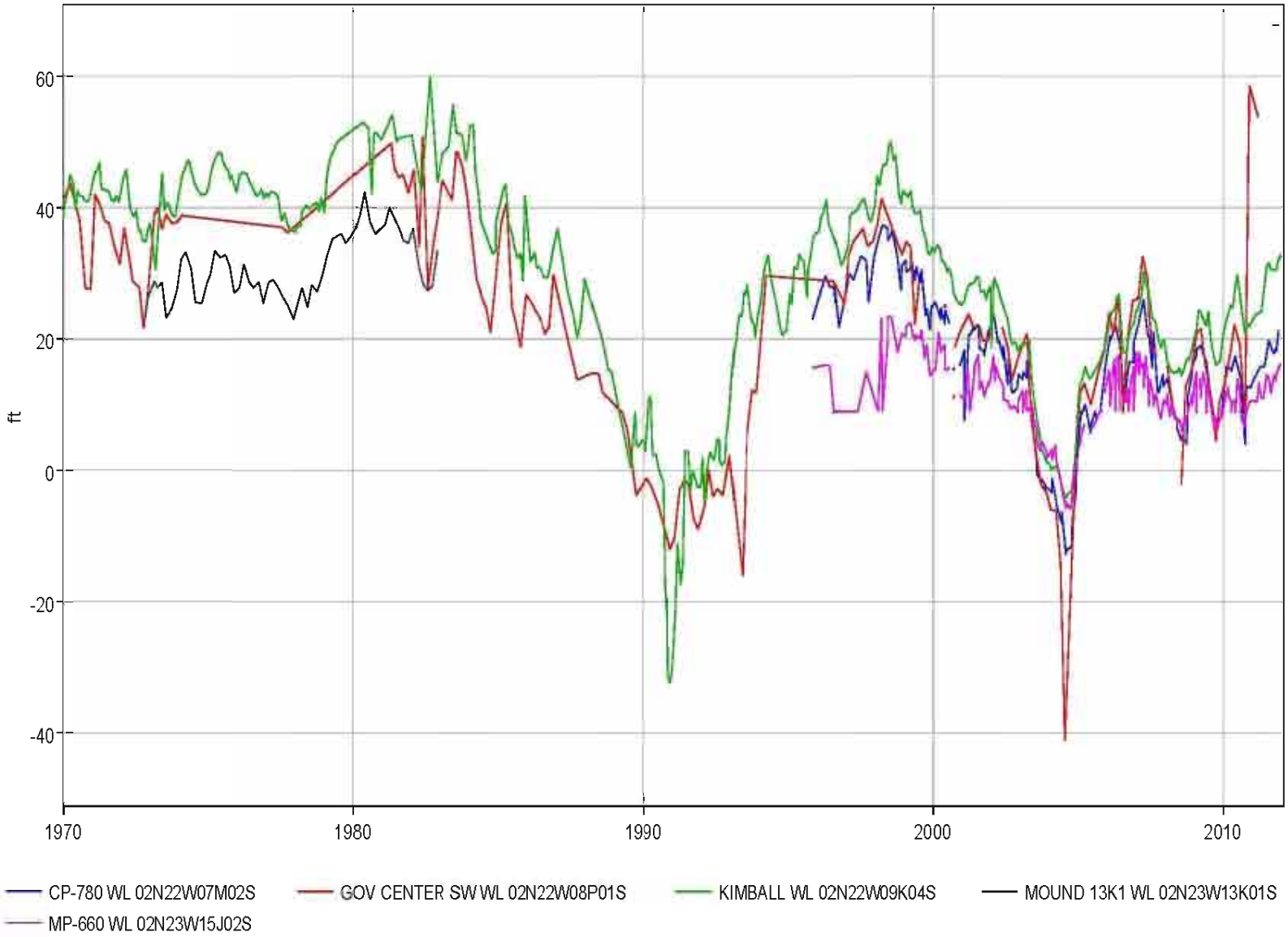


Figure 4-5. Recorded groundwater elevations, central Mound basin.

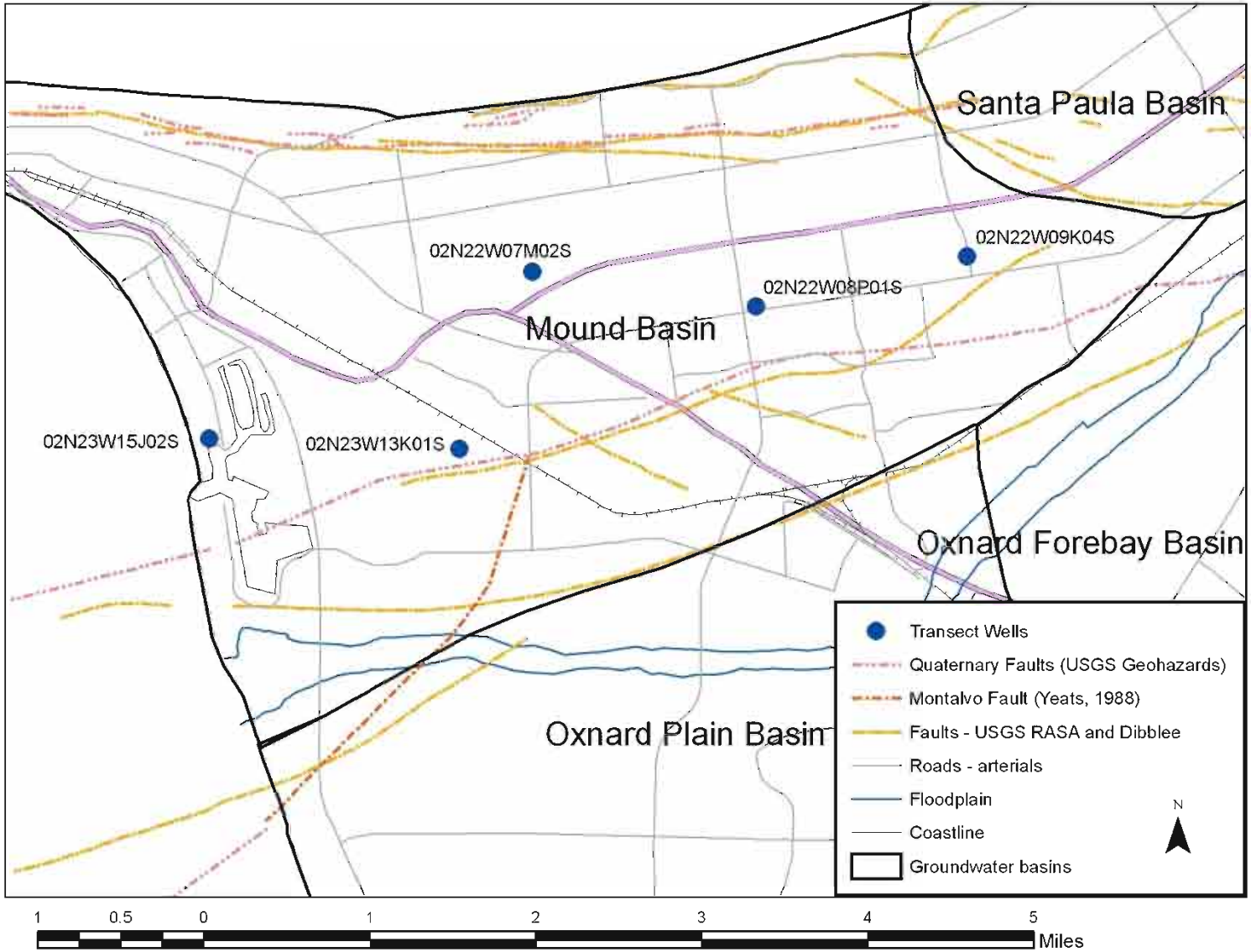


Figure 4-6. Location map for central Mound basin wells with WLE records.

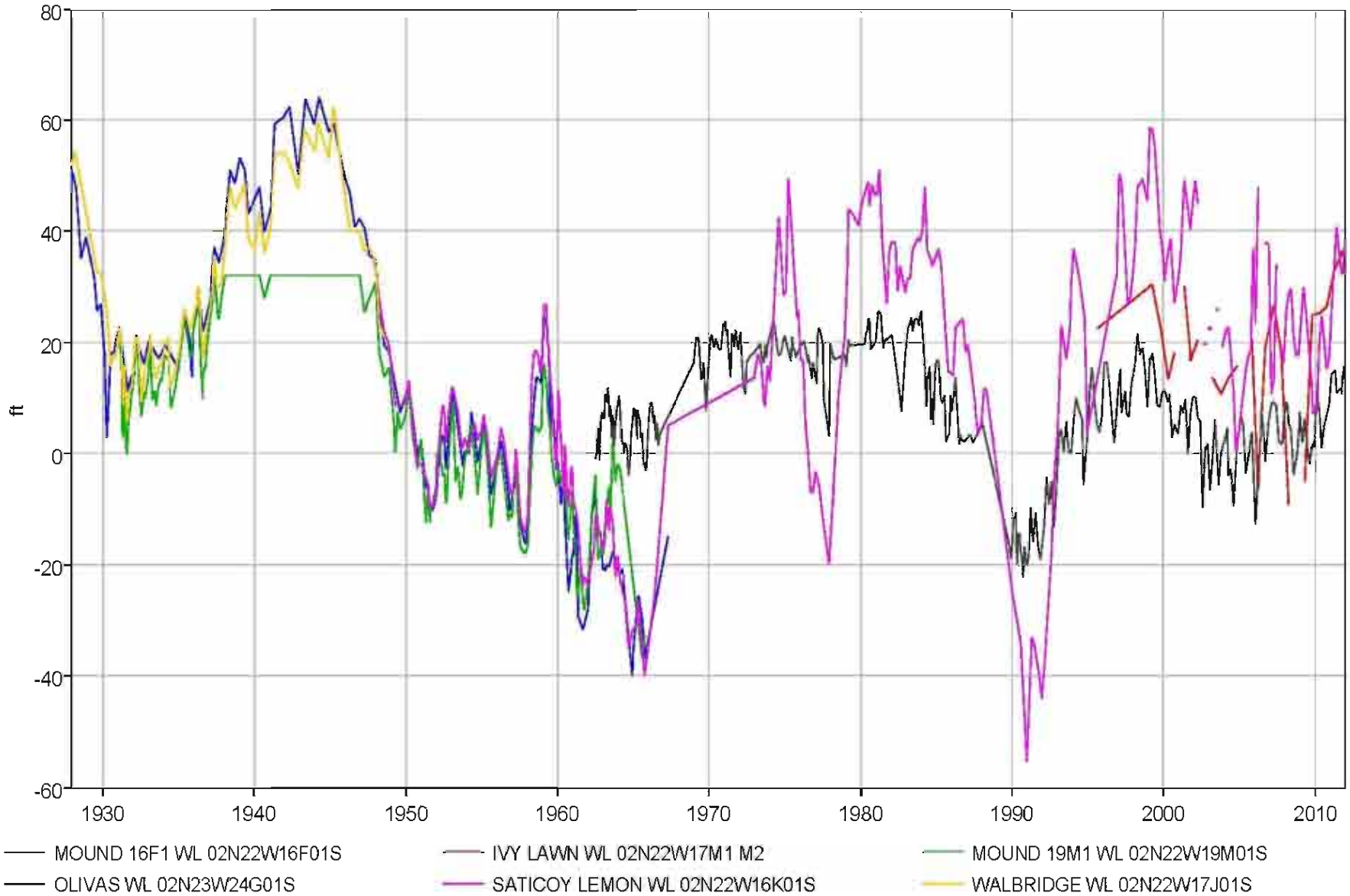


Figure 4-7. Recorded groundwater elevations, southern Mound basin.

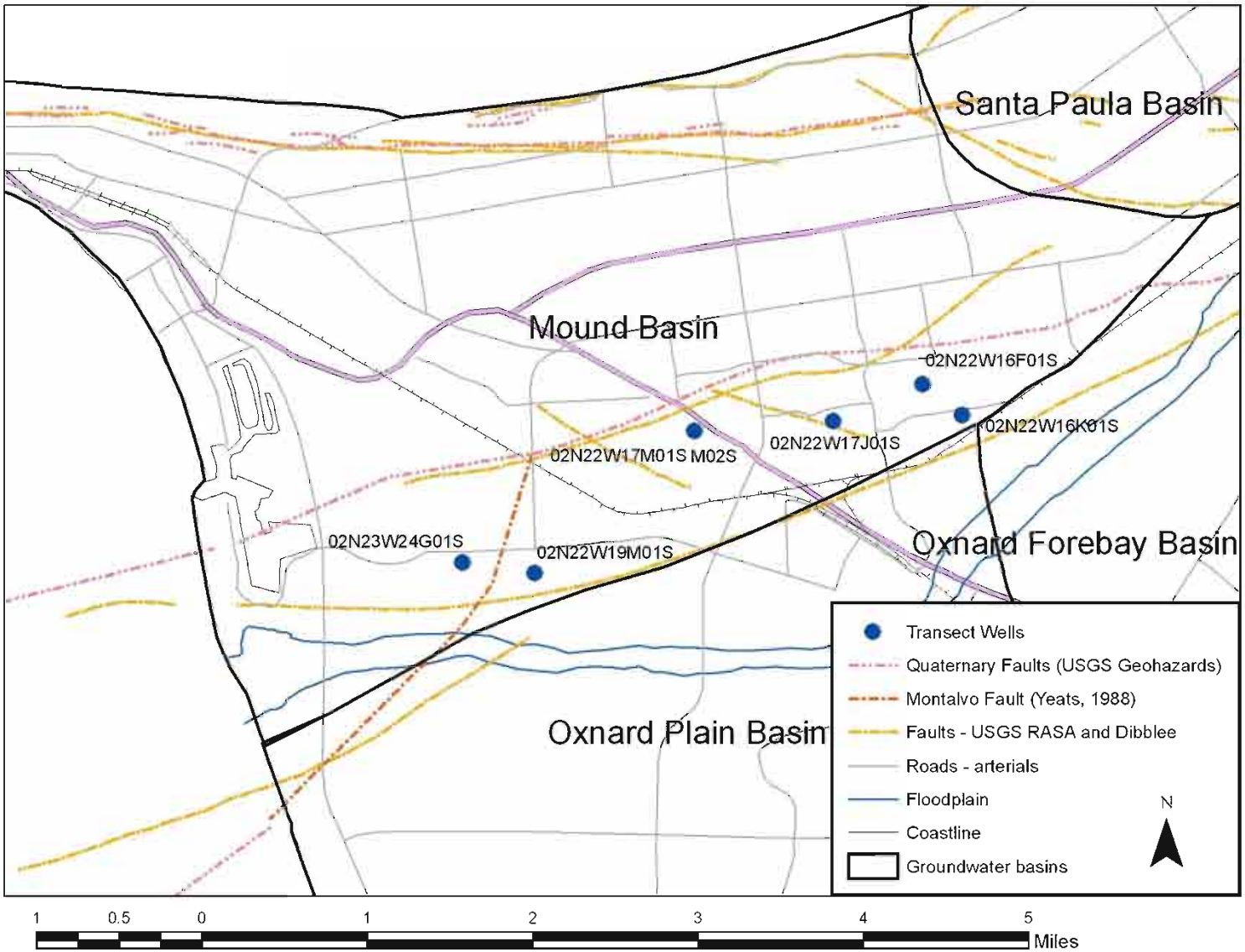


Figure 4-8. Location map for southern Mound basin wells with WLE records.

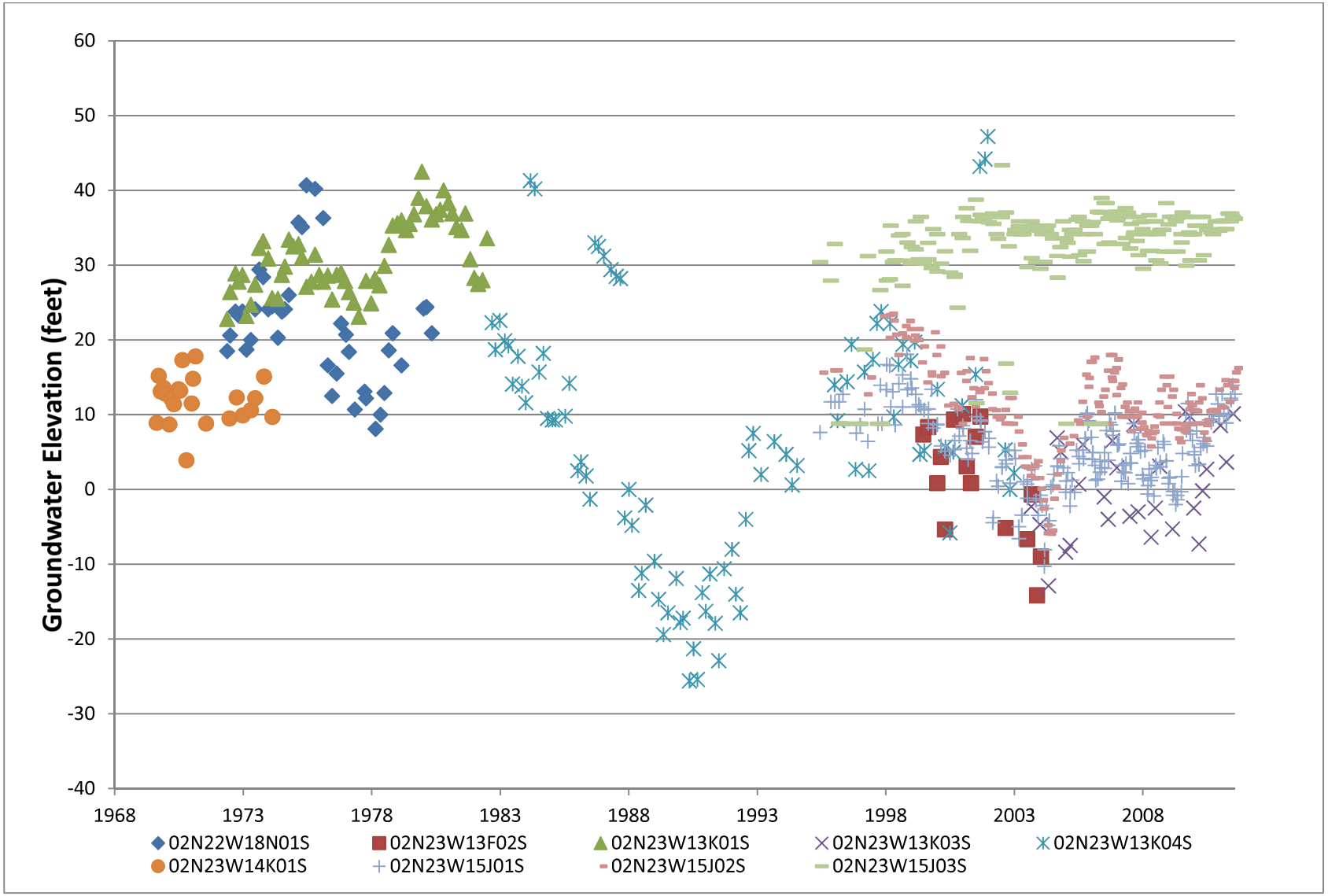


Figure 4-9. Recorded groundwater elevations, western Mound basin.

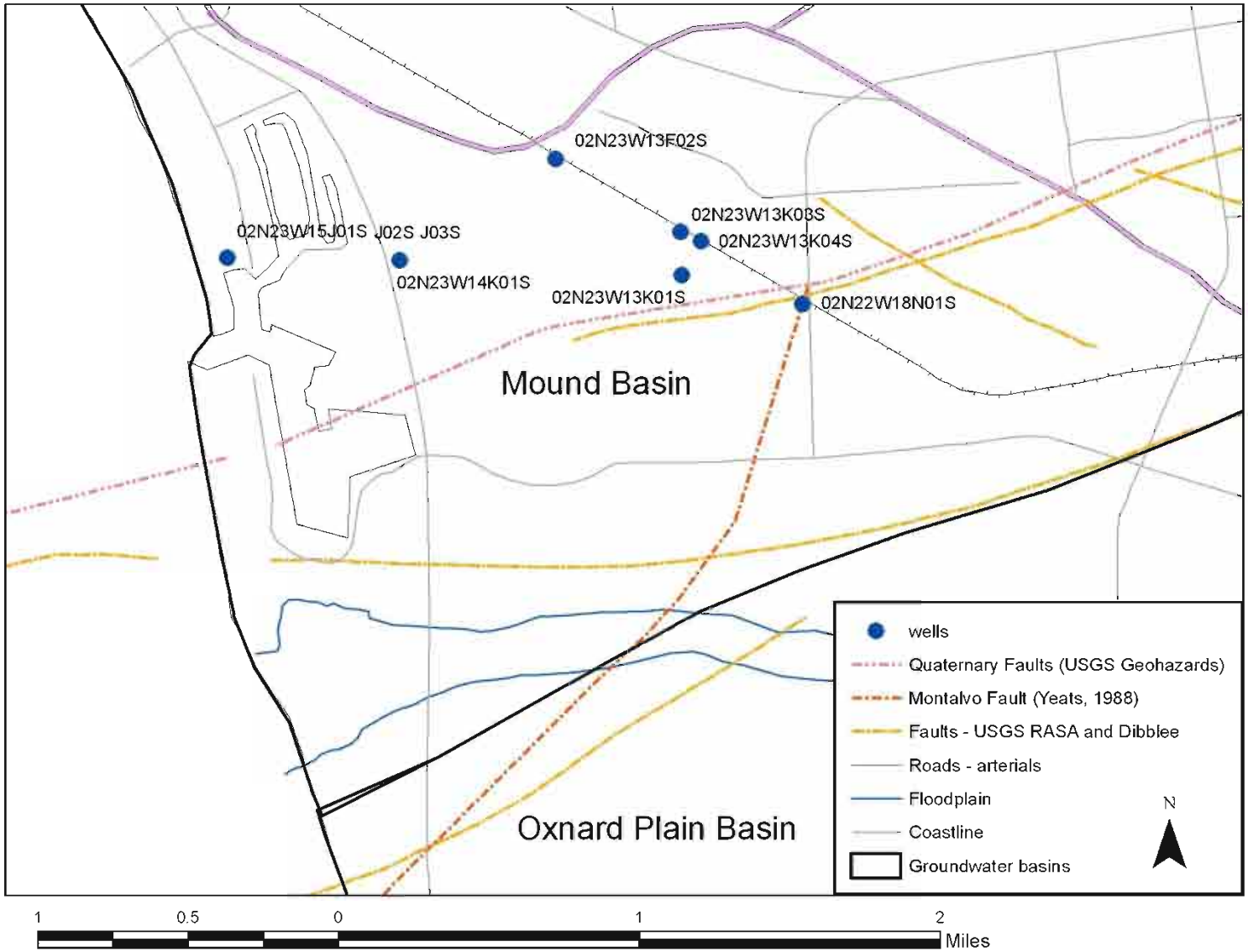


Figure 4-10. Location map for western Mound basin wells with WLE records.

Figure 5-1. Distribution of Mound basin pumping, 2010 calendar year.

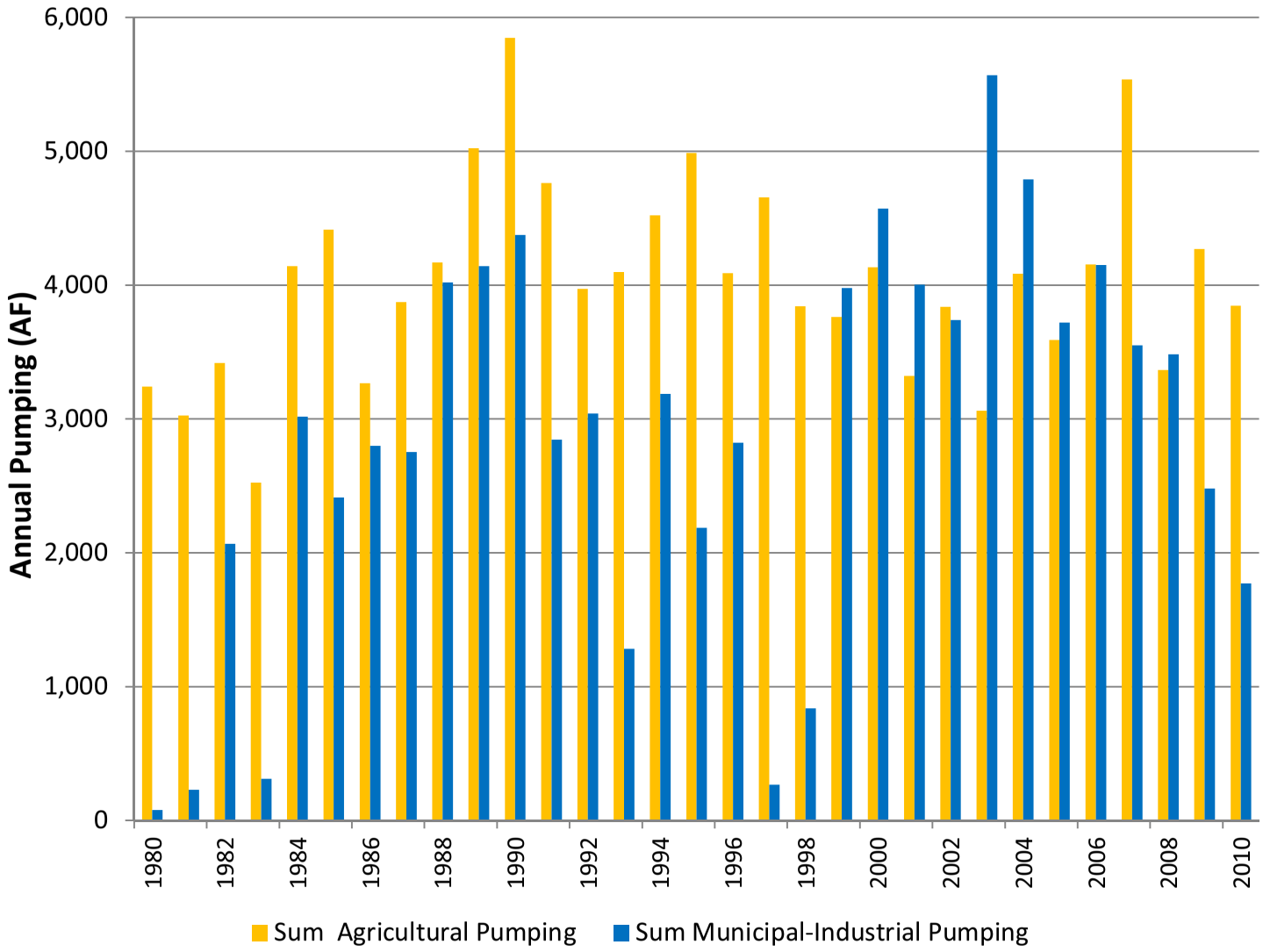


Figure 5-2. Annual Mound basin pumping totals by water use.

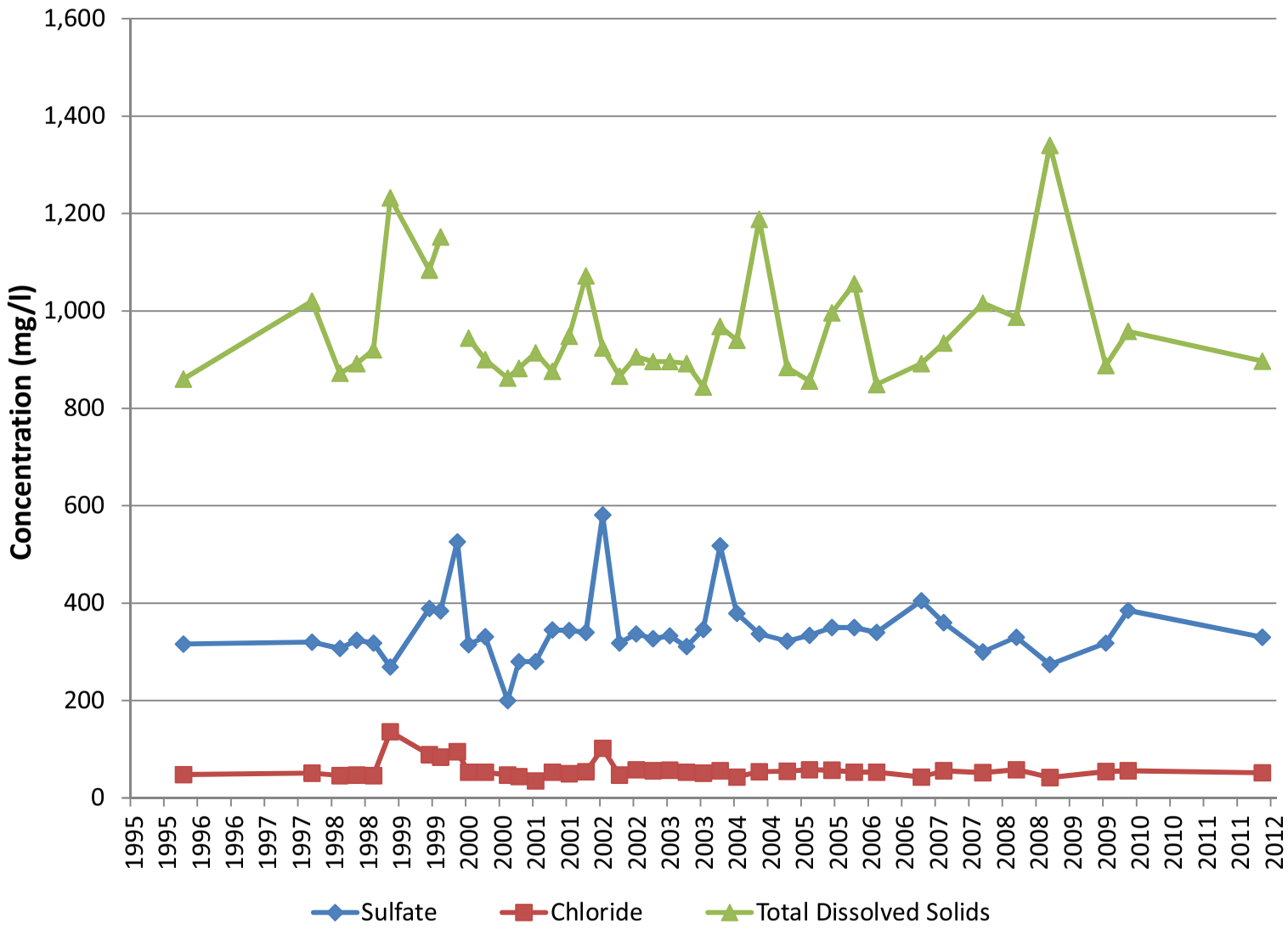


Figure 6-1. Well 02N22W07M02S water quality records (monitoring well CP-780).

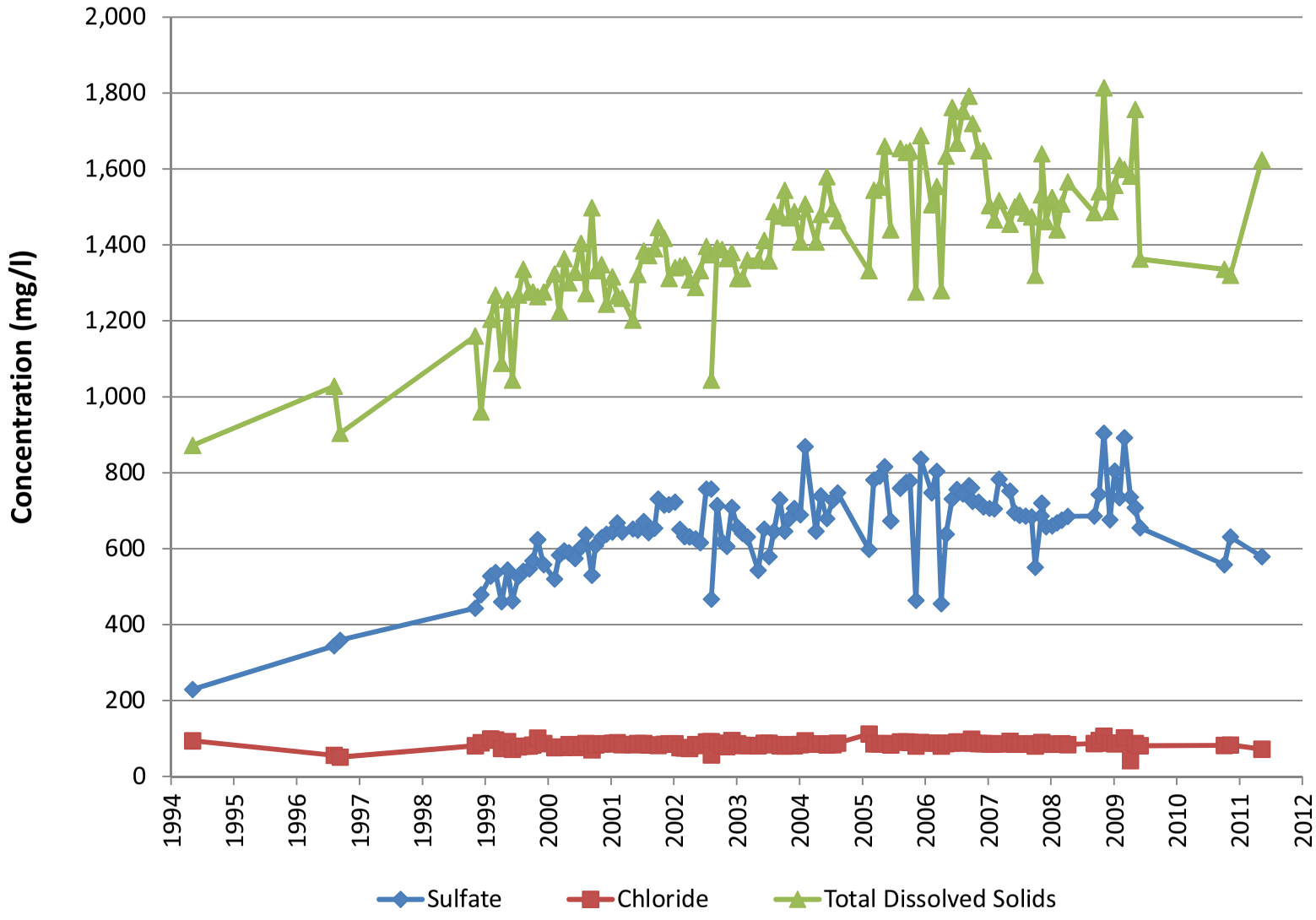


Figure 6-2. Well 02N22W08F01S water quality records (Victoria 2).

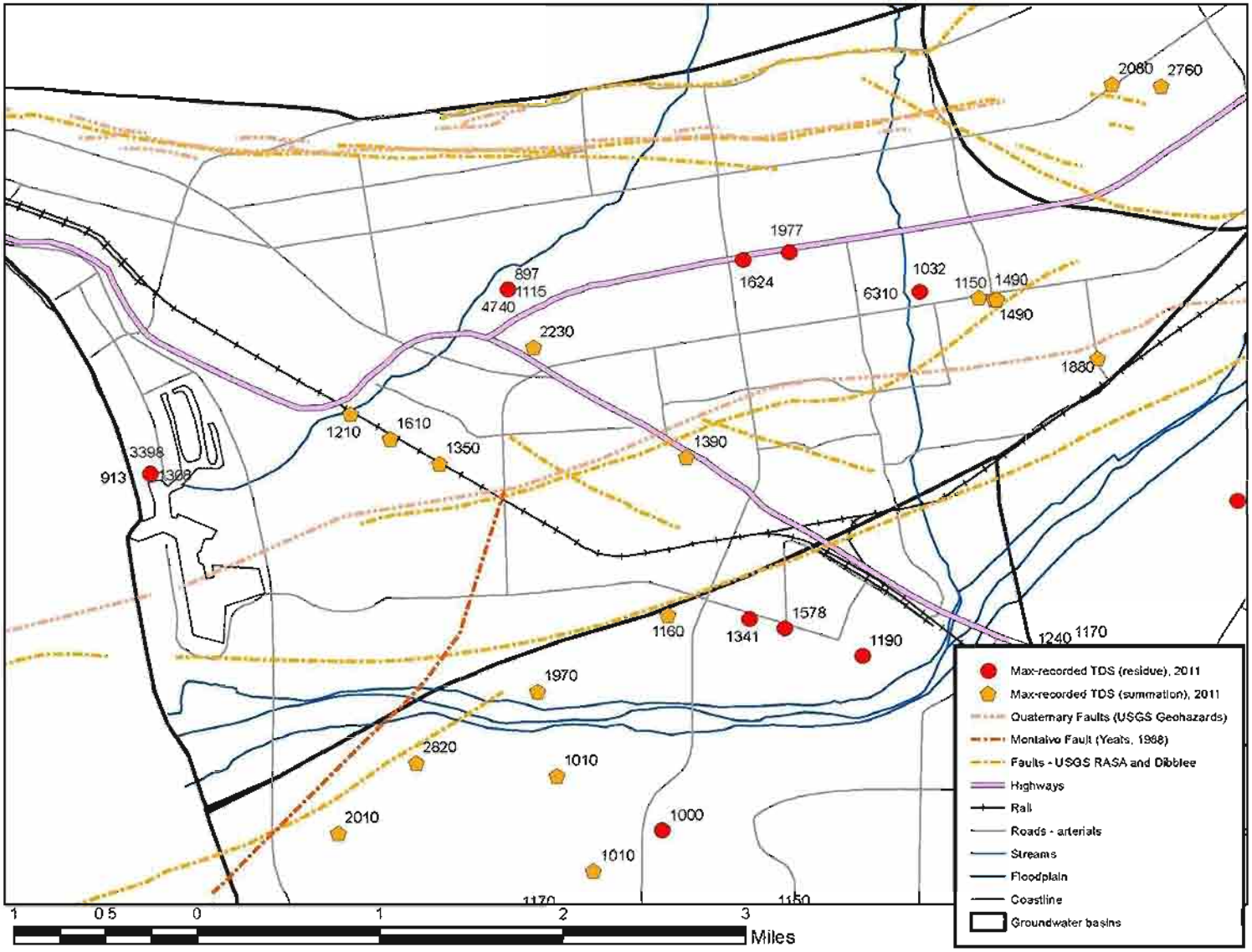


Figure 6-3. Maximum-recorded Total Dissolved Solids in 2011.

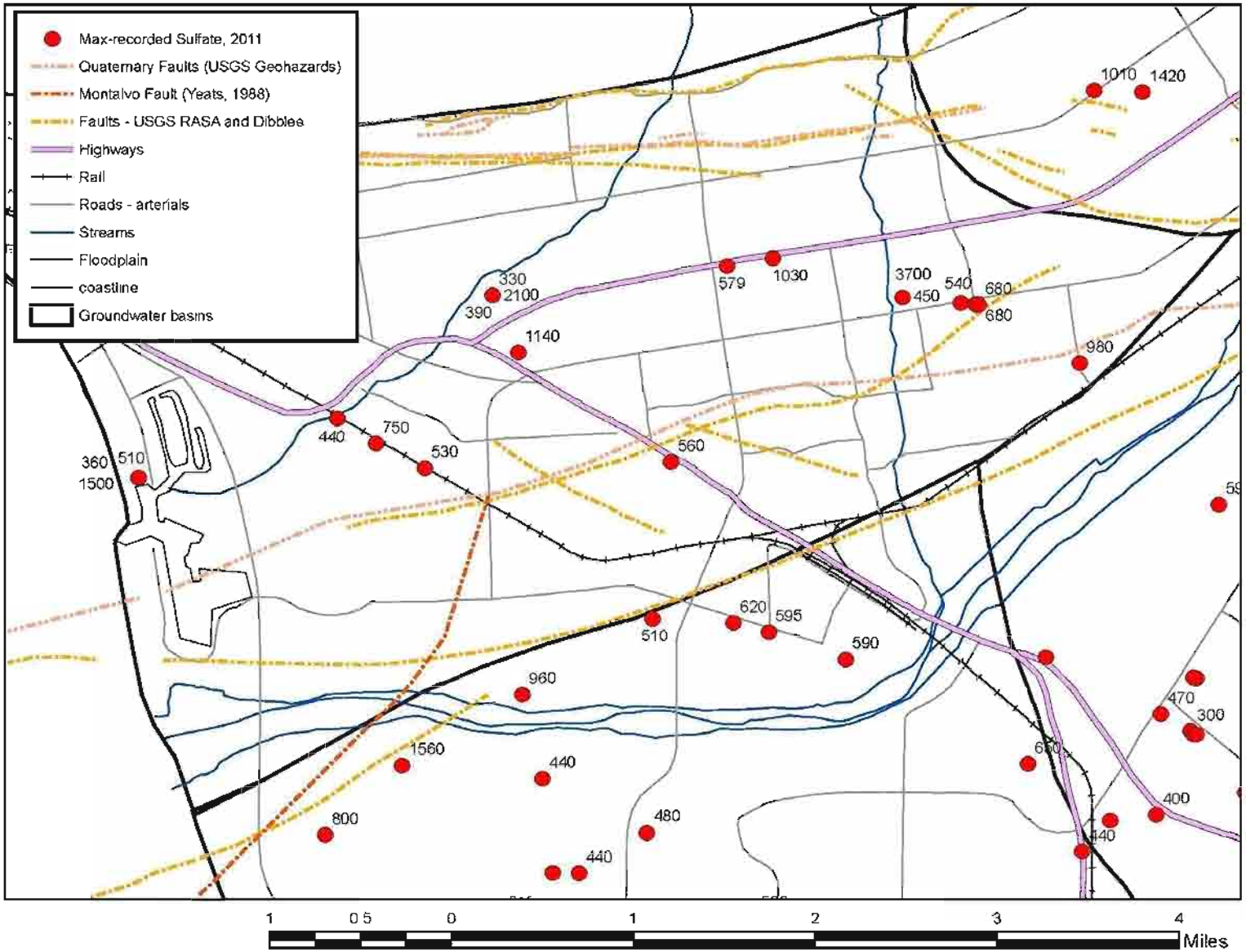


Figure 6-4. Maximum-recorded sulfate concentration in 2011.

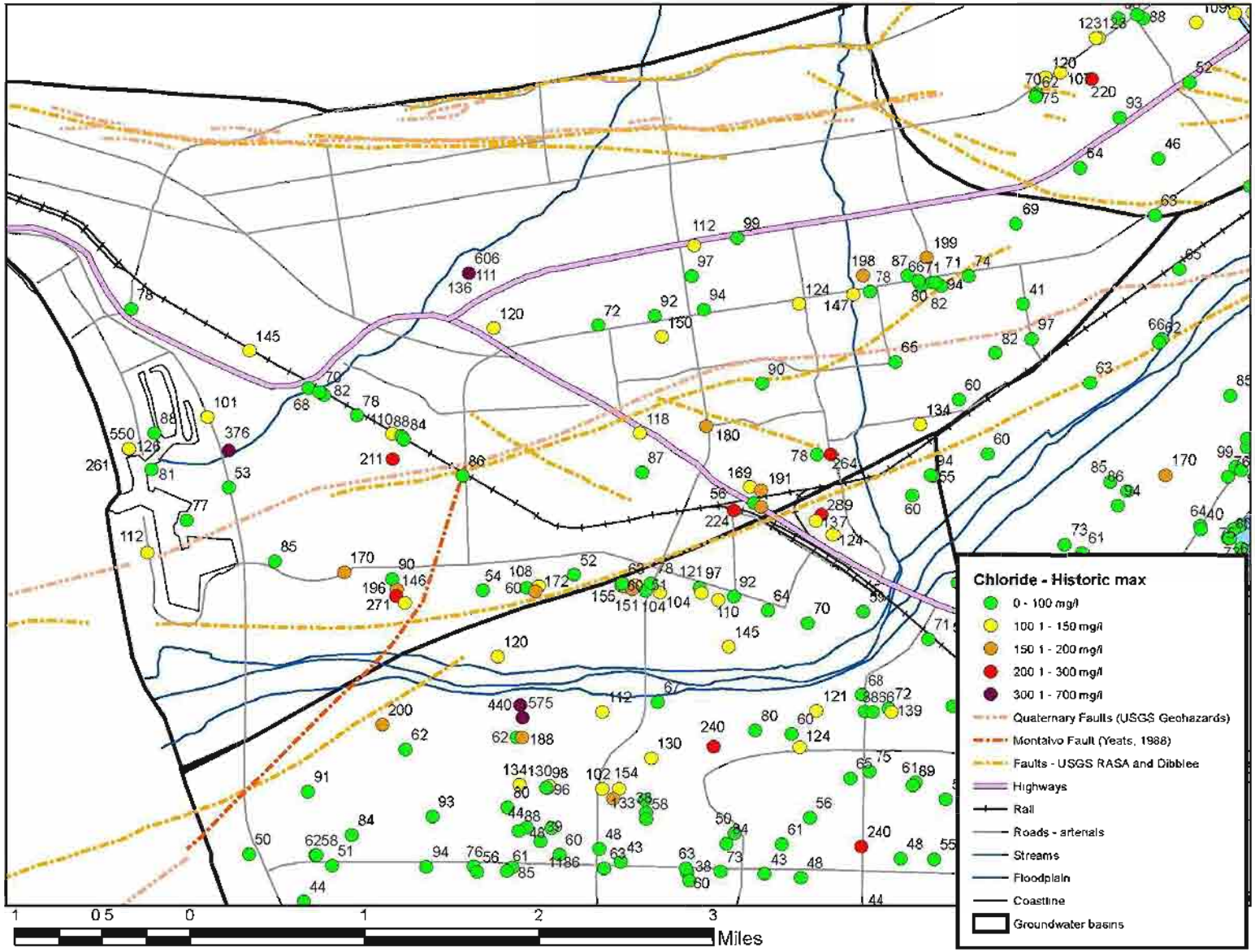


Figure 6-5. Maximum-recorded chloride concentration, all historic records.

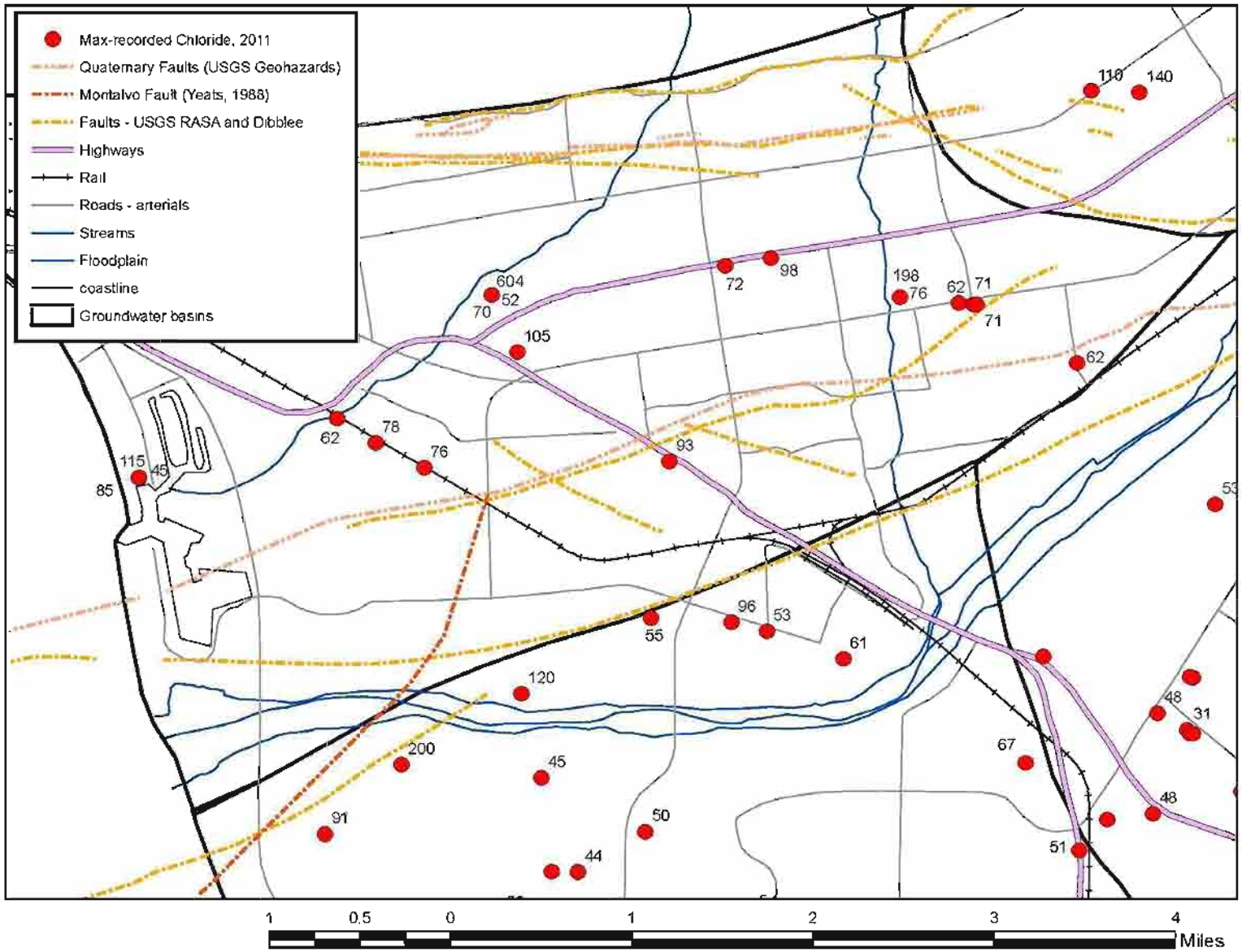


Figure 6-6. Maximum-recorded chloride concentration in 2011.

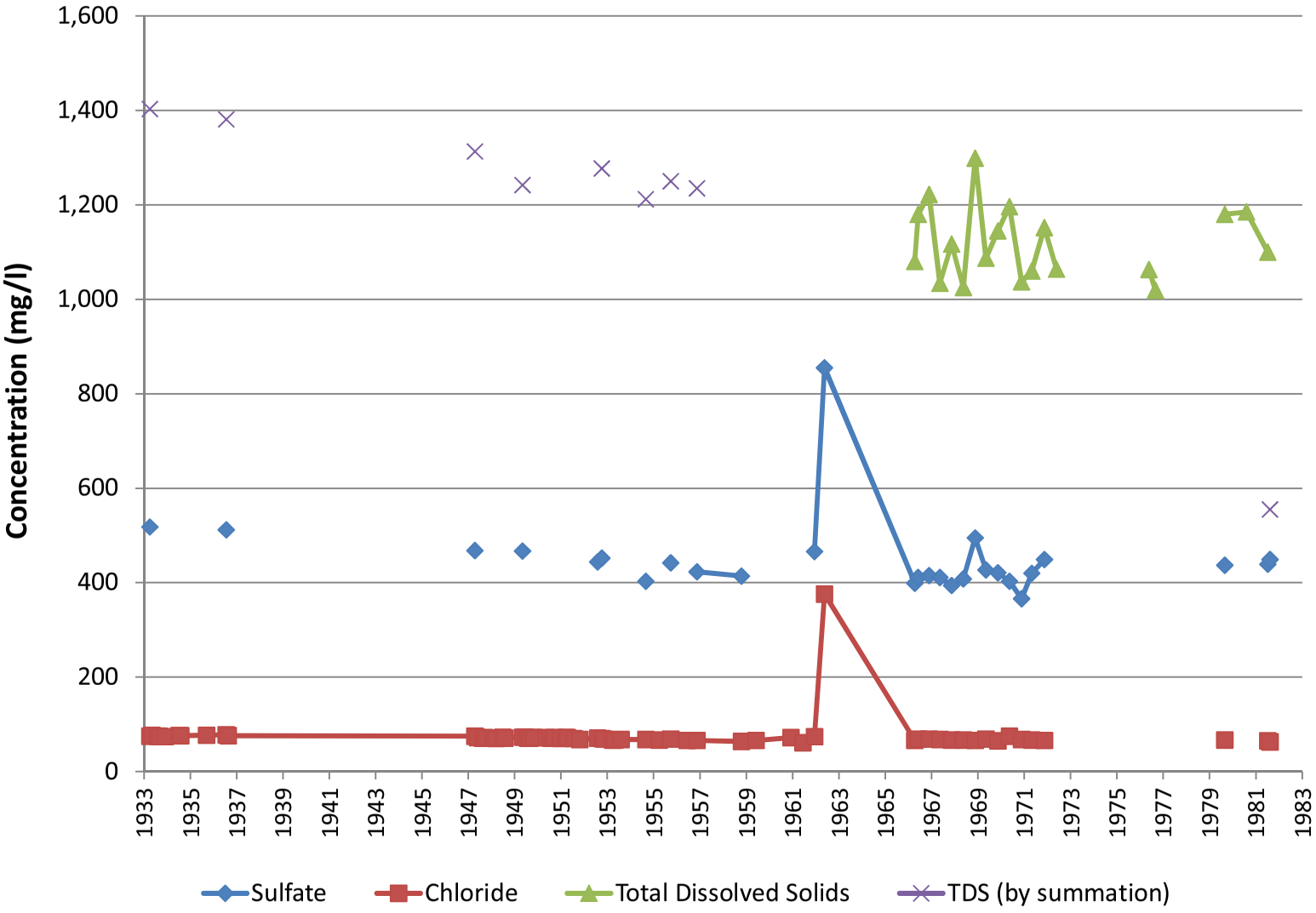
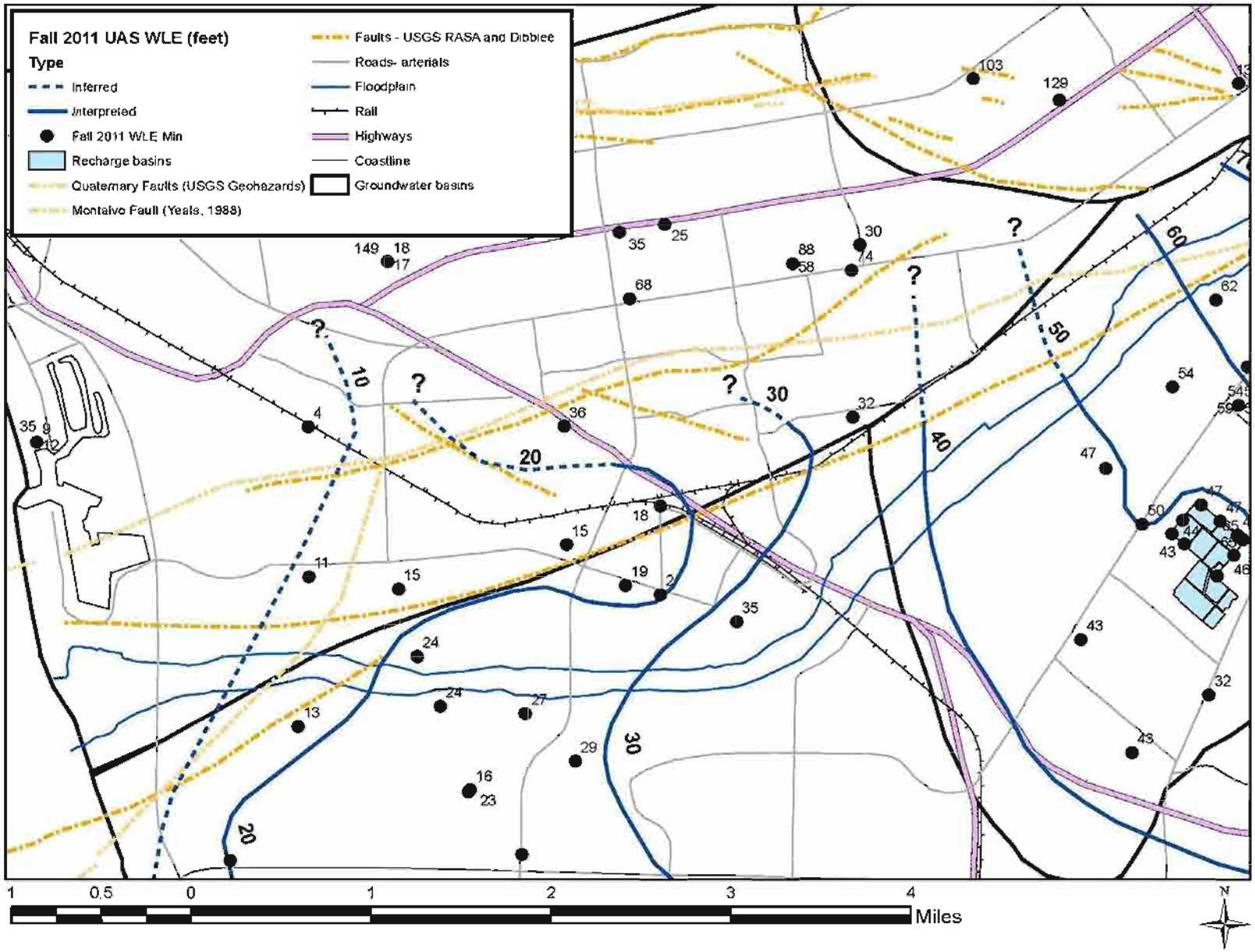
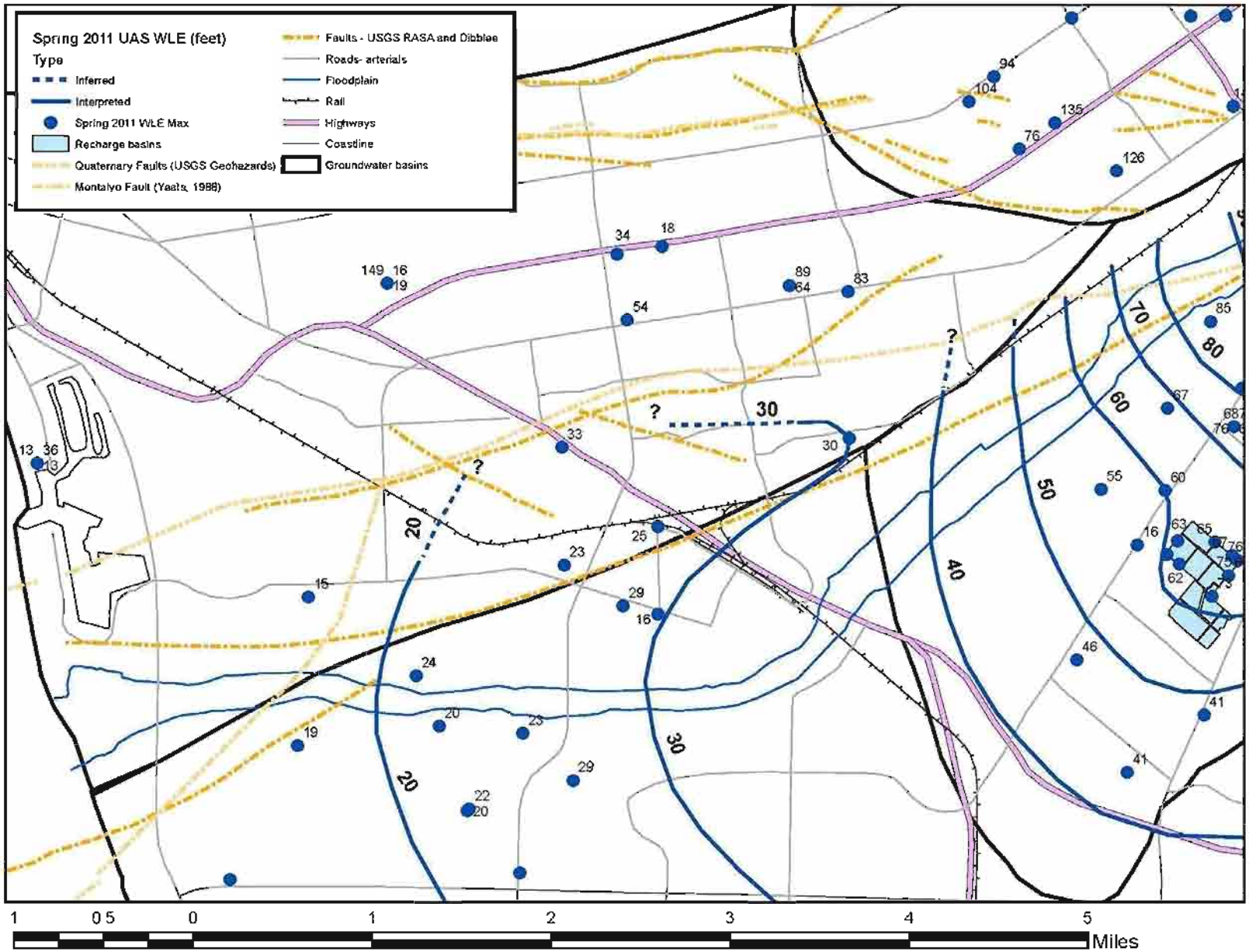


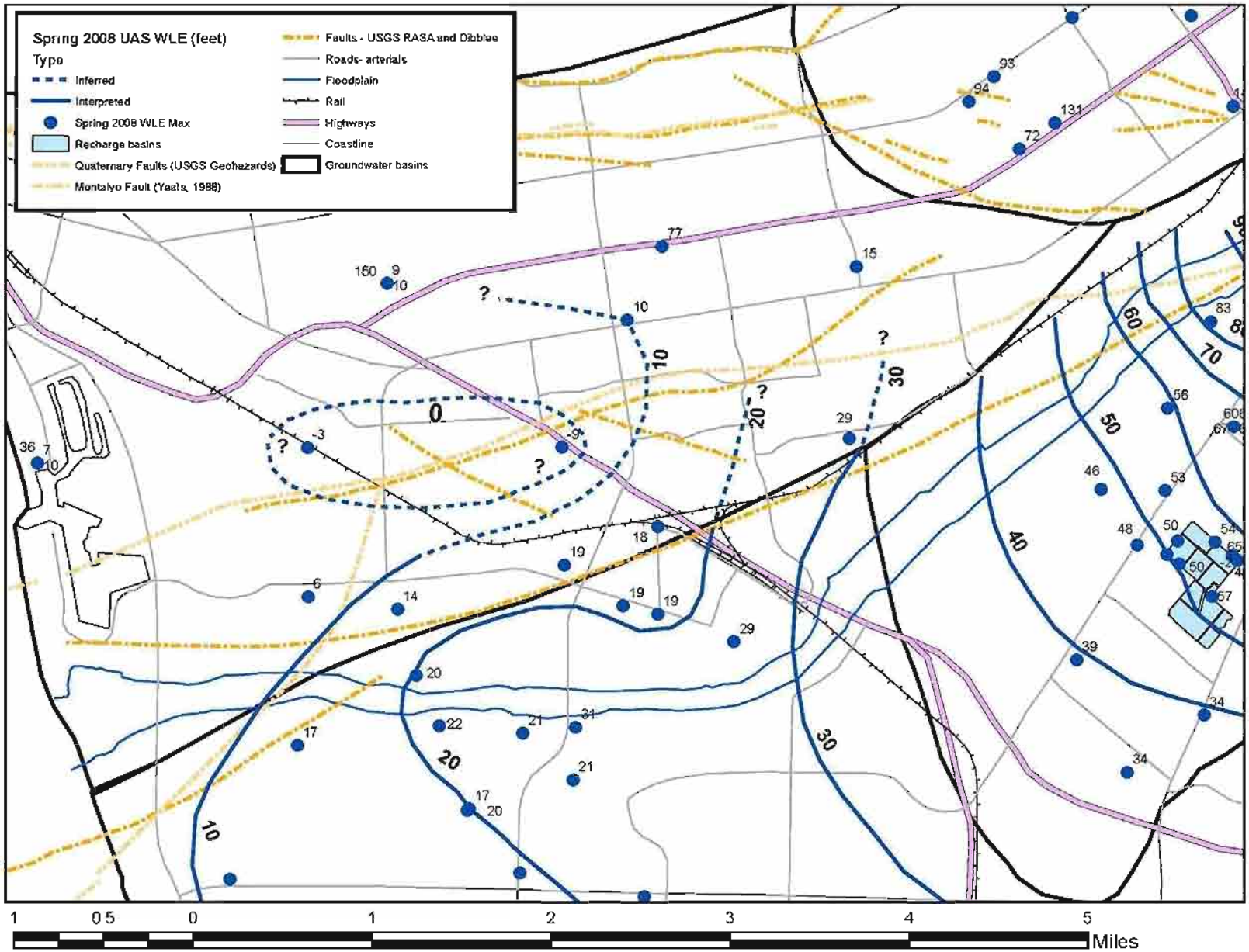
Figure 6-7. Well 02N23W14K01S water quality records.

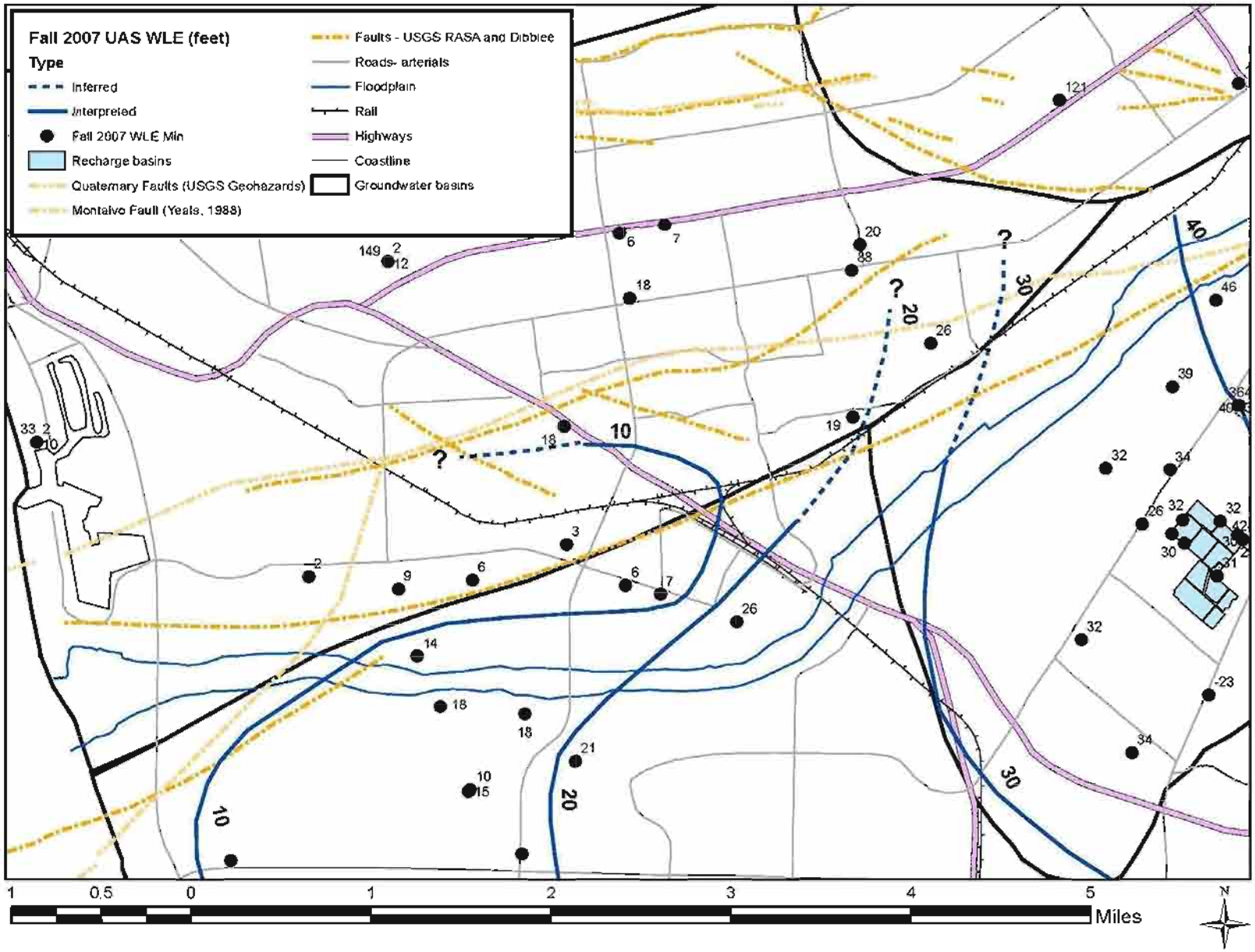
10 APPENDIX B - GROUNDWATER ELEVATION MAPS

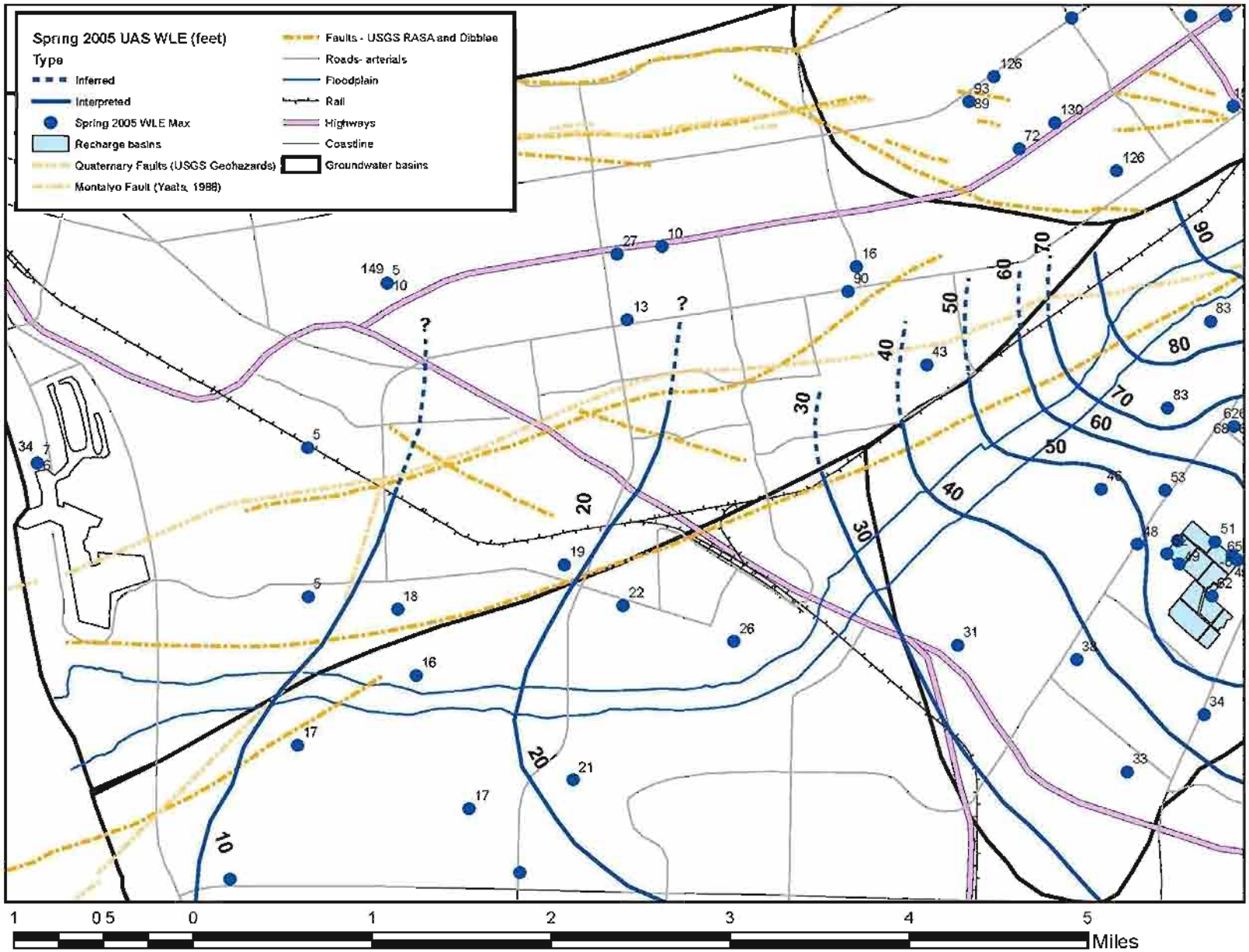
Appendix B contains representative groundwater elevation maps for 2001-2001. If sufficient data were available, both spring and fall groundwater elevation maps are included.

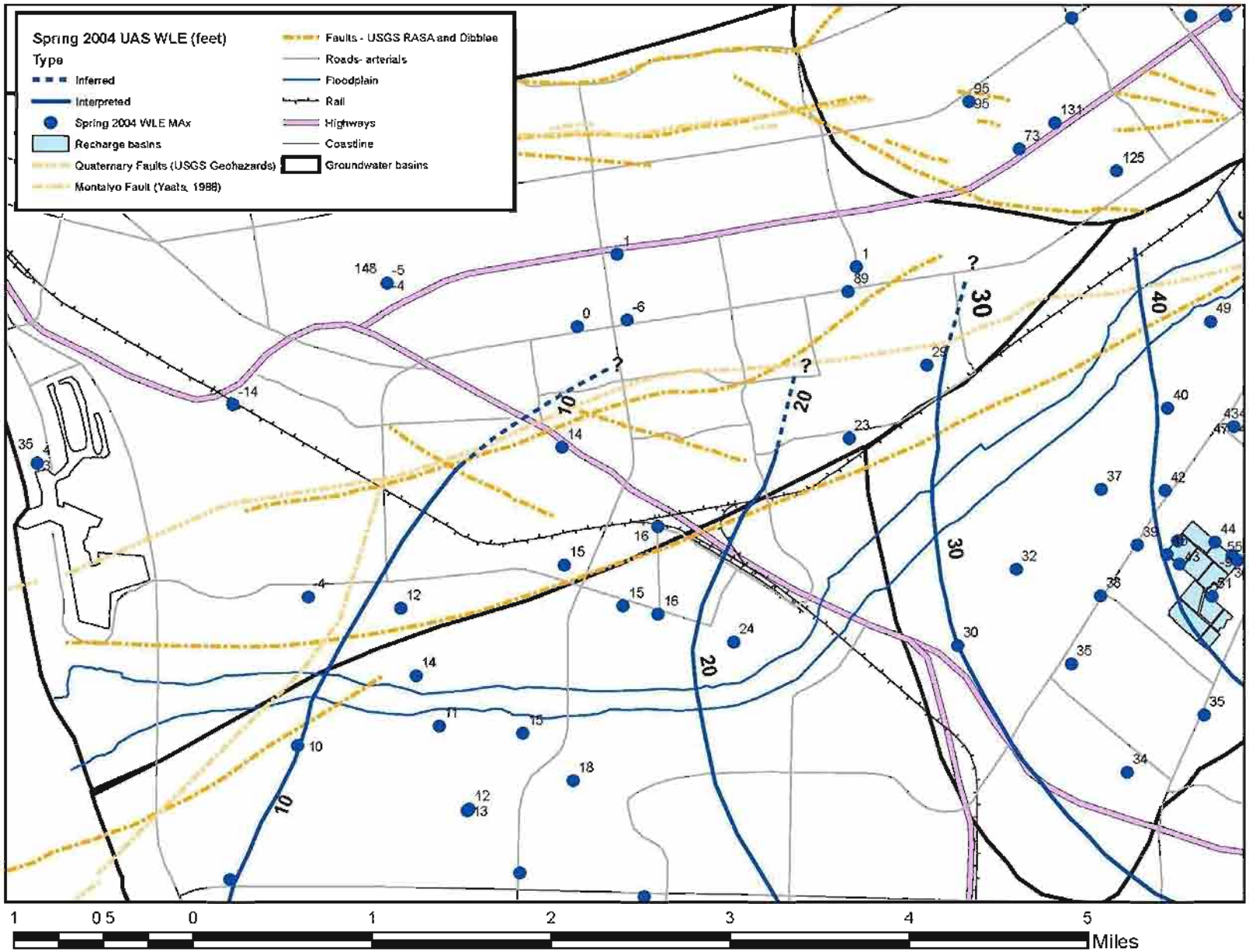

Fall 2011 UAS WLE (feet)
Type
Inferred
Interpreted
Fall 2011 WLE Min
Recharge basins
Quaternary Faults (USGS Geohazards)
Montalvo Fault (Yeats, 1988)
Faults - USGS RASA and Dibblee
Roads- arterials
Floodplain
Rail
Highways
Coastline
Groundwater basins
1 0.5 0 1 2 3 4
Miles
N

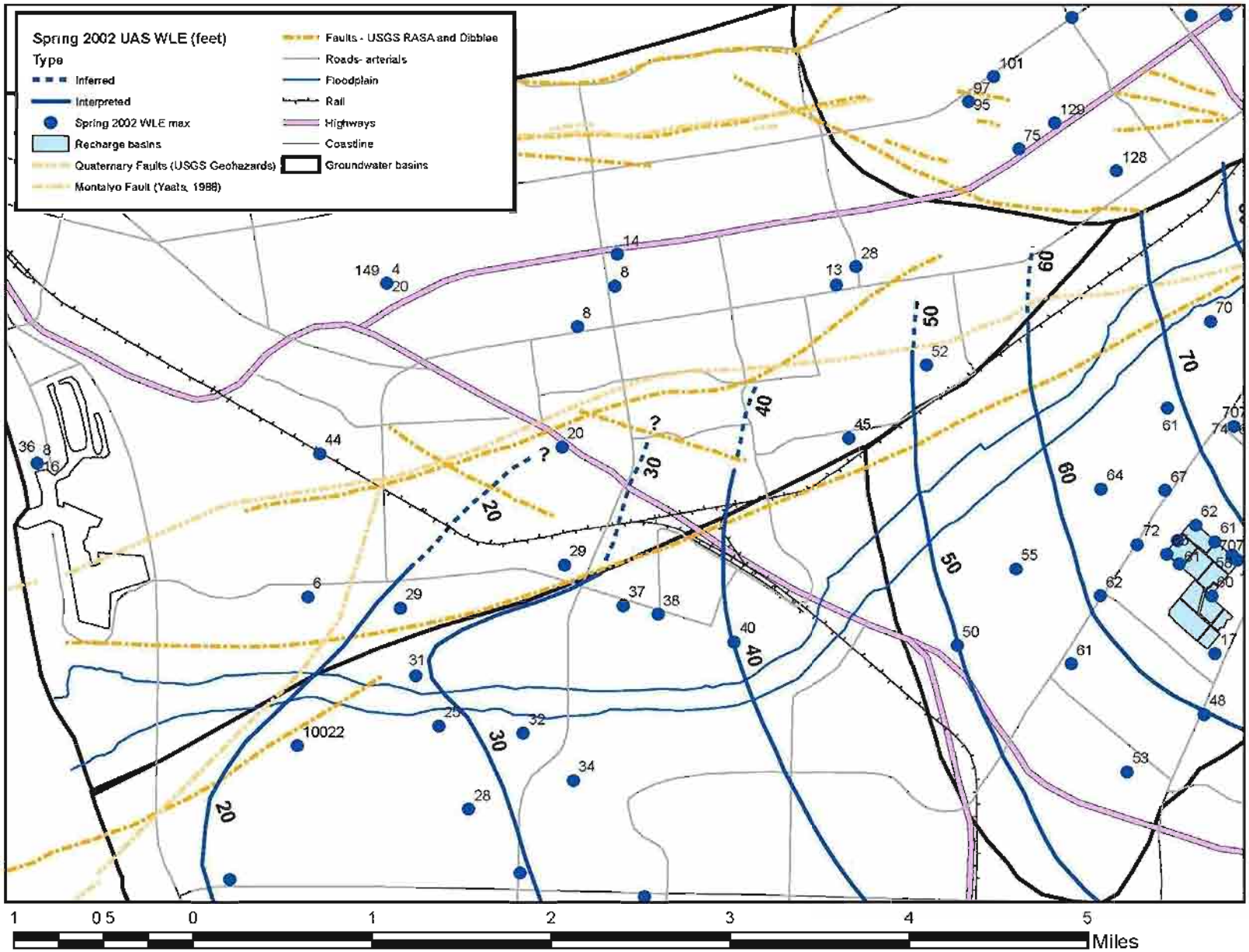

Spring 2011 UAS WLE (feet)
Type
Inferred
Interpreted
Spring 2011 WLE Max
Recharge basins
Quaternary Faults (USGS Geohazards)
Montalvo Fault (Yeats, 1988)
Faults - USGS RASA and Dibblee
Roads- arterials
Floodplain
Rail
Highways
Coastline
Groundwater basins
1 0 5 0 1 2 3 4 5
Miles

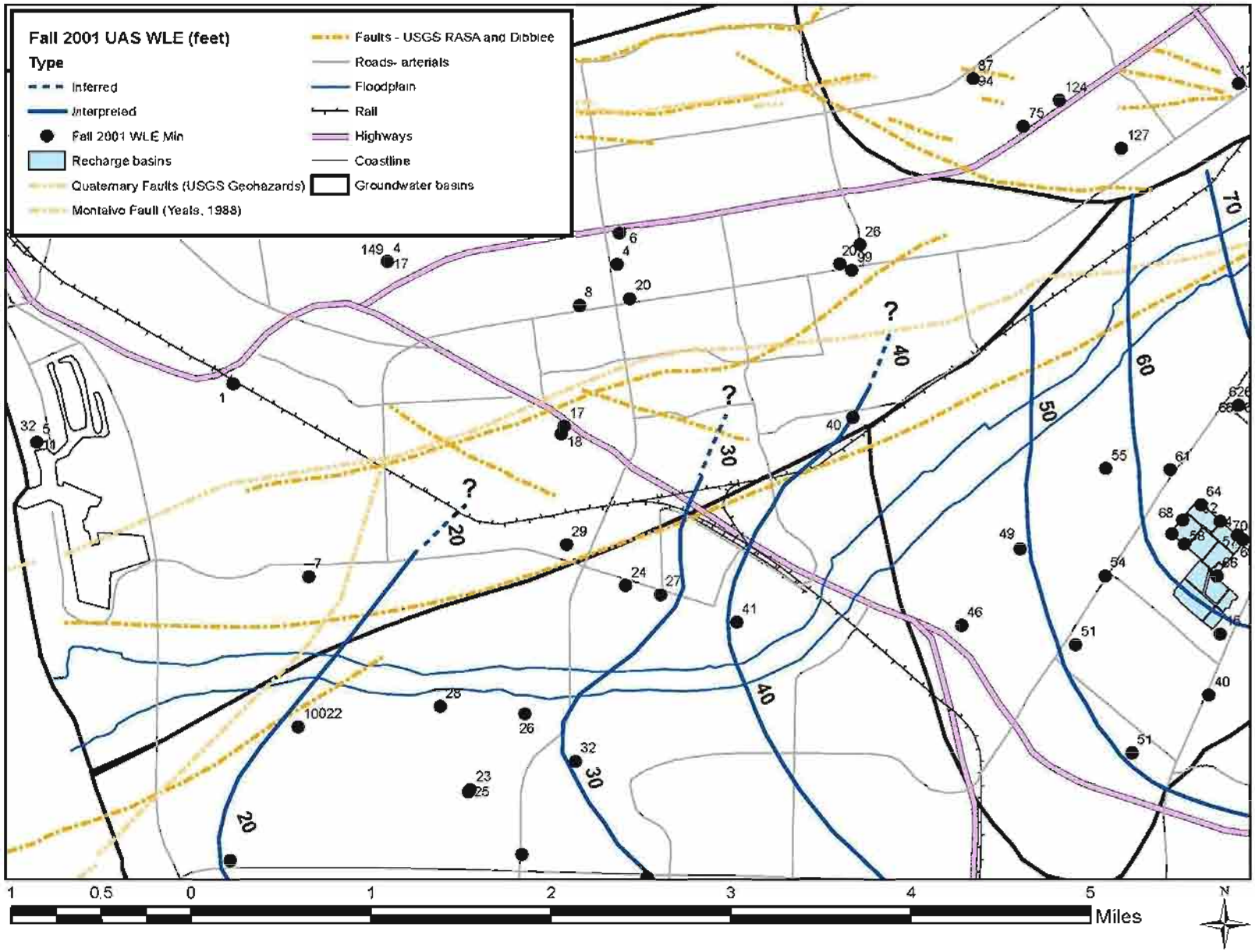

Spring 2008 UAS WLE (feet)
Type
Inferred
Interpreted
Spring 2008 WLE Max
Recharge basins
Quaternary Faults (USGS Geohazards)
Montalvo Fault (Yeats, 1988)
Faults - USGS RASA and Dibblee
Roads- arterials
Floodplain
Rail
Highways
Coastline
Groundwater basins
1 0.5 0 1 2 3 4 5
Miles


Fall 2007 UAS WLE (feet)
Type
Inferred
Interpreted
Fall 2007 WLE Min
Recharge basins
Quaternary Faults (USGS Geohazards)
Montalvo Fault (Yeats, 1988)
Faults - USGS RASA and Dibblee
Roads- arterials
Floodplain
Rail
Highways
Coastline
Groundwater basins
1 0.5 0 1 2 3 4 5
Miles
N


Spring 2005 UAS WLE (feet)
Type
Inferred
Interpreted
Spring 2005 WLE Max
Recharge basins
Quaternary Faults (USGS Geohazards)
Montalvo Fault (Yeats, 1988)
Faults - USGS RASA and Dibblee
Roads- arterials
Floodplain
Rail
Highways
Coastline
Groundwater basins
1 0.5 0 1 2 3 4 5
Miles


Spring 2004 UAS WLE (feet)
Type
Inferred
Interpreted
Spring 2004 WLE MAx
Recharge basins
Quaternary Faults (USGS Geohazards)
Montalvo Fault (Yeats, 1988)
Faults - USGS RASA and Dibblee
Roads- arterials
Floodplain
Rail
Highways
Coastline
Groundwater basins
10
20
30
40
1 0.5 0 1 2 3 4 5
Miles


Spring 2002 UAS WLE (feet)
Type
Inferred
Interpreted
Spring 2002 WLE max
Recharge basins
Quaternary Faults (USGS Geohazards)
Montalvo Fault (Yeats, 1988)
Faults - USGS RASA and Dibblee
Roads- arterials
Floodplain
Rail
Highways
Coastline
Groundwater basins
1 0.5 0 1 2 3 4 5
Miles


Fall 2001 UAS WLE (feet)
Type
Inferred
Interpreted
Fall 2001 WLE Min
Recharge basins
Quaternary Faults (USGS Geohazards)
Montalvo Fault (Yeats, 1988)
Faults - USGS RASA and Dibblee
Roads- arterials
Floodplain
Rail
Highways
Coastline
Groundwater basins
1 0.5 0 1 2 3 4 5
Miles
N

United Water Conservation District

Comprehensive Annual Financial Report
for the
Fiscal Year Ended June 30, 2012

Prepared By:
Finance Division

106 N. 8th Street, Santa Paula, CA 93060 • (805) 525-4431 • www.unitedwater.org

United Water Conservation District
Comprehensive Annual Financial Report
For the Fiscal Year Ended June 30, 2012

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Introductory Section

Board of Directors
Daniel C. Naumann, President
Lynn Maulhardt, Vice President
F.W. Richardson, Secretary/Treasurer
Sheldon G. Berger
Bruce E. Dandy
Robert Eranio
Roger E. Orr

Legal Counsel
Anthony H. Trembley

General Manager
E. Michael Solomon

UNITED WATER CONSERVATION DISTRICT
"Conserving Water since 1927"

December 19, 2012

To the Honorable Board of Directors of United Water Conservation District:

We are pleased to present the United Water Conservation District's (District) Comprehensive Annual Financial Report (CAFR) for the year ended June 30, 2012. This report was prepared in accordance with generally accepted accounting principles as promulgated by the Governmental Accounting Standards Board (GASB) and other accounting and rule making bodies.

District management assumes full responsibility for the completeness and reliability of the information contained in this report, based upon a comprehensive framework of internal controls that has been established for this purpose. Because the cost of internal controls should not exceed its anticipated benefits, the objective is to provide reasonable, rather than absolute, assurance that the financial statements are free of any material misstatements.

Fanning and Karrh, Certified Public Accountants, have issued an unqualified ("clean") opinion on the District's financial statements for the year ended June 30, 2012. The independent auditors' report is located at the front of the financial section of this report (pages 12-13).

Management's discussion and analysis (MD&A) immediately follows the independent auditors' report and provides a narrative introduction, overview, and analysis of the basic financial statements. The MD&A complements this letter of transmittal and should be read in conjunction with it.

Profile of the Government

In 1925, the founding organization of today's United Water Conservation District, the Santa Clara River Protection Association (Association), was formed to protect the runoff of the Santa Clara River from being exported outside the watershed. This effort was successful, and in 1927 the Association was reorganized into the Santa Clara Water Conservation District by vote of the county residents.

In 1950, the District reformed under the State Water Conservation Act of 1931, as the United Water Conservation District, to issue bonds to raise money for construction of the Santa Felicia Dam (SFD), creating Lake Piru and other conservation facilities. The District is divided into seven divisions and is governed by an elected seven-member Board of Directors, serving four year staggered terms.

The District covers approximately 214,000 acres in central Ventura County, California.

The District administers a "basin management" program for the Santa Clara Valley and Oxnard Plain, utilizing the Santa Clara River and its tributaries for replenishment of groundwater. The District is the sole groundwater recharger for the Oxnard Plain.

The District's facilities include the Santa Felicia Dam, Lake Piru Recreation Area, Saticoy, El Rio and Piru spreading grounds, the Freeman Diversion, the Saticoy Well Field, the Pleasant Valley, Oxnard-Hueneme and Pumping Trough delivery systems (pipelines) that include wells, reservoirs and booster pumping stations.

The District's mission is to *manage, protect, conserve and enhance the water resources of the Santa Clara River, its tributaries, and associated aquifers in the most cost effective and environmentally balanced manner.* This mission statement provides the overall policy direction for District staff to manage and prioritize its programs and activities.

The Board adopts the District's annual operating and capital improvement budget by no later than June 30th for the upcoming fiscal year (July 1 through June 30). The budget is prepared by staff by fund, department, account (e.g. utilities, maintenance, etc.) and project in order to proportionally allocate costs to the District's primary cost centers (funds) and submitted to the Board in a fund-account presentation with a detailed discussion of the proposed budget which is reviewed and deliberated on from approximately May 1 until the public hearing in June when the spending plan is adopted.

Local Economy

The District is located in the center of Ventura County, a county with a strong economic base with a large and diverse labor pool. The area includes major industries: agriculture, biotechnology, telecommunications and advanced technologies, manufacturing, tourism, military testing and development. The Port of Hueneme (which is located within the boundaries of the District) is the State's smallest but only deep-water port between Los Angeles and San Francisco and plays a significant role in the local economy.

Some of the best soil in the nation for agriculture production resides within Ventura County. The crops grown had a total value totaling well over $1,844,260,000 in calendar year 2011, an approximately $15 million decrease when compared to 2010. Ventura County ranks 8th in agricultural production among California counties and 10th in the nation. Within the District boundaries, agriculture remains especially important along the coastal Oxnard Plain and the interior Santa Clara Valley communities of Santa Paula, Fillmore and Piru.

While Ventura County continues to experience some economic downturn related to the housing market, the rate of decline experience in FY 2011-12 was less than the prior year. In FY 2011-12, property assessment for the County decreased .16% as compared to FY 2010-11. The County Assessor's Office projects that in FY 2012-13, countywide property tax assessments will increase .61%, which will likely have a positive impact on the District's General/Water Conservation Fund (formally the General Fund).

Another indication that the economy in Ventura County is experiencing some improvement can be seen in the unemployment numbers. For October 2012, the California Employment Development Department listed a civilian labor force for Ventura County of 440,000 (not

seasonally adjusted) and an unemployment rate of 8.6% with a ranking of 11th in the State of California. This represents a 1.9% decrease over the prior year. The statewide October 2012 unemployment rate was 9.8%.

Long-term Financial Planning

In FY 2011-12, the District issued no new debt but instead focused on the completion of several capital projects that were funded in prior years with Series 2005B and Series 2006A water revenue bonds and 2009 Certificates of Participation. No new debt is planned for FY 2012-13. In FY 2011-12, completed capital improvement projects include: the OH Gas Booster Building, Reasoner Canyon Bank Protection and a District Wide Communication Network project. In FY 2012-13, a proposed Seawater Intrusion Barrier project was cancelled due to the District's re-evaluation of water conservation projects and the City of Oxnard's reevaluation of its participation in the project. The planned PVP Reservoir Leak Repair CIP was cancelled; other reservoir stabilization work was performed instead as a maintenance project. The replacement of the Oak Lane Restroom was cancelled and the budgeted Series 2009 COPs funds were reallocated to several other Lake Piru Recreation Area capital improvement and maintenance projects that meet the criteria of the Certificate of Participation funds that will be undertaken in FY 2012-13.

The District continued to make substantial progress on the Habitat Conservation Plan (HCP) and is close to completing the evaluation, analysis and selection of an alternative fish passage facility for the Freeman Diversion. In FY 2012-13, efforts will focus on geotechnical survey of the Santa Clara River bedrock above the Freeman and the design, specification and permitting of a hardened ramp fish passage facility.

Progress was made on the Federal Energy Regulatory Commission (FERC) and Department of Dam Safety (DODS) required Probable Maximum Precipitation/Flood (PMP/PMF) study. The findings from the completed PMP/PMF studies showing that rainfall amounts are substantially lower than suggested by the National Weather Service model were submitted to FERC and DODS. While FERC and DODS did not approve the District's study findings, FERC did inform the District verbally that it plans to reject the site-specific PMP/PMF. However, they also stated that it plans to eliminate the use of the National Weather Service rainfall model which is the cause for the significant speculative potential flooding scenario that could lead to significant District capital improvement expenditures.

The District's effort to comply with the SFD FERC license also progressed in FY 2011-12. FERC accepted several required plans and the District began implementation of the geomorphology study. The District's Groundwater Department continued to make significant progress on the three-year effort to update the Ventura County Regional Groundwater Flow Model. The existing model is not sufficiently detailed to be used to address the types of groundwater resource management planning and demands required of the District.

Currently, the District does not have an approved Water Management Plan and it is anticipated that the District will begin developing a Water Management Plan in FY 2012-13 and that it will be submitted to the Board for consideration in the near future. The amended Plan will attempt to address the projects necessary to resolve the highest priority water resource needs of the District in the future, especially as it deals with the impacts of the ESA requirements.

In FY 2011-12, the District's Fund Reserve Policy's established goal for the General Fund (reclassified as the General/Water Conservation Fund in FY 2012-13) was to maintain $2.5 - $3 million dollars in unrestricted unassigned fund balance. This reserve balance provides rate stabilization capabilities, funding for one-time unanticipated expenditures, necessary operational capital during negative cash flow periods and emergency funds that are necessary for repairs and maintenance of District facilities that have been damaged or destroyed by a natural disaster, major accident or mechanical malfunction, etc. In FY 2012-13, the reserve level was increased by the Board of Directors to $4 - $5 million dollars to address cash flow issues that resulted from increasing expenditures associated with environmental compliance requirements, capital projects, legal costs and an aging infrastructure. The District also maintains fiscally responsible reserve levels in its other primary operating funds. The minimum reserve levels in several of these funds are set per negotiated levels between the District and its contracted customers and contractual reserve levels. As of June 30, 2012, the reserve levels for all of the District's funds are within the acceptable limits or above the amounts set by the District's Reserve Policy.

While recreation is not part of the core operation of the District, providing public access to recreational facilities at Lake Piru is a requirement of the permit that was issued as part of the construction of the Santa Felicia Dam in 1955. In FY 2011-12, the District continued to operate the Lake Piru Recreation Area with a significantly reduced District presence at the lake. In place of a larger workforce at Lake Piru, the District relies on a contract concessionaire to plan and carry out recreation operations and services. The term of the District's original five year operating agreement with its concessionaire, Recreational Resource Management (RRM), was extended eight years to December 2020 for the operation of the lake's recreation services and facilities. In FY 2011-12, the District and RRM continued work on long range improvement and operational plans. This effort will carry over to FY 2012-13 as the District and RRM work together to streamline operations and enhance services.

In summary, the District faces some significant costs in the near future. Compliance with environmental and regulator mandates are the largest expected impacts while rehabilitation and/or replacement of aging infrastructure will be necessary to prevent operational impacts. The Board has made decisions to raise rates in the past few years to begin dealing with these costs. The City of Ventura lawsuits results could have a major impact to future District financial planning.

Relevant Financial Policies

The District has written, detailed financial policies for:

- Reserves
- Investments
- Budget Amendments
- Budget Submittal/Preparation
- Procurement
- Expense Reimbursement
- Disclosure of Reimbursement (Government Code Section 53065.5)
- Fixed Assets
- Vehicle and Equipment Replacement and Maintenance

- Engineering Projects and Contract Administration
- Financial Records Management Retention and Destruction
- Fraud Prevention/Detection Policy

In FY 2012-13, the District adopted an Environmental Activity Cost Allocation Policy to provide clearer direction on how activities associated with the District's efforts to comply with the Federal Endangered Species Act and miscellaneous environmental mandates are funded.

As time allows, staff also plans to develop thorough policies for:

- District-wide Risk Management (the District is currently insured comprehensively for property loss, tort liability, and workers' compensation). The goal of the written policy will be to ensure consistent application of risk management and risk transfer throughout the District.
- Disposition of Surplus assets.

<u>Major Initiatives</u>

- The District continues to expend time and resources to gain compliance with FERC requirements associated with the operating license for SFD. In FY 2011-12, the District submitted several plans to FERC including the fish passage feasibility assessment study plan and ramping rate and depth relationship plan. Efforts to complete the fish passage feasibility plan will continue through FY 2013-14. The District's efforts to complete some of the remaining plans are being slowed as a result of issues associated with access to private lands. NMFS has directed the District to prepare and submit monitoring plans based on two scenarios, with and without access to private lands, and resubmit the plans back to FERC. The District is and will continue to work towards compliance with the environmental requirements of its FERC license.

- The District continued the long process of complying with environmental requirements related to the operations of the Freeman Diversion including compliance with the ESA, which lists Southern California steelhead as an endangered species. The independent panel formed in compliance with the settlement agreement with CalTrout, issued a final report with its recommendations for improving fish passage. Based on the panel's conclusions, the District began the design and specification of a new fish passage facility anticipated to cost $24 to $30 million. In FY 2012-13, the District will continue the design work. As of November 2012, the District performed a geotechnical survey of the Santa Clara River bedrock above the Freeman Diversion. The resulting data will be used in developing the specification for the construction of the new passage facility. The next step is to take the fish passage facility from its current conceptual design to a final design.

- The District is also in the process of preparing an HCP in order to receive a future incidental take permit for the Freeman Diversion under section 10 requirements of the ESA. While the HCP could lead to a loss of water yield and decrease the amount available for groundwater recharge, the District must proceed forward in order to carry out its mission to protect vital water resources. In accordance with the District's newly adopted Environmental Activities Cost Allocation Policy,

expenditures associated with HCP are funded 50/50 by the General/Water Conservation Fund and Freeman Fund. Cost associated with ESA compliance that are tied to the physical operation and maintenance of the Freeman Diversion, including capital improvements, are funded by the Freeman Fund.

- The District continues to wait for official written notification from FERC regarding its stated rejection of the District's and Department of Water Resources' (DWR) site-specific "Probable Maximum Flood" and "Probable Maximum Precipitation" (PMF /PMP) studies. The studies, approved by the Board of Consultants, provide findings that show rainfall amounts substantially lower than those suggested by the National Weather Service (NWS) model. The potential flooding scenario under the existing NWS model could result in significant capital improvement cost to the SFD spillway and height of the dam wall. However, FERC and the California Division of Safety of Dams (DSOD) have also verbally stated that they plan to eliminate the use of the existing NWS rainfall model. Such action would most likely delay any future work on this project for several years until such time as the NWS is able to complete a new model.

- A structural analysis of the Santa Felicia Dam outlet works structures was performed to determine the seismic adequacy. While the final results of the analyses have not been received, preliminary reports indicate that two structures (intake tower and penstock) are insufficient to withstand the largest credible earthquake. In FY 2012-13, the District will continue efforts to finalize the structural analysis and develop recommendations to replace the two structures. It is anticipated that the rehabilitation of the two structures is in the order of $13 to $30 million.

- In August 2011 and August 2012, the City of Ventura filed petitions for writ of mandate, petitions for writ of administrative mandate, complaints for declaratory relief and complaints for determination of invalidity against the District seeking to invalidate the fiscal year 2011-12 and FY 2012-13 water rates adopted by the District's Board of Directors. The District is vigorously defending the action. It is anticipated that until the question of the District's rate setting methodology and the other matters contained in the City's lawsuits have been fully resolved, Ventura will file new lawsuit each August on similar grounds.

Awards and Acknowledgements

The Government Finance Officers Association of the United States and Canada (GFOA) awarded a Certificate of Achievement for Excellence in Financial Reporting to the District for its comprehensive annual financial report (CAFR) for the fiscal year ended June 30, 2011. In order to be awarded a Certificate of Achievement, the District must publish an easily readable and efficiently organized CAFR. This report must satisfy both generally accepted accounting principles and applicable legal requirements.

A Certificate of Achievement is valid for a period of one year only. Staff believes that the current CAFR continues to meet the Certificate of Achievement Program's requirements and is submitting it to the GFOA to determine its eligibility for their certificate.

Acknowledgments

We would like to thank the entire staff (in particular Christine Williams, the District's Controller, Stacey Steffensen, Senior Accountant, and Karon Webb, Senior Accountant, of the Finance Division) for their contributions and assistance in the preparation of this year's Comprehensive Annual Financial Report. We would also like to recognize the efforts of the District's auditors, Fanning and Karrh, CPA's. Finally, to the Board of Directors, sincere appreciation for its innovative leadership, and the latitude and support in maintaining a sound financial system that includes integrity, reliability and appropriate technical support, without which this report could not be prepared.

We would like to assure the Board that its dedicated staff embraces the mission of the District and pursues continuous improvements to our operations, while remaining fiscally responsible and accountable to all those whom we serve.

Respectfully submitted,

E. Michael Solomon
General Manager

Mary Kanatzar
Administrative Services Manager

Certificate of Achievement for Excellence in Financial Reporting

Presented to

United Water Conservation District, California

For its Comprehensive Annual
Financial Report
for the Fiscal Year Ended
June 30, 2011

A Certificate of Achievement for Excellence in Financial Reporting is presented by the Government Finance Officers Association of the United States and Canada to government units and public employee retirement systems whose comprehensive annual financial reports (CAFRs) achieve the highest standards in government accounting and financial reporting.

President

Executive Director

United Water Conservation District
BOARD OF DIRECTORS
AND EXECUTIVE MANAGEMENT
June 30, 2012

Board of Directors

Daniel C. Naumann
President
Representing Division 6

Lynn E. Maulhardt
Vice President
Representing Division 4

F. W. Richardson
Secretary/Treasurer
Representing Division 1

Sheldon G. Berger
Representing Division 7

Bruce Dandy
Representing Division 5

Robert Eranio
Representing Division 3

Roger E. Orr
Representing Division 2

Executive Management

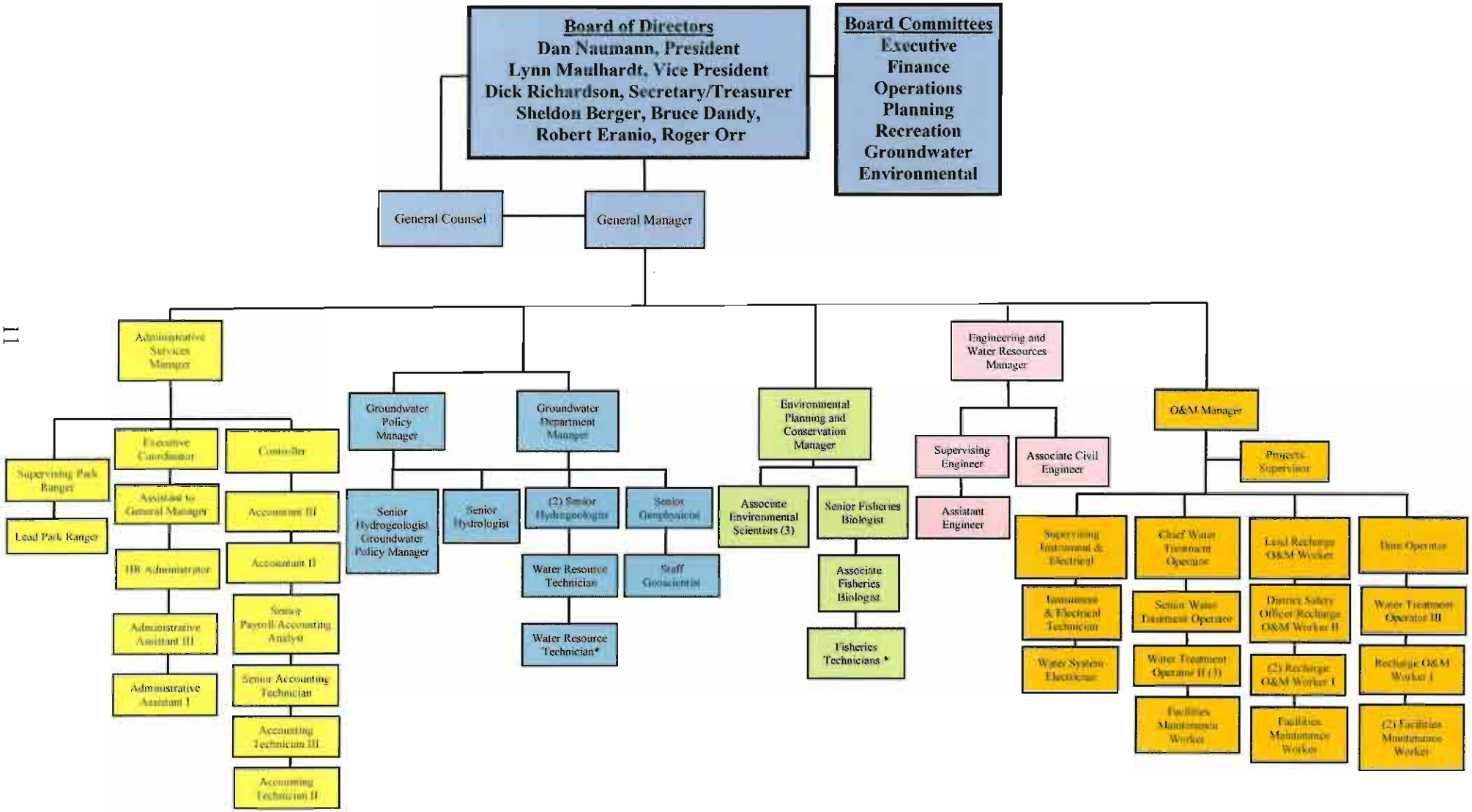
E. Michael Solomon
General Manager

Anthony H. Trembley
Legal Counsel

Organizational Chart

UNITED WATER CONSERVATION DISTRICT

June 2012



* Temporary, extra-help or seasonal positions, as needed

Financial Section

Fanning & Karrh
Certified Public Accountants

A Professional Corporation

290 Maple Court, Suite 140
Ventura, California 93003
Telephone (805) 654-0450
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INDEPENDENT AUDITORS' REPORT

To the Honorable Board of Directors of
United Water Conservation District:

We have audited the accompanying financial statements of the governmental activities, the business-type activities, each major fund and the aggregate remaining fund information of United Water Conservation District as of and for the year ended June 30, 2012, which collectively comprise United Water Conservation District's basic financial statements as listed in the table of contents. These financial statements are the responsibility of United Water Conservation District's management. Our responsibility is to express opinions on these basic financial statements based on our audit.

We conducted our audit in accordance with auditing standards generally accepted in the United States of America and the standards applicable to financial audits contained in *Government Auditing Standards*, issued by the Comptroller General of the United States. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for our opinions.

In our opinion, the financial statements referred to above present fairly, in all material respects, the respective financial position of the governmental activities, the business-type activities, each major fund and the aggregate remaining fund information of United Water Conservation District as of June 30, 2012 and the respective changes in financial position and, where applicable, cash flows thereof for the year then ended in conformity with accounting principles generally accepted in the United States of America.

In accordance with *Government Auditing Standards*, we have also issued our report dated December 19, 2012, on our consideration of United Water Conservation District's internal control over financial reporting and on our tests of its compliance with certain provisions of laws, regulations, contracts and grants agreements and other matters. The purpose of that report is to describe the scope of our testing of internal control over financial reporting and compliance and the results of that testing and not to provide an opinion on internal control over financial reporting or on compliance. That report is an integral part of an audit performed in accordance with *Government Auditing Standards* and should be considered in assessing the results of our audit.

Accounting principles generally accepted in the United States of America require that the management's discussion and analysis and Required Supplementary Information on pages 14 through 33 and 67 through 71 be presented to supplement the basic financial statements. Such information, although not a part of the basic financial statements, is required by the Governmental Accounting Standards Board, who considers it to be an essential part of financial reporting for placing the basic financial statements in an appropriate operational, economic, or historical context. We have applied certain limited procedures to the required supplementary information in accordance with auditing standards generally accepted in the United States of America, which consisted of inquiries of management about the methods of preparing the information and comparing the information for consistency with management's responses to our inquiries, the basic financial statements, and other knowledge we obtained during the audit of the basic financial statements. We do not express an opinion or provide any assurance on the information because the limited procedures do not provide us with sufficient evidence to express an opinion or provide any assurance.

Our audit was conducted for the purpose of forming opinions on the financial statements that collectively comprise United Water Conservation District's financial statements as a whole. The introductory section and statistical section are presented for purposes of additional analysis and are not a required part of the basic financial statements. The introductory section and statistical section have not been subjected to the auditing procedures applied in the audit of the basic financial statements and, accordingly, we do not express an opinion or provide any assurance on them.

Fanning & Kane

December 19, 2012

Management's Discussion and Analysis (MD&A)

This section of United Water Conservation District's (District) annual financial report presents management's narrative overview and analysis of the District's financial activities during the fiscal year that ended on June 30, 2012 (FY 2012). The purpose of the MD&A is to provide users of the District's basic financial statements with a narrative introduction, overview and analysis of those statements. The goal is to provide the MD&A in an objective and easily readable format of the District's financial activities based on currently known facts, decisions and conditions. You are encouraged to read the MD&A in conjunction with the transmittal letter, which can be found at the front of this report and the District's financial statements, which follow this MD&A section. Generally Accepted Accounting Principles (GAAP) identifies specific topics that are to be addressed in the MD&A relative to the District's particular circumstances. The letter of transmittal, which can be found on pages 2-8, provides the appropriate place for District management to address topics not identified by GAAP for inclusion within the MD&A.

Financial Highlights

- The District's total assets ($98,123 thousand) exceeded its total liabilities ($26,507 thousand) at the end of FY 2012 by $71,616 thousand (which represents the District's total net assets). The District's total net assets increased by $4,078 thousand over the course of this year's operations (total net assets as of June 30, 2011 were $67,538 thousand compared to $71,616 thousand at June 30, 2012).

- The $4,078 thousand increase in District total net assets is the result of a $2,441 thousand increase in governmental activities combined with a $1,637 thousand increase in business-type activities during the fiscal year ended June 30, 2012.

- The total net assets of the District at the close of the fiscal year ended June 30, 2012 ($71,616 thousand) includes $11,159 thousand (15.58%) in *unrestricted* net assets that may be used by the District to meet ongoing obligations to constituents, customers and creditors. The District's unrestricted net assets increased by $2,996 thousand from $8,163 thousand at June 30, 2011.

- Of the District's total net assets ($71,616 thousand), $58,680 thousand (81.94%) comprise investments in *capital assets* (e.g. land, dams, structures, buildings, machinery and equipment, etc.), less any related debt used to acquire those assets that is still outstanding as of June 30, 2012. These capital assets are used to provide District services and therefore *are not* available for future spending. The $58,680 thousand at June 30, 2012 represents a $809 thousand increase in investments in capital assets from $57,871 thousand at June 30, 2011.

- Current year-end restricted net assets of $1,777 thousand comprise the remaining balance of the District's total net assets, an increase of $273 thousand from the prior year's *restricted net assets* of $1,504 thousand. Restricted net assets represent assets of the District whose use is subject to constraints that are either (a) externally imposed by creditors (such as through debt covenants), grantors, contributors, or laws or regulations of other governments or (b) imposed by law through constitutional provisions or enabling legislation. The increase of $273

thousand was entirely the net result of a $273 thousand increase in governmental-type activities ($1,777 thousand at June 30, 2012 compared to $1,504 thousand at June 30, 2011). There were no business-type activities that resulted in restricted net assets at June 30, 2012 or at June 30, 2011.

- The District's total revenues increased by $1,817 thousand as compared to the prior year's total revenues ($20,132 thousand in FY 2012 as compared to $18,315 thousand in FY 2011). The increase is primarily a result of the increase in charges for services ($17,642 thousand in FY 2012 compared to $15,879 FY 2011). Operating grants increased by $100 thousand as compared to the prior year ($100 thousand in FY 2012 as compared to $0 in FY 2011). Property taxes increased by $66 thousand in FY 2012 compared to FY 2011 ($2,016 thousand in FY 2012 compared to $1,950 thousand in FY 2011). Other general revenues increased by $145 thousand ($259 thousand in FY 2012 as compared to $114 thousand in FY 2011). Revenue increases were partially offset by decreases of $237 thousand in capital grants ($44 thousand in FY 2012 as compared to $281 thousand in FY 2011) and a decrease of $20 thousand in unrestricted investment earnings ($71 thousand in FY 2012 as compared to $91 thousand in FY 2011).

- The District's total expenses increased $208 thousand compared to the prior year's expenses ($16,054 thousand in FY 2012 as compared to $15,846 thousand in FY 2011). The increase is primarily the result of a $485 thousand increase in water conservation expenses ($7,518 thousand in FY 2012 compared to $7,033 thousand in FY 2011). Recreation facility expenses increased by $61 thousand as compared to FY 2011 ($816 thousand in FY 2012 as compared to $755 thousand in FY 2011). The increases in FY 2012 were partially offset by a decrease of $83 thousand in Freeman Diversion facility expenses ($1,492 thousand in FY 2012 as compared to $1,575 thousand in FY 2011), a decrease of $178 thousand in water delivery and treatment facilities expenses ($4,531 thousand in FY 2012 as compared to $4,709 thousand in FY 2011) and a decrease in interest on long-term debt by $78 thousand ($931 thousand in FY 2012 as compared to $1,009 thousand in FY 2011).

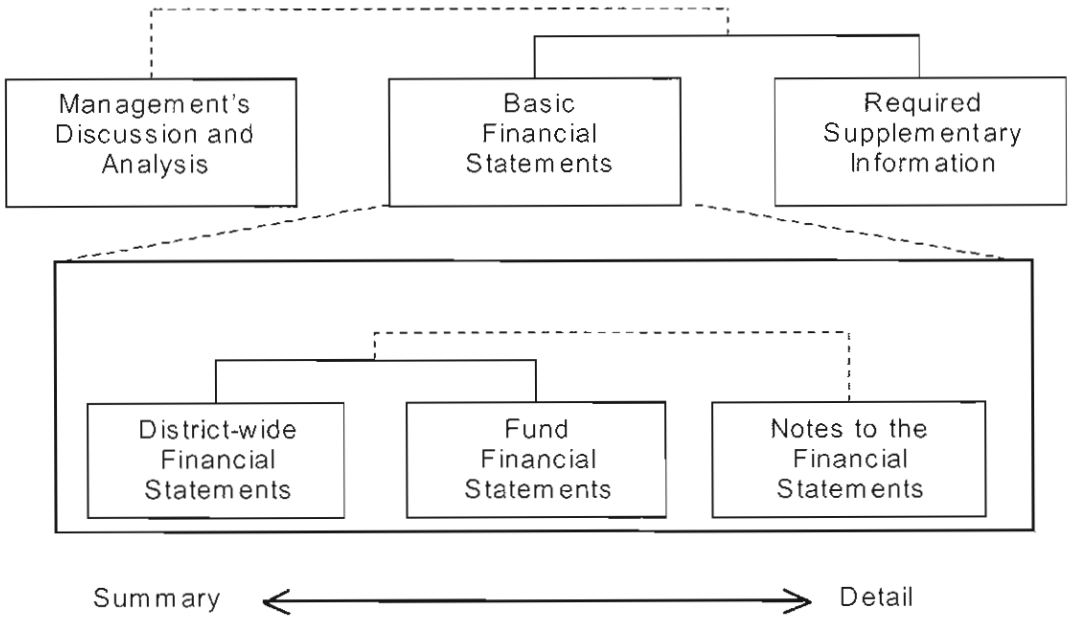
- The District's long-term liabilities decreased by $3,330 thousand ($25,379 thousand at June 30, 2012 compared to $28,709 thousand at June 30, 2011). Long-term liabilities decreased by $2,526 thousand in governmental activities and $804 thousand in business activities.

Discussion of the Financial Statements

This discussion and analysis introduces the District's basic financial statements. The District's financial statements comprise three components: 1) district-wide financial statements, 2) fund financial statements, and 3) notes to the financial statements. This report also contains other supplementary information in addition to the basic financial statements. Table A shows how the required parts of this annual report are arranged and are related to each other.

Table A

Required Components of District's Annual Financial Report



District-wide financial statements provide both long-term and short-term information about the District's finances, in a manner similar to a private-sector business.

The *Statement of Net Assets* reports all of the District's assets and liabilities, with the difference between the two reported as *net assets*. Over time, the increases or decreases in net assets indicate whether the District's financial position is improving or deteriorating.

The *Statement of Activities* reports how the District's net assets changed during the most recent fiscal year. It reports all of the revenues and expenses for the year regardless of when cash is received or paid.

The district-wide financial statements of the District are divided into two categories:

- *Governmental activities* are principally supported by taxes, charges for services and intergovernmental revenue. The District's governmental activities include water conservation, general operating, Lake Piru Recreation facilities and State Water Project importation.

- *Business-type activities* charge fees for services. The District's business-type activities include the Freeman Diversion facility and the three water distribution systems (Oxnard-Hueneme, Pleasant Valley and Pumping Trough Pipelines).

The district-wide financial statements can be found on pages 34-35 of this report.

Fund financial statements provide more detail about the District's *funds*, not the District as a whole. Funds are groupings of related accounts that the District uses to maintain control over resources that have been segregated for specific activities or objectives. All of the funds of the

District can be divided into three categories: governmental funds, proprietary funds, and fiduciary funds.

Governmental funds account for essentially the same functions reported as *governmental activities* in the district-wide financial statements. Governmental fund financial statements focus on (1) the near term inflows and outflows of spendable resources and (2) the *balances of resources at year-end* that are available for spending. Consequently, the governmental funds statements provide a detailed *short-term* view that is useful in evaluating near-term financing requirements. Because this information does not include the additional long-term focus of the district-wide statements, both the Governmental Fund Balance Sheet and the Governmental Fund Statement of Revenues, Expenditures, and Changes in Fund Balances, provide a reconciliation to explain the relationship between *governmental funds* and *governmental activities.*

The District maintains two individual governmental funds. The governmental fund statements present information separately for the General Fund and the State Water Import Fund. The District adopts an annual appropriated budget for its General Fund and State Water Import Fund. Budgetary comparison schedules are provided in the required supplementary section to demonstrate compliance with this budget.

The basic governmental fund financial statements can be found on pages 36-37 of this report.

Proprietary funds report services for which the District charges customers a fee. Proprietary funds consist of enterprise funds (fees charged to external users) and internal service funds (fees charged to internal units of the District). The District's *enterprise funds* report the functions presented as *business-type activities* in the district-wide financial statements but provide more detail and additional information, such as cash flows. The District does not currently use internal service funds for centralized services.

The District uses enterprise funds to account for its Freeman Diversion facility, Oxnard-Hueneme Pipeline, Pleasant Valley Pipeline and Pumping Trough Pipeline.

The basic proprietary fund financial statements can be found on pages 38-43 of this report.

Fiduciary funds account for resources held for the benefit of parties outside the District. The district-wide financial statements *do not* reflect the fiduciary funds because the resources of those funds are *not* available to support the District's own programs. The basic fiduciary fund financial statements can be found on pages 44-45 of this report.

Notes to the financial statements provide additional information essential to a full understanding of the data provided in the district-wide and fund financial statements. The notes to the financial statements can be found on pages 46-66 of this report.

The Basic Financial Statements are followed by a section of Required Supplementary Information that further explains and supports the information in the financial statements.

District-wide Financial Analysis

Net Assets. As noted earlier, net assets indicate whether the District's financial position is improving or deteriorating. In the case of the District, total assets exceeded total liabilities by $71,616 thousand at June 30, 2012. This is an increase of $4,078 thousand from the prior year's net assets of $67,538 thousand (See Table 1).

Table 1
United Water Conservation District's Net Assets
(in thousands of dollars)

	Governmental Activities		Business-type Activities		Total	
	2012	2011	2012	2011	2012	2011
Current and other assets	$ 9,523	$ 9,681	$ 7,531	$ 6,155	$ 17,054	$ 15,836
Capital assets	38,235	38,625	42,834	43,730	81,069	82,355
Total assets	47,758	48,306	50,365	49,885	98,123	98,191
Long-term liabilities outstanding	21,097	23,623	4,282	5,086	25,379	28,709
Other liabilities	812	1,275	316	669	1,128	1,944
Total liabilities	21,909	24,898	4,598	5,755	26,507	30,653
Net assets:						
Invested in capital assets, net of related debt	19,661	18,747	39,019	39,124	58,680	57,871
Restricted	1,777	1,504	-	-	1,777	1,504
Unrestricted	4,411	3,157	6,748	5,006	11,159	8,163
Total net assets	$ 25,849	$ 23,408	$ 45,767	$ 44,130	$ 71,616	$ 67,538

The largest portion of the District's net assets ($58,680 thousand or 81.94%) reflects its investment in capital assets (e.g. land, dams, structures, machinery and equipment, etc.) less any related debt used to acquire those assets that is still outstanding. There was an increase in the District's investment in capital assets of approximately $809 thousand from the prior year ($57,871 thousand). This increase is due primarily to completed construction of projects, purchases of additional or replacement machinery and equipment and the reduction of outstanding debt. The increase was partially offset by depreciation expenses ($2,474 thousand) for existing District capital assets in FY 2012.

The District uses these capital assets to provide services for its customers and constituents; consequently, these assets are *not available* for future spending. Although the District's investment in its capital assets is reported net of related debt, it should be noted that the resources needed to repay this debt must be provided by other sources, since the capital assets themselves cannot be used to liquidate these liabilities.

In addition, a portion of the District's total net assets for FY 2012 represents restricted resources totaling $1,777 thousand (an increase of $273 thousand in FY 2012 when compared to total restricted resources of $1,504 thousand in 2011) that are subject to external restrictions (legal or contractual) on how they may be used. The remaining balance of the District's net assets ($11,159 thousand) is unrestricted and may be used to meet the District's ongoing obligations to its constituents and creditors. This represents an increase in total unrestricted net assets of approximately $2,996 thousand from the prior year ($8,163 thousand). The unrestricted net assets for governmental-type activities increased by $1,254 thousand ($4,411 thousand at June 30, 2012

compared to $3,157 thousand at June 30, 2011) and unrestricted net assets for business-type activities increased by $1,742 thousand ($6,748 thousand at June 30, 2012 compared to $5,006 thousand at June 30, 2011).

The $2,441 thousand increase (or 10.43%) in governmental activities' total net assets is the result of total governmental activities' revenues exceeding total expenses for the year from the operational and financial activity (that will be discussed later). This increase is comprised of a $914 thousand increase in investment in capital assets (net of related debt), an increase of $273 thousand in restricted net assets and an increase of $1,254 thousand of unrestricted net assets. The $914 thousand increase in investment in capital assets (net of related debt) is primarily related to purchases of capital assets and debt payments made that decreased the District's outstanding debt. Restricted net assets for governmental activities increased by $273 thousand which is primarily the result of the District requesting a property tax assessment of $1,000 thousand, as compared to $1,400 thousand in FY 2011, to meet necessary expenditures and maintain the District's policy of a fund balance of approximately $1 million in the State Water Importation Fund.

Total net assets of the District's business-type activities increased a total of $1,637 thousand (or 3.71%) from $44,130 thousand at June 30, 2011 to $45,767 thousand at June 30, 2012. These resources can only be used by the District to finance the continuing operations of the business-type activities and not toward governmental-type activities.

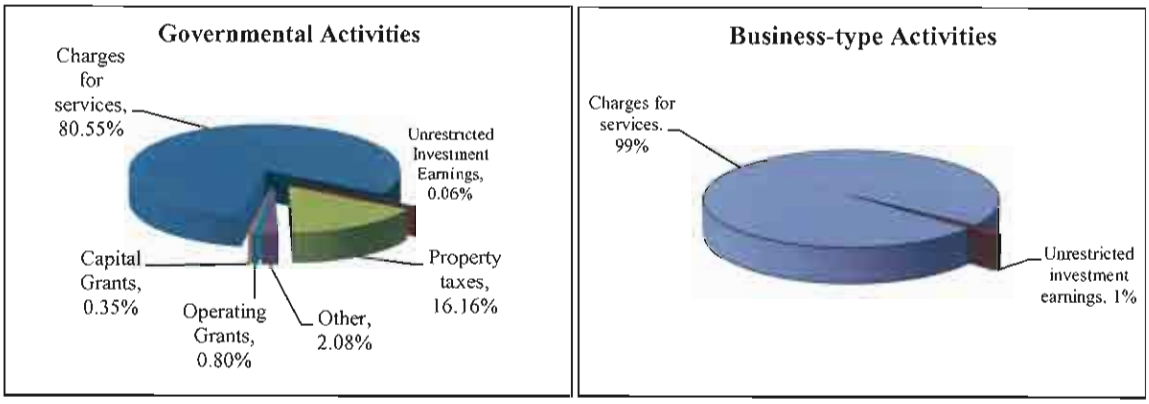
Net assets invested in capital assets (net of related debt) decreased by $105 thousand for business-type activities from $39,124 thousand at June 30, 2011 to $39,019 thousand at June 30, 2012. This decrease is the result of completed construction and purchase of additional or replacement machinery and equipment net of the reduction of debt.

Unrestricted net assets (which represent the residual balance of total net assets after the elimination of invested capital assets net of related debt and restricted net assets) increased for the business-type activities by $1,742 thousand from the prior year.

Changes in Net Assets. The District's total revenue increased by 9.92% or $1,817 thousand from the prior fiscal year. As reflected in Table 2, there was an increase of $1,763 thousand in charges for services, an increase of $100 thousand in operating grants, an increase of $66 thousand in property tax receipts, and an increase of $145 thousand in other revenue over the prior year. Charges for service increased due to a 46.15% increase in the District's groundwater extraction charge effective July 1, 2011, an increase in water deliveries, and the elimination of Zone C which moved previous Zone C customers to Zone B which has a higher extraction charge. The increase in operating grants is a result of grant reimbursements from grant funded projects as compared to the prior year. Other revenue increased primarily as the result of the Fox Canyon Groundwater Management Agency (FCGMA) contributing to the District's groundwater modeling efforts and professional hydrogeologist services the District provided to Calleguas Municipal Water District and FCGMA. These increases were partially off-set by a decrease of $237 thousand in capital grants and a decrease of $20 thousand in investment earnings over the prior year. The decrease in capital grants is a result of the larger number of grant funded projects completed in FY 2011 as compared to FY 2012. The lower investment earnings is due to lower investment rates.

Table B

United Water Conservation District's Revenues by Source for FY 2012



The overall change in the District's total expenses over the prior year is not significant (an increase of 1.31%) and will be further discussed in this document.

The District operates one potable water system (Oxnard-Hueneme Pipeline) and two agricultural water systems (Pleasant Valley and Pumping Trough Pipelines). The District also operates the Freeman Diversion Dam facilities, Santa Felicia Dam and Lake Piru, three spreading grounds for groundwater recharge and the Saticoy Well Field which enhances groundwater management. The District has a contractual agreement for a Table A allocation of 5,000 acre-feet of the State Water Project that requires yearly payments for capital, operations and maintenance costs (Notes 8 and 9 on pages 57 and 58) incurred by the State for constructing and delivering State Water from Northern California. In FY 2012, the District contracted to purchase additional Table A State Project Water from Casitas Municipal Water District (1,260 acre feet) to be delivered in FY 2012 in order for the District to receive its full allocation of State Water.

In summary, the District's net assets for FY 2012 increased $4,078 thousand as a result of operations. This is an increase of $1,609 thousand over the prior year's net asset increase ($2,469 thousand) that occurred primarily as a result of a $1,763 thousand increase in charges for services revenue and also due to an increase in water deliveries and the elimination of Zone C.

Revenues from the District's ***governmental activities*** increased 13.54% or $1,487 thousand (from $10,985 thousand in FY 2011 to $12,472 thousand in FY 2012), while total expenses increased 4.9% or $469 thousand (from $9,562 thousand in FY 2011 to $10,031 thousand in FY 2012). The increase in net assets for governmental activities was $2,441 thousand in FY 2012 ($23,408 thousand beginning balance at July 1, 2011 compared to $25,849 thousand ending balance at June 30, 2012). This compares to a $1,423 thousand increase in net assets in FY 2011.

Table 2
Changes in United Water Conservation District's Net Assets
(in thousands of dollars)

	Governmental Activities		Business-type Activities		Total	
	2012	2011	2012	2011	2012	2011
Revenues:						
Program revenues:						
Charges for services	$ 10,045	$ 8,622	$ 7,597	$ 7,257	$ 17,642	$ 15,879
Operating grants and contributions	100	-	-	-	100	-
Capital grants and contributions	44	281	-	-	44	281
General revenues:						
Property taxes	2,016	1,950	-	-	2,016	1,950
Unrestricted investment earnings	8	18	63	73	71	91
Other	259	114	-	-	259	114
Total revenues	12,472	10,985	7,660	7,330	20,132	18,315
Expenses:						
Water conservation	7,518	7,033	-	-	7,518	7,033
State Water Project importation	766	765	-	-	766	765
Freeman Diversion facility	-	-	1,492	1,575	1,492	1,575
Water delivery and treatment facilities	-	-	4,531	4,709	4,531	4,709
Lake Piru recreation facility	816	755	-	-	816	755
Interest on long-term debt	931	1,009	-	-	931	1,009
Total expenses	10,031	9,562	6,023	6,284	16,054	15,846
Increase in net assets	2,441	1,423	1,637	1,046	4,078	2,469
Net assets - beginning	23,408	21,985	44,130	43,084	67,538	65,069
Net assets - ending	$ 25,849	$ 23,408	$ 45,767	$ 44,130	$ 71,616	$ 67,538

The increase of $1,487 thousand in governmental activities' revenues from the prior year is largely the result of a $1,423 thousand increase in charges for services, an increase in operating grants of $100 thousand and an increase of $145 thousand in other revenue. The $1,423 thousand increase in charges for services is primarily the result of a 46.15% rate increase in the groundwater extraction charge. These increases were partly offset by a decrease in capital grants ($237 thousand).

The increase of $469 thousand in governmental activities' expenses from the prior year is the result of an increase in water conservation expenses ($485 thousand) and an increase in Lake Piru recreation facility expenses ($61 thousand) over the prior year. The increase in water conservation expenses was primarily the result of an increase in salary, contractual and operating expenses. These increases were offset by a decrease in interest on long-term debt ($78 thousand) over the prior year. The decrease in interest on long-term debt is the result of lower existing outstanding debt of the District.

Business-type activities revenues increased 4.50% or $330 thousand ($7,330 thousand in FY 2011 to $7,660 thousand in FY 2012). Total charges for services increased $340 thousand ($7,257 thousand in FY 2011 to $7,597 thousand in FY 2012) and unrestricted investment earnings decreased $10 thousand ($73 thousand in FY 2011 compared to $63 thousand in FY 2012). The increase in charges for services is a result of an increase in water deliveries as compared to FY 2011, primarily in the Pleasant Valley Pipeline Fund due to an increase in the availability of surface water.

Total expenses decreased 4.15% or $261 thousand ($6,284 thousand in FY 2011 to $6,023 thousand in FY 2012).

Total expenses for the water delivery and treatment facilities decreased by 3.78% or $178 thousand (from $4,709 thousand in FY 2011 to $4,531 thousand in FY 2012). Total expenses for the Freeman Diversion facility decreased by 5.27% or $83 thousand (from $1,575 thousand in FY 2011 to $1,492 thousand in FY 2012).

There were no transfers in either FY 2011 or FY 2012.

In summary, the District's business-type activities' revenue increased by $330 thousand to a total of $7,660 thousand in FY 2012 and expenses decreased by $261 thousand to $6,023 thousand in FY 2012, which resulted in an excess of $1,637 thousand in revenues over expenses. This $1,637 thousand represents the net increase in total assets for business-type activities for the year ended June 30, 2012.

Financial Analysis of the District's Funds

As noted earlier, the District uses fund accounting to ensure and demonstrate compliance with finance-related legal requirements.

The focus of the District's ***governmental funds*** (pages 36-37) is to provide information on near-term inflows, outflows, and balances of spendable resources. Such information is useful in assessing the District's financing requirements. In particular, unrestricted fund balance, less any amounts committed or assigned, may serve as a useful measure of a District's net resources available for spending at the end of a fiscal year. Fiscal year 2012 is the second year the District has implemented the effects of GASB Statement No. 54 which established new categories for reporting fund balance and revised the definitions for governmental fund types. The categories for reporting fund balance can be found in the basic financial statements, balance sheet for governmental funds, on Page 36 of this report. A more detailed description of fund balance for governmental funds can be found in Note 1 starting on Page 50 of this report.

At the end of the 2012 fiscal year, the District's governmental funds reported combined ending fund balance of $8,520 thousand, an increase of $291 thousand in comparison to the prior year-end fund balance total of $8,229 thousand. Approximately 58.08% of the ending fund balance ($4,948 thousand) constitutes unrestricted unassigned fund balance, which is available for spending at the District's discretion. Additionally, of the remaining fund balance ($8,520 thousand – total fund balances less unrestricted fund balance of $4,948 thousand), $3,572 thousand is restricted. Of the restricted fund balance ($3,572 thousand), $1,795 thousand represents the remaining funds available from the Series 2005B Revenue Bonds, Series 2006A Revenue Bonds and 2009 Certificate of Participation bonds issued for Board approved capital improvement projects that should occur over the next few years and $1,777 thousand that may only be used toward the payment of the District's State Water contract costs.

The District has two operating funds that comprise the governmental funds' activities:

1. General Fund
2. State Water Import Fund

The General Fund is the primary operating fund of the District. At the end of the current fiscal year, the unrestricted unassigned fund balance of the General Fund was $4,948 thousand while total fund balance was $6,744 thousand. As a measure of the General Fund's liquidity, it may be useful to compare both unrestricted fund balance and total fund balance to total fund expenditures. Unrestricted fund balance represents 43.56% of total General Fund expenditures ($11,359 thousand), while total fund balance represents 59.37% of that same amount. Total fund balance includes $878 thousand in bond proceeds expected to be used for projects and expenditures previously approved by the Board but not yet spent and $918 thousand debt service reserve for the 2009 Certificate of Participation bonds.

The fund balance of the District's General Fund increased by $18 thousand during the current fiscal year ($6,744 thousand at June 30, 2012 compared to $6,726 thousand at June 30, 2011). The $18 thousand increase in fund balance during FY 2012 is primarily the result of revenues exceeding expenditures described in further detail below.

A summary of the financial activity for FY 2012 is as follows:

- Total General Fund revenue for FY 2012 ($11,377 thousand) increased $1,895 thousand from the prior year amount of $9,482 thousand.

    1. $1,830 thousand increase in charges for services.
    2. $145 thousand increase in other revenues.
    3. $66 thousand increase in tax revenue.
    4. $136 thousand decrease in grant revenue.
    5. $10 thousand decrease in earnings on investments.

    The $1,830 increase in charges for services compared to the prior year is primarily due to a 46.15% increase in the water conservation groundwater extraction charge and an increase in groundwater extraction, which was offset by a decrease of $712 thousand in supplemental water payments received from the City of Oxnard ($1,212 thousand in FY 2012 compared to $1,925 thousand in FY 2011). The $145 thousand increase in other revenue was primarily due to the District providing contractual hydrogeological services for Calleguas Municipal Water District and the Fox Canyon Groundwater Management Agency which had not been provided in the prior year. There was a $136 thousand decrease in grant revenues when compared to FY 2011. The District received $145 thousand in grant funds in the current year primarily for seismic studies, forebay surface geophysics and forebay piezometers. Grant funding of $281 thousand was received in FY 2011.

    Total expenditures in FY 2012 of $11,359 thousand decreased by $171 thousand from the prior year ($11,530 thousand).

    1. $602 thousand decrease in capital outlay.
    2. $69 thousand decrease in interest payments.
    3. $33 thousand increase in debt service.
    4. $456 thousand increase in water conservation.
    5. $11 thousand increase in Lake Piru recreation facilities.

The decrease in capital outlay over the prior year is primarily the result of completed capital improvement projects in FY 2011 that were not carried over into FY 2012, delay of work effort (SFD Penstock Coating and Intake Structure) and the decision of the Board to postpone projects due to reprioritization (Ferro-Rose Recharge and Seawater Intrusion Barrier). The increase in water conservation activities was primarily the result of an increase in legal fees associated with the lawsuit filed by the City of Ventura challenging the District's FY 2012 rate increase and an increase in professional service expenses resulting from an increased effort to meet a number of deadlines for completing mandatory studies and plans related to Federal Energy Regulatory Commission (FERC) compliance. The debt service increase ($33 thousand) over the prior year is the result of scheduled principal payments made which reduced existing outstanding debt of the District.

The State Water Import Fund has a total fund balance of $1,777 thousand, an increase of $273 thousand from the prior year-end ($1,504 thousand). The increase in the fund balance from the prior year is largely attributable to the District's request for a property tax assessment of $1 million to meet the necessary expenditures and maintain a fund balance of approximately $1 million in the State Water Importation Fund. The full $1,777 thousand fund balance is restricted and is available for spending only toward the costs of the District's annual State Water contract payments.

The District's ***proprietary funds*** (pages 38-43) provide the same type of information found in the district-wide financial statements, but in more detail.

At year-end, the net assets of the District's proprietary funds totaled $45,767 thousand. This is a total increase of $1,637 thousand in net assets when compared to FY 2011 year-end total net assets of $44,130 thousand.

Table 3
Proprietary Funds
(in thousands of dollars)

	Net Assets Increase/Decrease
Freeman Diversion	$ 1,273
Oxnard Hueneme Pipeline	375
Pleasant Valley Pipeline	98
Pumping Trough Pipeline	(109)
Total change in proprietary net assets	$ 1,637

The $1,273 thousand increase in the net assets in the Freeman Diversion Fund ($28,209 thousand at June 30, 2012 compared to $26,937 thousand at June 30, 2011) is primarily due to operating revenues of $2,757 thousand and non-operating revenues of $8 thousand exceeding operating expenditures of $1,486 thousand and non-operating expenditures of $6 thousand. When compared to FY 2011, operating revenues increased $155 thousand and operating expenses decreased $59 thousand. The $155 thousand increase in charges for services was the result of an increase in groundwater extractions and water deliveries when compared to the prior year. The $59 thousand decrease in operating expenses was primarily due to a decrease in professional fees as a result of a planned reduction in fish passage costs with the substantial completion of the work of the independent consulting fish passage panel.

The $375 thousand increase in total net assets for the Oxnard-Hueneme Pipeline Fund was due to operating revenues of $3,241 thousand and non-operating revenues of $5 thousand exceeding operating expenditures of $2,742 thousand and non-operating expenditures of $129 thousand. Charges for services increased $7 thousand as compared to the prior year ($3,174 thousand in FY 2011 compared to $3,181 thousand in FY 2012). The increase in charges for services is related to higher water deliveries of 515 acre-feet when compared to FY 2011. The increase in operating revenues was partially offset by a decrease of $66 thousand in operating expenses when compared to the prior year. The decrease is primarily the result of a decrease of $64 thousand in repair and maintenance resulting from not having to perform less chlorination activities and replacing fewer anodes as compared to the prior year, a decrease of $38 thousand in utilities resulting from over projecting an increase in the electrical rate in FY 2012. There was also a $22 thousand decrease in salaries when compared to the prior year primarily as a result of two vacant positions in O&M staff and the shifting of work from the OH Pipeline Fund to the Freeman Diversion Fund for the desilting basin cleanout project, which took more man-hours than projected. Operating expense decreases were offset by operating expense increases for benefits ($20 thousand), supplies and services ($42 thousand), and general and administrative ($19 thousand).

There was an increase in net assets ($98 thousand) for the Pleasant Valley Pipeline Fund. The increase is a result of operating revenues ($450 thousand) and non-operating revenues ($49 thousand) exceeding operating expenses ($339 thousand) and non-operating expenses ($62 thousand). This increase is primarily due to an increase in water deliveries as a result of an increase in available surface water. This increase was partially offset by a $23 thousand decrease in operating expenses over the prior year. Total operating expenses decreased primarily as a result of a $27 thousand decrease in maintenance and repair due to fewer maintenance projects as compared to the prior year.

There was a reduction in the net assets ($109 thousand) for the Pumping Trough Pipeline Fund. The decrease is a result of operating expenses ($1,221 thousand) and non-operating expenses ($38 thousand) exceeding operating revenues ($1,148 thousand) and non-operating revenues ($2 thousand). There was a $112 increase in operating revenue when compared to FY 2011. Charges for services increased $129 thousand compared to the prior year as a result of a 914 acre feet increase in water deliveries. Operating expenses decreased $55 thousand as compared to FY 2011 primarily as a result of a decrease in maintenance expenses due to the replacement of the moss screen equipment at the Freeman Diversion that is partially funded by the Pumping Trough Pipeline Fund that was not performed in FY 2012.

General Fund Budgetary Highlights

Differences between the General Fund's original budget of $12,761 thousand in appropriations, as adopted by the Board of Directors in June 2011, and the final amended expenditure budget of $16,534 thousand (original budget appropriations plus Board approved expenditure revisions of $3,774 thousand through June 30, 2012), is briefly summarized as follows:

- $2,697 thousand carryover appropriation for prior year construction in progress appropriations.
- $438 thousand carryover appropriation for prior year operating appropriation encumbrances (the largest portion, $203 thousand, relating to contractual services).
- $78 thousand supplemental appropriation during the fiscal year for the development of a study plan for assessing fish passage at the Santa Felicia Dam.
- $280 thousand supplemental appropriation during the fiscal year for costs associated with the City of Ventura lawsuit.
- $81 thousand supplemental appropriation during the fiscal year for legal fees related to Federal Energy Regulatory Commission license compliance.
- $29 thousand supplemental appropriation during the fiscal year for District infrastructure maintenance.
- $3 thousand supplemental appropriation during the fiscal year for water right permits.
- $24 thousand supplemental appropriation during the fiscal year for Castaic Lake flood flow water storage and release.
- $2 thousand supplemental appropriation during the fiscal year for general and administrative cost increases.
- $20 thousand supplemental appropriation during the fiscal year for relocation of the Environmental Planning and Conservation Department to a Santa Paula office facility.
- $43 thousand supplemental appropriation during the fiscal year for wireless data system improvement to support District-wide communication.
- $79 thousand supplemental appropriation during the fiscal year for the purchase of a patrol boat for Lake Piru.

The final budget adopted by the Board included revenue projections of $12,248 thousand. By the end of FY 2012, total revenues of $11,456 thousand were received while actual expenditures totaled $11,840 thousand, resulting in a shortfall of $384 thousand. The difference between the final budget's projected $4,287 thousand shortfall and the actual $384 thousand shortfall at year-end was due to revenues coming in $792 thousand lower than the final $12,248 thousand revenue projection while actual expenditures were $4,695 thousand lower than the final budget appropriation of $16,534 thousand

Actual revenues of $11,456 thousand came in $792 thousand less than the final amended budget of $12,248 thousand. The primary reasons for this $792 thousand difference were lower than planned decrease in water deliveries to the City of Oxnard as a result of the City continuing to pump their wells in FY 2012 versus utilizing pipeline deliveries, lower than expected groundwater extractions and other revenue projected as a result of the Bypass Pipeline capital improvement project that was significantly reduced by the El Rio spreading grounds rehabilitation and moss screen gate upgrade projects.

Overall, actual expenditures of $11,840 thousand came in $4,695 thousand less than the final amended budget of $16,534 thousand. The primary reasons for this $4,695 thousand difference were timing delays in capital project completions and lower than anticipated contractual costs, most of which were estimated for work related to the District's Federal Energy Regulatory Commission (FERC) licensing efforts for the Santa Felicia Dam and its Habitat Conservation Plan (HCP) for the Freeman Diversion operations. Both the licensing and HCP efforts include significant

Endangered Species Act compliance requirements that are being developed by the District in consultation with federal and state agencies.

Table 4
United Water Conservation District's Capital Assets
Net of Depreciation
(in thousands of dollars)

	Governmental Activities		Business-type Activities		Total	
	2012	2011	2012	2011	2012	2011
Land	$ 16,920	$ 16,920	$ 1,221	$ 1,221	$ 18,141	$ 18,141
Dams	2,359	2,416	24,252	24,564	26,611	26,980
Structures and improvements	12,236	12,596	16,748	17,405	28,984	30,001
Equipment	1,109	948	537	497	1,646	1,445
Intangibles	4,504	4,966	-	-	4,504	4,966
Construction in progress	1,107	779	76	43	1,183	822
Total	$ 38,235	$ 38,625	$ 42,834	$ 43,730	$ 81,069	$ 82,355

Capital Asset and Debt Administration

The District's investment in ***capital assets*** (see Table 4) for its governmental and business-type activities as of June 30, 2012 amounts to $81,069 thousand (net of accumulated depreciation). This investment in capital assets includes land, dams, structures and improvements, equipment, intangibles, and construction in progress for capital projects. The total decrease in the District's investment in capital assets for the current fiscal period when compared to FY 2011 was 1.56% or $1,286 thousand. Governmental activities' investment in capital assets decreased by 1.01% or $390 thousand and business-type activities decreased 2.05% or $896 thousand.

Capital assets completed during the fiscal year included the following:

- OH Gas Booster Building $121 thousand.
- Reasoner Canyon Bank Protection $74 thousand.
- District Wide Communication Network $53 thousand.

Additional information on the District's capital assets can be found in Note 4 to the financial statements on pages 53 and 54 of this report.

The District had ***long-term debt*** outstanding of approximately $24,184 thousand at the end of the current fiscal year compared to $27,659 thousand at the end of the prior fiscal year (see Table 5). This current year-end amount, $24,184 thousand, was comprised of debt backed by the full faith and credit of the District, $1,354 thousand (5.60%) of property tax assessment debt for which the District is liable in the event of default by the property owners subject to the assessment and $22,830 thousand (94.40%) representing bonds secured solely by specified revenue sources (i.e. revenue bonds and Certificate of Participation Bonds).

Table 5
United Water Conservation District's Outstanding Debt
(in thousands of dollars)

	Governmental Activities		Business-type Activities		Total	
	2012	2011	2012	2011	2012	2011
Assessment with District commitment	$ 1,354	$ 1,429	$ -	$ -	$ 1,354	$ 1,429
Revenue bonds and COP (backed by specific tax and fee revenues)	19,015	21,555	3,815	4,675	22,830	26,230
Total	$ 20,369	$ 22,984	$ 3,815	$ 4,675	$ 24,184	$ 27,659

The decrease of $3,475 thousand (12.56%) in the District's total debt in FY 2012 is the result of scheduled principal payments made on all outstanding debt during the year.

Most of the current District indebtednesses (Revenue Bonds) are rated "AAA" by Moody's and/or "AAA" by Standard and Poor's while the 2009 Certificate of Participation is "AA" rated by Standard and Poor's. These "AAA" ratings for the revenue bonds are based on the issuance of bond insurance policies for all debt issued to date. These policies guarantee the scheduled payment of principal and interest on the bonds when due. No insurance policy was purchased for the 2009 Certificate of Participation.

Additional information on the District's long-term debt can be found in Note 9 starting on page 58 of this document.

Economic Factors, Other Significant Factors and Next Year's Budgets and Rates

With the financial markets and the state and national economies still experiencing uncertainty, continued low investment interest rates, a housing market that is just beginning to show signs of improvement, increasing environmental compliance requirements and increasingly unpredictable weather conditions (climate change possibly) that impact, negatively or positively, water demands, the District has reviewed its operations and has determined the impacts to the District could be as follows:

- Slight increase to property tax revenue as a result of fewer foreclosures and delinquent property tax payers experienced over the prior years.
- Increased legal costs related to the two lawsuits filed by the City of Ventura (and the potential for a lawsuit each fiscal year until the matter is decided) regarding the District's groundwater extraction charge.
- Decreased or flat groundwater extraction and water deliveries revenues as a result of the City of Oxnard's decision not to continue participating in the supplemental M&I program, while PHWA's installation of meters throughout its service area has reduced the amount of water being used within their area.
- Continued significant environmental compliance costs impacts in relations to capital improvements, legal, and professional services for environmental related issues.
- Despite recent pension reform legislation, increases in employer contributions for the District's retirement plan (CALPERS).

- Increases in District funded employee health insurance plan costs.
- Continued insignificant revenue sources from investment earnings.

The District will continue to monitor the effects, if any, and the associated inherent risks to the District proactively.

In considering the District's other significant factors, the following should be noted:

The District faces several challenging and fiscally significant projects over the next several years, largely the result of regulatory and legislative mandates. In particular, the District has received two jeopardy biological opinions from the National Marine Fisheries Services (NMFS) under the Federal Endangered Species Act (ESA). The lower Santa Clara River Watershed within the District's boundaries is considered a major migration corridor and habitat for the endangered Southern California steelhead (an endangered species of fish under the ESA, listed in 1997).

The Federal Energy Regulatory Commission (FERC) provides the license that is necessary for the District to operate the District's Santa Felicia Dam (SFD) and hydroelectric plant. In FY 2009, the District was issued a new 40-year FERC license. NMFS issued a jeopardy biological opinion (BiOp) related to the Southern California steelhead, an endangered species under the ESA. FERC in turn inserted the BiOp with its "reasonable and prudent alternatives" (RPA) into their order and issued the new operating license for the Santa Felicia Dam Project. The BiOp, under Section 7 of the ESA, calls for the District to implement multi-pronged reasonable and prudent alternatives to reduce the effects of the District's activities on steelhead such that it no longer creates a jeopardy situation. The RPA includes requirements that the District undertake actions that include operational changes that could significantly reduce the water yield of the SFD project. To date, four of the eight BiOp required plans have been approved by FERC. The District has completed implementation of one, the study plan of geomorphic effects. Two other required plans have been developed to understand and evaluate the relationship between flows and water depths of lower Piru Creek. The District is using these results to develop water release ramping rates. The District has not yet begun implementation of the other FERC approved plan, a study plan for assessing the feasibility of providing fish passage at the Santa Felicia Dam. In its approval, FERC stated that the District must obtain NMFS' agreement on that plan before it can initiate implementation. The District is currently working to obtain NMFS' agreement. Of the remaining four plans (the four yet to be approved BiOp required plans), one, the water release plan, has been completed and the District is in the process of seeking to amend its license with this plan, as required by FERC. This process is expected to be completed by December 2013. In FY 2012-13, the District expects to complete two of the four remaining plans and file them with FERC for approval. A third plan (habitat improvement plan) will be completed and filed with FERC early in the following fiscal year. The remaining two plans will contain the results obtained from implementation of the passage feasibility study plan. At this time, the earliest the District expects these plans to be completed is June 2015. In addition to the requirements of the BiOp under the new FERC license, there are a number of other significant license conditions. The District has completed some of the conditions, including the implementation of some required plans, and efforts will continue in FY 2012-13. All work performed to comply with the FERC license will be funded from groundwater extraction fees as provided by the District's newly adopted Environmental Activities Cost Allocation Policy (effective July 1, 2012). The full impact on the finances and operations of the District resulting from efforts to comply with the FERC license requirements (including the BiOp) is unknown.

Known and unknown license compliance expenditures will continue to impact the Water Conservation activities fund reserves and impact future rate decisions. A number of the required plans under the FERC license could be more comprehensive if they included actions to be implemented on portions of Piru Creek that fall under private ownership. Currently those landowners have denied the District access to this property for the purposes of implementing environmental requirements of the FERC license. As a result, efforts to complete the required plans and implement approved plans may result in additional unanticipated expenditures depending on how this issue affects the District's ability to comply with the license requirements.

The District has been engaged in an extensive process to bring its operations at the Freeman Diversion into compliance with the Endangered Species Act (ESA) for steelhead. This effort includes the initial time spent on the section 7 consultation process with NMFS through the U.S. Bureau of Reclamation. This effort resulted in a BiOp issued by NMFS in 2008 for the effects of the Diversion on steelhead. However, it has since been nullified as a result of Reclamation's withdrawal from the project. Since 2007, the District has been pursuing an incidental take permit through section 10 of the ESA to bring the project into compliance. This requires the District to develop a Habitat Conservation Plan (HCP). In addition, the District is required to comply with a settlement agreement with Cal Trout, a non-governmental organization, in which the District agreed to undertake several measures including the design and construction of a new fish passage facility anticipated to cost between $24 and $30 million. The first step of the design phase of the fish passage facility is to perform a geotechnical survey of the bedrock in the Santa Clara River above the Freeman Diversion. This survey work was completed in November 2012. The second step is to take the fish passage facility from its current conceptual design to a final design. The District has contracted with a firm to complete the hydraulic modeling which will determine the dimensions and operational features of the structure. This work is expected to be completed by April 2014. As noted above, the District is also in the process of preparing a HCP in order to receive an incidental take permit for the Freeman Diversion operations, construction of the fish passage facility, and other activities. The District's current goal is to obtain the permit and complete all other compliance requirements to allow for construction of the fish passage facility to begin March 2015. Ultimately the HCP could lead to a loss of water yield and decrease the amount of water available for groundwater recharge. In accordance with the District's newly adopted Environmental Activities Cost Allocation Policy, some expenditures associated with the HCP completion are funded 50/50 by the General/Water Conservation Fund and the Freeman Fund. Costs associated with ESA compliance that are tied to the physical operation and maintenance of the Freeman Diversion, including capital improvements, are funded 100% by the Freeman Fund.

The District has expended significant time and funds over the past several years conducting required "Probable Maximum Precipitation/Probable Maximum Flood" (PMP/PMF) studies for the SFD. The results of these studies will determine what, if any, physical modifications are necessary to be made to the SFD. The District joined efforts with the California Department of Water Resources (DWR), owner and operator of the upstream Pyramid Dam, to update the PMP/PMF studies. The DWR funded the development of the site-specific studies and the District funded the work of an independent Board of Consultants that was responsible for evaluating and approving the PMP/PMF study results. The studies were completed and approved by the Board of Consultants and its findings show rainfall amounts that are substantially lower than those suggested by the National Weather Service (NWS) model. FERC and the California Division of Safety of Dams (DSOD) reviewed the studies and FERC verbally informed the District and DWR that it

plans to reject the District's revised site-specific PMP/PMF. However, FERC also stated that it plans to eliminate the use of the "HMR 58-59", the NWS rainfall model, which is the cause for the significant speculative potential flooding scenario that could result in significant capital improvement costs to the SFD spillway and height of the dam wall. The District still has not received written notification of FERC's decision. Work on this effort has been halted pending receipt of written notification from FERC.

Under the District's dam safety program, a structural analysis was performed to determine the seismic adequacy of the Santa Felicia Dam outlet works. A structural analysis of the penstock was completed and concluded that the integrity of the supports are seismically inadequate to withstand the largest credible earthquake and preliminary reports suggest that the existing coating needs to be replaced with a modern coating system. Also a preliminary report identifying design options for the replacement of the intake tower, which is within nine feet of being covered in silt, has been submitted to the District and is under review. Once the report has been finalized, it will be submitted to FERC and DSOD. The purpose of the outlet works is to convey water from upstream of the dam and release it downstream of the dam. The failure of the intake tower could prevent water releases from the reservoir and failure of the penstock could drain the reservoir and might cause serious damage to the dam. The ultimate final design for both projects will require the District to expend significant financial resources, currently estimated at $13 to $30 million.

In August 2011 and August 2012, the City of Ventura filed petitions for writ of mandate, petitions for writ of administrative mandate, complaints for declaratory relief and complaints for determinations of invalidity against the District seeking to invalidate the fiscal year 2011-12 and fiscal year 2012-13 water rates adopted by the District's Board of Directors. The District filed an answer and a cross-complaint for declaratory relief of the lawsuit filed in 2011 and will do the same regarding the lawsuit filed in 2012. Other parties have intervened in the action. The District has and will continue to vigorously contest the City's action. At this time, no amounts have been accrued in the accompanying financial statements. If the outcome of the lawsuits is unfavorable and the City prevails, it is anticipated that the outcome will have materially adverse impact on the finances of the District.

In preparing the District's FY 2012-13 budget, several factors were considered:

- Ensure appropriate funding for status quo operations and all necessary or operational efficiencies maintenance.
- Ensure health and safety issues for constituents and employees were addressed.
- Ensure all legally mandated requirements of the District were fully funded.
- Ensure that appropriate (fiscally prudent) reserve levels, per the District's Reserve Policies, for all funds are maintained or potentially achieved.
- Proactive awareness and accountability of District's mission as the groundwater guardian.
- Address major rehabilitation or replacement for key District infrastructure that are necessary due to the aging process before more serious emergency repairs are needed.
- Proactive conservation efforts, education and public awareness.
- Balance water conservation efforts with environmental concerns.

At the end of the fiscal year 2011-12, the cash reserve fund balance in the General Fund was $2,559 thousand. The District's General/Water Conservation Fund (previously the General Fund) adopted FY 2012-13 Budget anticipates a net surplus of approximately $1,999 thousand by year-end June 30, 2013. Any shortfall that occurs would be subtracted from the beginning unrestricted unassigned fund balance.

Since the beginning of FY 2012-13 (July through October 2012), the Board has authorized the use of an additional $133 thousand of unrestricted fund balance from District funds. This $133 thousand represents supplemental appropriations the Board has approved in the current year in which no new or additional resources (i.e. grant funding, etc.) were available to offset the projected new costs.

Approved rates for FY 2012-13 (compared to FY 2011-12):

- General Fund Groundwater Replenishment Charge (39% increase):
  Municipal and Industrial customers: $85.50 per acre-foot increased to $119.25 per acre-foot
  Agricultural customers: $28.50 per acre-foot increased to $39.75 per acre-foot
- State Water property tax assessment decreased from $1,000 thousand to $532 thousand.
- Freeman Fund Facilities Charge:
  Municipal and Industrial customers (no change from FY 2012): $54 per acre-foot
  Agricultural customers (no change from FY 2012): $18 per acre-foot
- Pleasant Valley Pipeline Fund Water Delivery Rate:
  O&M charge (no change from FY 2012): $35 per acre-foot
- Pumping Trough Pipeline Fund Water Delivery Rate:
  O & M Charge (no change from FY 2012): $125 per acre-foot
  Tier Rate apply to excess water usage above the baseline (no change from FY 2012): $50 per acre-foot
- Saticoy Well Field O & M Charge (no change from FY 2012): $30 per acre-foot
- Oxnard-Hueneme Pipeline Fund (rate adjustment):
  Fixed cost (per unit of peak capacity) decrease from $24,178 to $23,305
  Variable Rate (per acre-foot) decrease from $149.00 to $148.35
  Marginal Rate (per acre-foot) $84.00 increased to $99.10
- Fixed Well Replacement charge for OHP (no change from FY 2012): $14.08 per acre-foot (monthly charge based on 75% sub-allocation acre-feet per contractor as shown in Water Delivery Agreement)

Economic – Demographic Data

Ventura covers 1,843 square miles and has 43 miles of coastline. The Pacific Ocean forms its southwestern boundary, with Los Angeles County to the southeast, Kern County to the north and Santa Barbara County to the west. The Los Padres National Forest accounts for the northern half of the county with residential, agricultural and business uses in the southern portion.

Population: The District operates within Ventura County which is located along the southern coast of California. The 2010 Census data records Ventura County's population at 825,669. The California Department of Finance (DOF) population estimate for Ventura County for January 2012

is 832,970. This represents an increase of approximately 0.6% over the DOF population estimate for 2011 of 827,874.

Employment: For October 2012, the California Employment Development Department shows the civilian labor force for Ventura County to be 440,000 (not seasonally adjusted) and an unemployment rate of 8.6% with a ranking of 11th in the State of California. This is a 1.2% decrease over the prior year unemployment rate. The statewide October 2012 unemployment rate is 9.8%. a decrease of 1.9% over the prior year.

Assessed Property Values and Housing: In FY 2011-12, the County's overall property assessments decreased 0.16% compared to FY 2010-11. The County Assessor's Office projects that in FY 2012-13 countywide property assessments will increase by 0.61%. The California Association of Realtors reports that the October 2012 median housing price in Ventura County was $416,350 whereas the October 2011 median was $399,160.

Agriculture remains a major business in Ventura County and a significant District rate payer in terms of volume of water deliveries and groundwater extraction. Ventura County ranked number eight among California counties in total crop value in 2010 according to the California Department of Food and Agriculture. Recent national data put Ventura County at number ten among all counties in the United States. According to the Ventura County Farm Bureau's 2011 report, the gross crop value for calendar year 2011 was $1.8 billion, approximately $15 million less than 2010. Strawberries remain the number one top grossing crop, with raspberries coming in second and nursery stock in third.

Requests for Information

This financial report is designed to provide a general overview of United Water Conservation District for all those with an interest in the District's finances. Questions concerning any of the information provided in this report or requests for additional financial information should be addressed to United Water Conservation District, Administrative Services Manager, 106 N. 8th Street, Santa Paula, CA 93060.

Basic Financial Statements

United Water Conservation District
Statement of Net Assets
June 30, 2012

	Governmental Activities	Business-type Activities	Total
Assets			
Cash and cash equivalents	$ 4,028,266	$ 5,368,103	$ 9,396,369
Receivables:			
Accounts (net of allowance for uncollectables of $20,406)	2,887,825	1,285,343	4,173,168
Taxes	163,070	-	163,070
Interest	3,131	4,367	7,498
Grants	139,132	-	139,132
Prepaid expenses and other assets	3,641	7,404	11,045
Restricted cash, cash equivalents and investments:			
Bond proceeds	1,795,863	-	1,795,863
Other receivable	117,046	-	117,046
Note receivable	-	739,559	739,559
Deferred bond issue costs - unamortized	385,777	126,205	511,982
Capital assets:			
Land and other assets not being depreciated	18,027,135	1,296,830	19,323,965
Other capital assets, net of depreciation	20,207,622	41,537,080	61,744,702
Total assets	47,758,508	50,364,891	98,123,399
Liabilities			
Accounts payable	492,265	248,319	740,584
Accrued interest payable	211,424	38,871	250,295
Accrued wages and benefits	109,054	28,487	137,541
Noncurrent liabilities:			
Due within one year	1,510,155	985,106	2,495,261
Due in more than one year	19,586,691	3,296,717	22,883,408
Total liabilities	21,909,589	4,597,500	26,507,089
Net Assets			
Invested in capital assets, net of related debt	19,661,529	39,018,729	58,680,258
Restricted for:			
State Water Import	1,776,709	-	1,776,709
Unrestricted	4,410,681	6,748,662	11,159,343
Total net assets	$ 25,848,919	$ 45,767,391	$ 71,616,310

The notes to the financial statements are an integral part of this statement.

United Water Conservation District
Statement of Activities
For the Year Ended June 30, 2012

			Program Revenues			Net (Expense) Revenue and Changes in Net Assets		
Functions/Programs	Expenses	Indirect Expense Allocation	Charges for Services	Operating Grants and Contributions	Capital Grants and Contributions	Governmental Activities	Business-type Activities	Total
Governmental activities:								
Water conservation	$ 6,373,512	$ 1,144,731	$ 8,825,755	$ 100,507	$ 44,308	$ 1,452,327	$ -	$ 1,452,327
Lake Piru recreational facilities	742,071	73,293	122,784	-	-	(692,580)	-	(692,580)
State Water Project importation	766,382	-	1,095,808	-	-	329,426	-	329,426
Interest on long-term debt	931,280	-	-	-	-	(931,280)	-	(931,280)
General and administrative	2,349,130	(2,349,130)	-	-	-	-	-	-
Total governmental activities	11,162,375	(1,131,106)	10,044,347	100,507	44,308	157,893	-	157,893
Business-type activities:								
Freeman Diversion facility	1,085,737	406,634	2,757,334	-	-	-	1,264,963	1,264,963
Water delivery and treatment facilities	3,806,779	724,472	4,840,351	-	-	-	309,100	309,100
Total business-type activities	4,892,516	1,131,106	7,597,685	-	-	-	1,574,063	1,574,063
Total government	$ 16,054,891	$ -	$ 17,642,032	$ 100,507	$ 44,308	157,893	1,574,063	1,731,956
General revenues:								
Property taxes						2,016,499	-	2,016,499
Unrestricted investment earnings						8,174	62,991	71,165
Miscellaneous						259,062	-	259,062
Total general revenues						2,283,735	62,991	2,346,726
Change in net assets						2,441,628	1,637,054	4,078,682
Net assets - July 1, 2011						23,407,291	44,130,337	67,537,628
Net assets - June 30, 2012						$ 25,848,919	$ 45,767,391	$ 71,616,310

The notes to the financial statements are an integral part of this statement.

United Water Conservation District
Balance Sheet
Governmental Funds
June 30, 2012

	General Fund	State Water Import Fund	Total Governmental Funds
Assets			
Cash and cash equivalents	$ 2,265,983	$ 1,762,283	$ 4,028,266
Receivables:			
Accounts (net of allowance for uncollectables of $17,515)	2,852,465	35,360	2,887,825
Taxes	124,844	38,226	163,070
Interest	1,725	1,406	3,131
Grants	139,132	-	139,132
Other	117,046	-	117,046
Restricted cash and cash equivalents	1,795,863	-	1,795,863
Prepaids and other assets	3,641	-	3,641
Total assets	$ 7,300,699	$ 1,837,275	$ 9,137,974
Liabilities and Fund Balances			
Liabilities:			
Accounts payable	$ 431,699	$ 60,566	$ 492,265
Accrued wages and benefits	109,054	-	109,054
Other liabilities	16,391	-	16,391
Total liabilities	557,144	60,566	617,710
Fund Balances:			
Restricted	1,795,863	1,776,709	3,572,572
Unrestricted:			
Unassigned	4,947,692	-	4,947,692
Total fund balances	6,743,555	1,776,709	8,520,264
Total liabilities and fund balances	$ 7,300,699	$ 1,837,275	

Amounts reported for *governmental activities* in the statement of net assets are different because:	
Capital assets used in governmental activities are not financial resources and therefore are not reported in the funds.	38,234,757
Some liabilities are not due and payable in the current period and therefore are not reported in the funds.	
Accrued interest payable	(211,423)
Accrued long-term liabilities	(711,364)
Bonds and notes payable	(19,983,315)
Net assets of governmental activities	$ 25,848,919

The notes to the financial statements are an integral part of this statement.

United Water Conservation District
Statement of Revenues, Expenditures, and Changes in Fund Balances
Governmental Funds
For the Year Ended June 30, 2012

	General Fund	State Water Import Fund	Total Governmental Funds
Revenues			
Taxes	$ 2,016,499	$ 1,084,910	$ 3,101,409
Charges for services	8,948,539	-	8,948,539
Earnings on investments	8,174	7,114	15,288
Grants	144,815	-	144,815
Other revenues	259,062	3,784	262,846
Total revenues	11,377,089	1,095,808	12,472,897
Expenditures			
Current:			
Water Conservation	6,430,332	-	6,430,332
Lake Piru Recreation facilities	535,883	-	535,883
State Water Project importation	-	692,408	692,408
Debt service			
Principal	2,537,409	87,743	2,625,152
Interest	896,836	54,544	951,380
Bond issuance costs	7,020	-	7,020
Capital outlay	951,648	-	951,648
Total expenditures	11,359,128	834,695	12,193,823
Excess of revenues over expenditures	17,961	261,113	279,074
Other Financing Sources			
Proceeds from financing	-	12,052	12,052
Net change in fund balances	17,961	273,165	291,126
Fund balances - July 1, 2011	6,725,594	1,503,544	8,229,138
Fund balances - June 30, 2012	$ 6,743,555	$ 1,776,709	$ 8,520,264

Net change in fund balances - total governmental funds	$ 291,126
Amounts reported for *governmental activities* in the statement of activities are different because:	
Governmental funds report capital outlays as expenditures. However, in the statement of activities, the cost of those assets is allocated over their estimated useful lives and reported as depreciation or amortization expense. This is the amount by which depreciation and amortization ($1,245,192) exceeded capital outlay ($951,648) in the curent period.	(293,544)
Debt proceeds provide current financial resources to governmental funds, but issuing debt increases long-term liabilities in the statement of net assets. Repayment of debt principal is an expenditure in the governmental funds, but the repayment reduces long-term liabilities in the statement of net assets. This is the amount by which payments exceeded proceeds (Note 9).	2,613,100
Some expenses reported in the statement of activities do not require the use of current financial resources and therefore are not reported as expenditures in governmental funds.	(169,054)
Change in net assets of governmental activities	$ 2,441,628

The notes to the financial statements are an integral part of this statement.

United Water Conservation District
Statement of Net Assets
Proprietary Funds
June 30, 2012

	Enterprise Funds	
	Freeman Diversion Fund	Oxnard-Hueneme Pipeline Fund
Assets		
Current assets:		
Cash and cash equivalents	$ 2,195,304	$ 1,623,164
Receivables:		
Accounts (net of allowance for uncollectables of $2,891)	859,327	277,998
Interest	1,886	1,256
Prepaid expenses and other assets	-	6,639
Current portion of note receivable	-	-
Current portion of deferred bond issue costs - unamortized	874	10,606
Total current assets	3,057,391	1,919,663
Noncurrent assets:		
Note receivable	-	-
Deferred bond issue costs - unamortized	3,874	65,015
Capital assets:		
Land	679,894	14,558
Construction in progress	67,971	2,668
Dams	24,252,189	-
Structures and improvements	7,339,452	15,493,649
Equipment	577,700	1,024,381
Less accumulated depreciation	(7,484,895)	(7,459,339)
Total noncurrent assets	25,436,185	9,140,932
Total assets	28,493,576	11,060,595
Liabilities		
Current liabilities:		
Accounts payable	39,260	162,119
Accrued interest payable	1,093	25,252
Accrued wages and benefits	9,801	14,479
Compensated absences	55,841	58,979
Current portion of bonds payable	46,714	528,773
Total current liabilities	152,709	789,602
Noncurrent liabilities:		
Compensated absences	36,476	54,732
Other post employment benefits other than pensions	61,012	58,957
Bonds payable	34,164	1,574,731
Total noncurrent liabilities	131,652	1,688,420
Total liabilities	284,361	2,478,022
Net Assets		
Invested in capital assets, net of related debt	25,351,433	6,972,414
Unrestricted	2,857,782	1,610,159
Total net assets	$ 28,209,215	$ 8,582,573

The notes to the financial statements are an integral part of this statement.

Enterprise Funds		
Pleasant Valley Pipeline Fund	Pumping Trough Pipeline Fund	Total
$ 945,123	$ 604,512	$ 5,368,103
34,340	113,678	1,285,343
763	462	4,367
-	765	7,404
187,515	-	187,515
4,476	2,192	18,148
1,172,217	721,609	6,870,880
552,044	-	552,044
14,535	24,633	108,057
526,403	-	1,220,855
2,668	2,668	75,975
-	-	24,252,189
3,272,730	15,247,365	41,353,196
127,251	280,772	2,010,104
(1,752,414)	(9,381,761)	(26,078,409)
2,743,217	6,173,677	43,494,011
3,915,434	6,895,286	50,364,891
8,093	38,847	248,319
4,099	8,427	38,871
1,396	2,811	28,487
15,103	31,342	161,265
182,028	66,326	823,841
210,719	147,753	1,300,783
14,524	22,478	128,210
16,808	40,388	177,165
611,637	770,810	2,991,342
642,969	833,676	3,296,717
853,688	981,429	4,597,500
1,382,973	5,311,909	39,018,729
1,678,773	601,948	6,748,662
$ 3,061,746	$ 5,913,857	$ 45,767,391

United Water Conservation District
Statement of Revenues, Expenses, and Changes in Fund Net Assets
Proprietary Funds
For the Year Ended June 30, 2012

	Enterprise Funds	
	Freeman Diversion Fund	Oxnard-Hueneme Pipeline Fund
Operating revenues		
Charges for services	$ 2,754,211	$ 3,181,037
Other operating revenue	3,123	60,372
Total operating revenue	2,757,334	3,241,409
Operating expenses		
Salaries	310,410	526,901
Benefits	165,025	294,334
Utilities	11,365	667,396
Repairs and maintenance	53,979	162,815
Professional fees	6,594	74,762
Other supplies and services	161,889	272,895
General and administrative	406,634	360,122
Depreciation	369,711	383,155
Total operating expenses	1,485,607	2,742,380
Operating income (loss)	1,271,727	499,029
Nonoperating revenues and (expenses)		
Interest income	7,634	4,867
Bond fees and expenses	(975)	(12,788)
Interest expense	(5,789)	(115,978)
Total nonoperating revenue (expense)	870	(123,899)
Income (loss)	1,272,597	375,130
Change in net assets	1,272,597	375,130
Total net assets - July 1, 2011	26,936,618	8,207,443
Total net assets - June 30, 2012	$ 28,209,215	$ 8,582,573

The notes to the financial statements are an integral part of this statement.

Enterprise Funds		
Pleasant Valley Pipeline Fund	Pumping Trough Pipeline Fund	Total
$ 450,041	$ 1,141,916	$ 7,527,205
356	6,629	70,480
450,397	1,148,545	7,597,685
58,481	109,919	1,005,711
34,288	71,392	565,039
9,853	174,101	862,715
29,040	98,944	344,778
563	9,148	91,067
28,955	95,027	558,766
110,174	254,176	1,131,106
67,863	408,253	1,228,982
339,217	1,220,960	5,788,164
111,180	(72,415)	1,809,521
48,712	1,778	62,991
(4,604)	(3,192)	(21,559)
(57,081)	(35,051)	(213,899)
(12,973)	(36,465)	(172,467)
98,207	(108,880)	1,637,054
98,207	(108,880)	1,637,054
2,963,539	6,022,737	44,130,337
$ 3,061,746	$ 5,913,857	$ 45,767,391

United Water Conservation District
Statement of Cash Flows
Proprietary Funds
For the Year Ended June 30, 2012

	Freeman Diversion Fund	Oxnard-Hueneme Pipeline Fund
Cash flows from operating activities		
Receipts from customers	$ 2,793,458	$ 3,382,514
Payments to suppliers	(643,901)	(1,733,017)
Payments to employees	(448,337)	(841,006)
Net cash provided by operating activities	1,701,220	808,491
Cash flows from capital and related financing activities		
Purchases of capital assets	(163,174)	(142,596)
Principal payments	(53,101)	(550,147)
Interest payments	(6,886)	(121,936)
Bond fees and expenses	(240)	(2,507)
Net cash used by capital and related financing activities	(223,401)	(817,186)
Cash flows from investing activities		
Interest received	6,639	5,382
Payments received on notes receivable	-	-
Net cash provided by investing activities	6,639	5,382
Net increase (decrease) in cash and cash equivalents	1,484,458	(3,313)
Balances - June 30, 2011	710,846	1,626,477
Balances - June 30, 2012	$ 2,195,304	$ 1,623,164
Reconciliation of operating income (loss) to net cash provided by operating activities:		
Operating income (loss)	$ 1,271,727	$ 499,029
Adjustments to reconcile operating income (loss) to net cash provided by operating activities -		
Depreciation expense	369,711	383,155
Change in assets and liabilities:		
Accounts receivable, net	36,124	141,105
Grants receivable	-	-
Accounts and other payables	(11,869)	(224,954)
Compensated absences	35,527	10,156
Net cash provided by operating activities	$ 1,701,220	$ 808,491

The notes to the financial statements are an integral part of this statement.

Enterprise Funds		
Pleasant Valley Pipeline Fund	Pumping Trough Pipeline Fund	Total
$ 493,185	$ 1,169,927	$ 7,839,084
(200,982)	(690,884)	(3,268,784)
(96,500)	(192,144)	(1,577,987)
195,703	286,899	2,992,313
(12,256)	(14,735)	(332,761)
(207,901)	(81,443)	(892,592)
(59,496)	(36,023)	(224,341)
33,064	(757)	29,560
(246,589)	(132,958)	(1,420,134)
48,770	1,791	62,582
178,255	-	178,255
227,025	1,791	240,837
176,139	155,732	1,813,016
768,984	448,780	3,555,087
$ 945,123	$ 604,512	$ 5,368,103
$ 111,180	$ (72,415)	$ 1,809,521
67,863	408,253	1,228,982
24,378	2,972	204,579
18,410	18,410	36,820
(29,956)	(76,505)	(343,284)
3,828	6,184	55,695
$ 195,703	$ 286,899	$ 2,992,313

United Water Conservation District
Statement of Fiduciary Net Assets
June 30, 2012

	Employee Benefits Trust Fund
Assets	
Cash and cash equivalents	$ 8,450
Accounts receivable	575
Total assets	9,025
Liabilities	
Accounts payable	-
Total liabilities	-
Net Assets	
Held in trust for employee benefits	$ 9,025

The notes to the financial statements are an integral part of this statement.

United Water Conservation District
Statement of Changes in Fiduciary Net Assets
For the Year Ended June 30, 2012

	Employee Benefits Trust Fund
Additions	
Contributions	$ 16,508
Deductions	
Benefits	10,444
Change in net assets	6,064
Net assets - July 1, 2011	2,961
Net assets - June 30, 2012	$ 9,025

The notes to the financial statements are an integral part of this statement.

Note 1. SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

The United Water Conservation District (the District) was formed in 1950 under the Water Conservation Act of 1931. A seven-member Board of Directors governs the District. The District's major operations include water conservation and groundwater extraction, water delivery and recreational facilities.

The District's financial statements are prepared in accordance with generally accepted accounting principles (GAAP). The Governmental Accounting Standards Board (GASB) is responsible for establishing GAAP for state and local governments through its pronouncements (Statements and Interpretations). Governments are also required to follow the pronouncements of the Financial Accounting Standards Board (FASB) issued through November 30, 1989 (when applicable) that do not conflict with or contradict GASB pronouncements. Although the District has the option to apply FASB pronouncements issued after that date to its business-type activities and enterprise funds, the District has chosen not to do so. The more significant accounting policies established in GAAP and used by the District are discussed below.

A. Reporting Entity

These financial statements present the District and its component unit, the United Water Conservation District Public Facilities Financing Authority. As defined by GASB, the financial reporting entity consists of the primary government, as well as component units, which are legally separate organizations for which elected officials of the primary government are financially accountable. Financial accountability is defined as:

(1) Appointment of a voting majority of the component unit's board and (2) fiscal dependency on the primary government, and either (a) the ability to impose will be the primary government, or (b) the possibility that the component unit will provide a financial benefit to or impose a financial burden on the primary government; or

(2) Fiscal dependency on the primary government.

The United Water Conservation District Public Facilities Financing Authority (PFFA) was established in 1993 to construct, acquire, maintain and improve the public facilities and improvements within the District boundaries. The District's Board of Directors acts as the governing body of the PFFA. Although legally separate, the PFFA is blended into the General Fund, Freeman Diversion Fund and the Oxnard-Hueneme Pipeline Fund. The PFFA does not issue separate financial statements.

B. Basic Financial Statements – District-wide Statements

The District's basic financial statements include both district-wide (reporting the District as a whole) and fund financial statements (reporting the District's major funds). Both the district-wide and fund financial statements categorize primary activities as either governmental or business-type. The District's water conservation, recreation facilities, state water import and general administrative services are classified as governmental activities. The Freeman diversion facility and the water delivery and treatment facilities are classified as business-type activities, and are generally financed by fees charged to external parties for goods or services.

In the district-wide Statement of Net Assets, both the governmental and business-type activities columns are presented on a consolidated basis by column and are reported on a full accrual, economic resource basis, which recognizes all long-term assets and receivables as well as long-term debt and obligations. The District's net assets are reported in three parts – invested in capital assets net of related debt, restricted net assets, and unrestricted net assets. The District first utilizes restricted resources to finance qualifying activities. The Statement of Net Assets includes all funds of the reporting entity except fiduciary funds. Interfund activity is eliminated in the governmental and business-type activities columns of the statement of net assets.

The district-wide Statement of Activities presents a comparison between expenses, both direct and indirect, and program revenues for each function of the business-type activities of the District and for each program of the governmental activities. Direct expenses are those that are clearly identifiable with a specific function or program. Indirect expenses are allocated among the operating funds of the District based on an allocation plan approved by the Board of Directors.

Program revenues include charges paid by the recipients of the goods or services offered by the programs and grants and contributions that are restricted to meeting the operational or capital requirements of a particular program. Revenues that are not classified as program revenues are presented as general revenues.

C. Basic Financial Statements – Fund Financial Statements

Fund financial statements report detailed information about the District. Each fund is accounted for by providing a separate set of self-balancing accounts that comprises its assets, liabilities, reserves, fund equity, revenues and expenditures/expenses. The various funds are reported by generic classification within the financial statements.

The emphasis in fund financial statements is on major funds in either the governmental or business-type activities categories. The focus of governmental and proprietary fund financial statements is on "major" funds. Major individual governmental funds and major individual proprietary funds are reported as separate columns in the fund financial statements, with "non-major" funds being aggregated and displayed in a single column. All of the District's governmental and proprietary funds were determined to be major funds at June 30, 2012.

The funds of the District are described below:

1. Governmental Funds:

The focus of the governmental funds' measurement (in the fund statements) is upon determination of financial position and changes in financial position (sources, uses, and balances of financial resources) rather than upon net income. The District reports the following major governmental funds:

a. **General Fund** is the general operating fund of the District. It is used to account for all financial resources except those required to be accounted for in another fund. Water conservation activities, recreational activities and general operating activities are accounted for in the General Fund. Generally, at the discretion of the Board of Directors, the District's groundwater extraction revenues fund the water conservation activities and property tax revenues fund the District's general operating activities and recreational activities of the District.

b. **Special revenue funds** are used to account for the proceeds of specific revenue sources that are legally restricted to expenditures for specified purposes. The *State Water Import Fund* accounts for the financial resources and expenditures necessary to pay for the District's annual entitlement to water from the State Water Project.

2. Proprietary Funds:

The focus of proprietary fund measurement is upon determination of operating income, changes in net assets, financial position, and cash flows. The generally accepted accounting principles applicable are those similar to businesses in the private sector.

Proprietary funds distinguish operating revenues and expenses from non-operating items. Operating revenues and expenses generally result from providing services and producing and delivering goods in connection with a proprietary fund's principal ongoing operations. The principal operating revenues of the District's enterprise funds are charges to customers for sales and services. The Pumping Trough Pipeline Fund also recognizes as operating revenue the fees, if any, intended to recover the cost of connecting new customers to the pipeline. Operating expenses for the enterprise funds include the cost of sales and services, administrative expenses, and depreciation on capital assets. All revenues and expenses not meeting this definition are reported as non-operating revenues and expenses.

The following is a description of the proprietary funds of the District:

Enterprise funds are required to be used to account for operations for which a fee is charged to external users for goods or services and the activity (a) is financed with debt that is solely secured by a pledge of the net revenues, (b) has third party requirements that the cost of providing services, including capital costs, be

recovered with fees and charges or (c) establishes fees and charges based on a pricing policy designed to recover similar costs.

The Freeman Diversion Fund accounts for the resources and expenses for the operations, maintenance, improvements and debt service of the Freeman Diversion Dam. The dam diverts water from the Santa Clara River for groundwater recharge and surface water delivery for agricultural use.

The Oxnard-Hueneme Pipeline Fund accounts for the resources and expenses for the operations, maintenance, improvements and debt service of the Oxnard-Hueneme pipeline. The District delivers potable water via groundwater from the El Rio spreading grounds to the Oxnard and Port Hueneme areas for municipal and industrial, and some agricultural usage.

The Pleasant Valley Pipeline Fund accounts for the resources and expenses for the operations, maintenance, improvements and debt service of the Pleasant Valley pipeline. The District diverts surface water at the Freeman Diversion Dam and transports it via the pipeline to the Pleasant Valley County Water District for agricultural use.

The Pumping Trough Pipeline Fund accounts for the resources and expenses for the operations, maintenance and improvements of the Pumping Trough pipeline. The pipeline provides a combination of Santa Clara River surface water and Fox Canyon aquifer water for agricultural use to replace the upper Oxnard aquifer wells in an over pumped area of the Oxnard Plain.

3. Fiduciary Funds:

Fiduciary funds are used to report assets held in a trustee or agency capacity for others and therefore are not available to support District programs. These funds are not incorporated into the district-wide statements. The District reports the following fiduciary fund:

The Employee Benefit Trust Fund is a private-purpose trust fund used to account for resources legally held in trust for the employee's Section 125 plan flexible spending accounts. The reporting focus is on net assets and changes in net assets and uses accounting principles similar to proprietary funds.

D. Basis of Accounting

Basis of accounting refers to the point at which revenues or expenditures/expenses are recognized in the accounts and reported in the financial statements. It relates to the timing of the measurements made regardless of the measurement focus applied.

1. Accrual:

Both governmental and business-type activities in the district-wide financial statements and the proprietary and fiduciary funds' financial statements are presented on the accrual basis of accounting. Revenues are recognized when earned and expenses are recognized when incurred. Earned but unbilled amounts for services provided are accrued and included in accounts receivable and recognized as revenue.

2. Modified Accrual:

The governmental funds' financial statements are presented on the modified accrual basis of accounting. Under the modified accrual basis of accounting, revenues are recorded when susceptible to accrual; i.e., both measurable and available. "Available" means collectible within the current period or soon enough thereafter to be used to pay liabilities of the current period. The District considers all revenue available if collected within 60 days after year-end. The District considers interest, certain taxes, grant revenues, groundwater charges and water delivery charges to be susceptible to accrual. Expenditures are generally recognized under the modified accrual basis of accounting when the related liability is

incurred. The exception to this general rule is that principal and interest on general obligation long-term debt, if any, is recognized when due.

E. Assets, Liabilities and Equity

1. Cash and Cash Equivalents:

The District's cash and cash equivalents are considered to be cash on hand, demand deposits, cash with fiscal agent, and short-term investments with original maturities of three months or less.

2. Investments:

Investments are carried at fair value.

The District's Investment Policy authorizes investments in the State of California Local Agency Investment Fund, U.S. Government Securities generally limited to Treasury Bills, Treasury Notes, Bonds or other direct obligations of the U.S. Government, U.S. Agencies generally limited to issuances by a federal agency or a U.S. Government – sponsored enterprise, Certificates of Deposit, Approved Bank Demand Deposit Accounts, Approved Bank Overnight Sweep Accounts and Money Market Funds.

3. Receivables:

Activity between funds that are representative of lending/borrowing arrangements outstanding at the end of the fiscal year are referred to as either "due to/from other funds" (i.e., the current portion of interfund loans) or "advances to/from other funds" (i.e., the non-current portion of interfund loans). Any residual balances outstanding between the governmental activities and business-type activities are reported in the district-wide financial statements as "internal balances."

The District's receivables consist of interest, certain taxes, grant revenues, groundwater charges and water delivery charges that are considered susceptible to accrual. Unbilled receivables for these items totaled approximately $2,796,660 in governmental funds and $1,227,289 in enterprise funds at June 30, 2012.

Property taxes are collected and remitted to the District by the County of Ventura. Taxes are levied annually on November 1 and are due one-half by December 10 and one-half by April 10. Major tax payments are received December through May and are recognized as revenue in the year received. Delinquent tax payments, received throughout the year, are recognized as revenue in the year received, except for those received within 60 days of year-end which are recognized as revenue as of June 30.

4. Prepaid Items:

Certain payments to vendors reflect costs applicable to future accounting periods and are recorded as prepaid items in the district-wide and proprietary fund financial statements. Prepaid items are recorded as expenditures in the governmental funds.

5. Capital Assets:

Capital assets are reported in the applicable governmental or business-type activity columns in the district-wide financial statements.

Capital assets purchased or acquired with an original cost of $5,000 or more are reported at historical cost. Contributed assets are reported at fair market value as of the date received. Additions, improvements and other capital outlays that significantly extend the useful life of an asset are capitalized. Other costs incurred for repairs and maintenance are

expensed as incurred. Depreciation on all assets is provided on the straight-line basis over the following estimated useful lives:

Dams	100 years
Structures and improvements	15-50 years
Equipment	3-25 years

6. Compensated Absences:

The District accrues vacation, annual leave and compensatory time in the period the fund liability is incurred. Sick leave liability is based on the amount accumulated at year-end by those employees who are eligible to receive termination payments.

7. Long-term Obligations:

In the district-wide financial statements and proprietary fund types in the fund financial statements, long-term debt and other long-term obligations are reported as liabilities in the applicable governmental activities, business-type activities, or proprietary fund type Statement of Net Assets. Bond premiums and discounts, as well as bond issuance costs, are deferred and amortized over the life of the bonds. Bonds payable are reported net of the applicable bond premium or discount. Bond issuance costs are reported as deferred charges and amortized over the term of the related debt.

In the fund financial statements, governmental fund types recognize bond premiums and discounts, as well as bond issuance costs, during the current period. The face amount of debt issued is reported as other financing sources. Premiums received on debt issuances are reported as other financing sources while discounts on debt issuances are reported as other financing uses. Issuance costs, whether or not withheld from the actual debt proceeds received, are reported as debt service expenditures.

8. Equity Classifications:

In the district-wide financial statements, equity is classified as net assets and displayed in three components:

a. Invested in capital assets, net of related debt – Consists of capital assets, less accumulated depreciation and any outstanding debt related to the acquisition, construction or improvement of those assets.
b. Restricted net assets – Consists of net assets with legal limitations imposed on their use by external restrictions by other governments, creditors or grantors.
c. Unrestricted net assets – All other net assets that do not meet the definition of "restricted" or "invested in capital assets, net of related debt."

Restricted net assets for governmental activities are restricted due to law through constitutional provisions or enabling legislation. Restricted net assets for business type activities are restricted due to debt covenants.

In the fund financial statements, governmental fund equity is classified as fund balance. Fund balance for governmental funds can consist of the following:

a. Nonspendable fund balance – Amounts that cannot be spent because they are either a) not in spendable form or b) legally or contractually required to be maintained intact.
b. Restricted fund balance – Amounts that are restricted to specific purposes when constraints placed on the use of recourses are either a) externally imposed by creditors, grantors, contributors, or laws or regulations of other governments or b) imposed by law through constitutional provisions or enabling legislation.
c. Committed fund balance – Amounts that can only be used for specific purposes pursuant to constraints imposed by formal action (majority vote) of the Board of Directors. Those committed amounts cannot be used for any other purpose unless formal action taken by the Board of Directors removes or changes the specified use. Committed fund balance will also incorporate contractual obligations to the extent that existing resources in the fund have

been specifically committed for use in satisfying those contractual requirements. Committed fund balance may include encumbered amounts for specific purposes that have not been previously committed.

d. Assigned fund balance – Amounts that are constrained by the District's intent to be used for specific purposes, but are neither restricted nor committed will be reported as assigned fund balance. Assigned fund balance may include encumbered amounts for specific purposes that have not been previously assigned. The Board of Directors has designated the assignment of assigned fund balance to the Finance Committee.

e. Unassigned fund balance – Represents residual fund balance that has not been restricted, committed, or assigned to specific purposes.

When both restricted and unrestricted fund balances are available for use, it is the District's policy to use restricted fund balance first, then unrestricted fund balance. Furthermore, committed fund balances are reduced first, followed by assigned amounts, and then unassigned amounts when expenditures are incurred for purposes for which amounts in any of those unrestricted fund balance classifications can be used.

At June 30, 2012, governmental fund balance consisted of the following:

	General Fund	State Water Fund
Fund Balances:		
Restricted for:		
Debt service reserve	$ 917,605	$ -
Debt covenants	878,258	-
State Water Importation	-	1,776,709
Unassigned	4,947,692	-
Total fund balances	$ 6,743,555	$ 1,776,709

Proprietary fund equity is classified the same as in the district-wide financial statements.

9. Budgets and Budgetary Accounting:

On or before June 30, the annual budget is adopted by the Board of Directors after holding a public hearing and provides for the general operation of the District. The operating budget includes proposed expenditures and the means of financing them. The Board of Directors has the legal authority to amend the budget for all funds at any time during the fiscal year. The appropriated budget is prepared by fund and activity. The legal level of budgetary control is at the fund level.

Encumbrance accounting is employed in the governmental funds. Encumbrances (i.e., purchase orders, contracts) outstanding at year-end are carried forward and added to the subsequent year's appropriation. The unencumbered balance of each appropriation lapses at year-end and reverts to the respective fund from which it was appropriated and becomes available for future appropriation.

F. Use of Estimates

The preparation of financial statements in conformity with generally accepted accounting principles requires management to make estimates and assumptions that affect certain reported amounts and disclosures. Accordingly, actual results could differ from those estimates.

Note 2. DEPOSITS AND INVESTMENTS

At June 30, 2012, the District's carrying amount of deposits was $566,891 and the bank balance was $790,720. The bank balance of $790,720 was insured. The District's custodial credit risk policy provides that all deposits will be collateralized with eligible securities having a market value of at least 110% of the amount of the deposits. Eligible securities are maintained with the financial institutions agent, are not held in the name of the District, and are included in those listed in California Government

Code Section 53651. Deposits are limited by the District's investment policy to a maximum of 15% of total cash and investments.

At June 30, 2012, the District had the following investments:

	Fair Value	Carrying Value
U.S. Government Money Market Funds	$ 2,316,644	$ 2,316,644
State of California Local Agency Investment Fund	8,256,951	8,256,951
County of Ventura Investment Pool	59,847	59,847
Total	$ 10,633,442	$ 10,633,442

The State of California Local Agency Investment Fund (LAIF) is an external investment pool. LAIF operates in accordance with appropriate state laws and regulations and is an unrated pool. The share value of the District's investment in LAIF is $8,246,892. The County of Ventura (County) Investment Pool operates in accordance with appropriate state laws and regulations and the investment policy of the County. The District's investment in the County of Ventura Investment Pool was rated AAAf by Standard & Poor's for a primary objective of safety and S1 by Standard & Poor's for a secondary objective of liquidity.

Credit Risk - The District manages its risk for its funds in accordance with state statutes and the District's investment policy. The criteria for selecting investments are, in order of priority, (1) safety – consideration of the potential loss of principal or interest, (2) liquidity – the ability to have funds available at any moment in time with a minimal potential loss and (3) yield – the optimum rate of return while preserving capital.

Concentration of Credit Risk - The District's investment policy provides that no more than 33% of the District's portfolio may be invested with a single firm or institution with the exception of the State of California Local Agency Investment Fund or obligations of the U.S. Government.

Interest Rate Risk – As a means of limiting its exposure to fair value losses arising from rising interest rates, the District limits and staggers its investments to instruments whose maturity does not exceed three years. All District investments are intended to be held to maturity.

Note 3. NOTE RECEIVABLE

The District has a water delivery contract with the Pleasant Valley County Water District (Pleasant Valley) that, as amended, states that Pleasant Valley agrees to pay to the District an annual amount sufficient to cover the debt service requirements of the 1996 Pleasant Valley Reservoir Improvement Project which was initially funded by the proceeds of the 1996 Certificates of Participation. Under the terms of the contract, Pleasant Valley agrees to make principal and interest payments each year until the year ending June 30, 2016 or until the note receivable is paid in full, even in the event that no water is delivered in any particular year or years. The terms of the note call for interest to be paid at the same rate of interest as the District pays on the underlying debt, which ranges from 3.4% to 5.25%.

Note receivable is comprised of the following at June 30, 2012:

Pleasant Valley County Water District	$ 739,559
Less current portion	(187,515)
Net note receivable	$ 552,044

Note 4. CAPITAL ASSETS

	Balance July 1, 2011	Increases	Decreases	Balance June 30, 2012
Governmental activities:				
Capital assets not being depreciated:				
Land	$ 16,919,903	$ -	$ -	$ 16,919,903
Construction in Progress	779,699	527,344	(199,811)	1,107,232
Total capital assets not being depreciated	17,699,602	527,344	(199,811)	18,027,135
Capital assets being depreciated:				
Dams	5,684,474	-	-	5,684,474
Structures and Improvements	20,698,259	176,365	-	20,874,624
Equipment	2,796,919	350,642	(52,644)	3,094,917
Intangibles	8,431,927	-	-	8,431,927
Total capital assets being depreciated	37,611,579	527,007	(52,644)	38,085,942
Less accumulated depreciation for:				
Dams	(3,268,572)	(56,845)	-	(3,325,417)
Structures and Improvements	(8,102,071)	(536,168)	-	(8,638,239)
Equipment	(1,849,181)	(189,575)	52,644	(1,986,112)
Intangibles	(3,465,948)	(462,604)	-	(3,928,552)
Total accumulated depreciation	(16,685,772)	(1,245,192)	52,644	(17,878,320)
Total capital assets being depreciated, net	20,925,807	(718,185)	-	20,207,622
Governmental activities capital assets, net	$ 38,625,409	$ (190,841)	$ (199,811)	$ 38,234,757
Business-type activities:				
Capital assets not being depreciated:				
Land	$ 1,220,855	$ -	$ -	$ 1,220,855
Construction in Progress	42,770	178,511	(145,306)	75,975
Total capital assets not being depreciated	1,263,625	178,511	(145,306)	1,296,830
Capital assets being depreciated:				
Dams	31,173,473	-	-	31,173,473
Structures and Improvements	34,290,250	141,664	-	34,431,914
Equipment	1,852,213	157,890	-	2,010,103
Total capital assets being depreciated	67,315,936	299,554	-	67,615,490
Less accumulated depreciation for:				
Dams	(6,609,550)	(311,736)	-	(6,921,286)
Structures and Improvements	(16,884,885)	(799,059)	-	(17,683,944)
Equipment	(1,354,990)	(118,190)	-	(1,473,180)
Total accumulated depreciation	(24,849,425)	(1,228,985)	-	(26,078,410)
Total capital assets being depreciated, net	42,466,511	(929,431)	-	41,537,080
Business-type activities capital assets, net	$ 43,730,136	$ (750,920)	$ (145,306)	$ 42,833,910

Depreciation expense was charged to functions/programs of the primary government as follows:

Governmental activities:		
Water conservation	$	891,737
Lake Piru Recreation facility		279,481
State Water Project importation		73,974
General and administrative		-
Total governmental activities depreciation	$	1,245,192
Business-type activities:		
Freeman Diversion facility	$	369,711
Water delivery and treatment facilities		859,271
Total business-type activities depreciation	$	1,228,982

Note 5. PENSION PLAN

Plan Description – The District's defined benefit pension plan provides retirement and disability benefits, annual cost-of-living adjustments, and death benefits to plan members and beneficiaries. The District contributes to the Public Agency portion of the California Public Employees' Retirement System (CalPERS), a cost-sharing multiple-employer defined benefit plan administered by CalPERS. CalPERS acts as a common investment and administrative agent for participating public employers within the State of California. State statutes within the Public Employees' Retirement Law establish menus of benefit provisions as well as other requirements. The District selects optional benefit provisions from the benefit menu by contract with CalPERS and adopts those benefits through local ordinance. CalPERS issues a separate comprehensive annual report. Copies of the CalPERS' annual financial report may be obtained from the CalPERS Executive Office, 400 P Street, Sacramento, CA 95814.

Funding Policy – Active plan members are required to contribute 8% of annual covered salary. Generally, the District makes the contributions required of District full-time employees and part-time employees (meeting certain hour's criteria) on their behalf and for their account. The District is required to contribute the actuarially determined remaining amounts necessary to fund the benefits for its members. The actuarial methods and assumptions used are those adopted by the CalPERS Board of Administration. The required employer contribution rate for fiscal year 2011-2012 was 19.919% and the employee portion paid by the District for full-time and part-time employees was 8%. The contribution requirements of the plan members are established by State statute and the employer contribution rate is established and may be amended by CalPERS.

Annual Pension Cost – For fiscal year 2011-2012, the District's annual pension cost of $963,769 was equal to the District's required and actual contributions (does not include employee share of $382,674 which was paid by the District). The required contribution for fiscal year 2011-2012 was determined as part of the June 30, 2009 actuarial valuation using the entry age actuarial cost method with the contributions determined as a percent of pay. The actuarial assumptions included (a) 7.75% investment rate of return (net of administrative expenses), (b) projected salary increases of 3.55% to 14.45% depending on age, service and type of employment, and (c) individual salary growth which is a merit scale varying by duration of employment coupled with an assumed annual inflation component of 3.00% and an annual production growth of 0.25%. Items (a) and (b) also included an inflation component of 3.00%. The actuarial value of the plan's assets was determined using a technique that smoothes the effect of short-term volatility in the market value of investments over a fifteen-year period depending on the size of investment gains and/or losses. The plan's unfunded actuarial accrued liability (or excess assets) is being amortized as a level percentage of projected payroll on a closed basis. The remaining amortization period at June 30, 2009 was 19 years.

Fiscal Year Ending	Annual Pension Cost (APC)	Percentage of APC Contributed	Net Pension Obligation
6/30/2010	$ 713,976	100%	-
6/30/2011	$ 788,323	100%	-
6/30/2012	$ 963,769	100%	-

Note 6. OTHER POST EMPLOYMENT BENEFITS

Plan Description – The District administers a single-employer defined benefit healthcare plan (Plan). The Plan provides post employment medical insurance to eligible retirees and their spouses through the California Public Employees Retirement System. State statutes within the Public Employees' Retirement Law establish menus of benefit provisions as well as other requirements and may be amended by CalPERS. The District selected an optional benefit provision specifically for health benefits in compliance with the Public Employees Medical and Hospital Care Act (PEMHCA). The Plan does not issue a public available report.

Funding Policy – The District's annual other post employment benefit (OPEB) cost (expense) is calculated based on the annual required contribution of the employer (ARC), an amount actuarially determined in accordance with the parameters of GASB Statement No. 45. The ARC representing a level of funding that, if paid on an ongoing basis, is projected to cover the normal cost each year and amortize any unfunded actuarial liabilities (of funding excess) over a period not to exceed thirty years. The District funds the plan on a pay-as-you-go basis and has recognized a liability for the difference between pay-as-you-go and the actuarially determined ARC. The District's contribution is determined using a 5% unequal method which is equal to 5% of actives contribution each year the District is in PEMHCA. The District joined PEMHCA effective 1999. For FY 2011-12, the District's contributed $72.80 per month per each plan member. The required contribution amount for plan members is the remaining amounts necessary to fund the full premium due, based on the benefit choice of the plan member, after the District's PEMHCA minimum (10/14/98 PEMHCA resolution) has been applied.

Annual OPEB Cost and Net OPEB Obligation – The following table shows the components of the District's annual OPEB expense for the years ended June 30, 2012 and 2011, the amount actually contributed to the plan and the changes in the District's obligation:

	2012	2011
Annual required contribution (ARC)	$ 144,100	$ 130,600
Interest on net OPEB obligation	10,001	4,847
Adjustment to annual required contribution	(18,102)	(8,448)
Annual OPEB cost (expense)	135,999	126,999
Pay as you go payments	(8,259)	(5,725)
Increase in net OPEB obligation	127,740	121,274
Net OPEB obligation - beginning of year	235,321	114,047
Net OPEB obligation - end of year	$ 363,061	$ 235,321

The District's annual OPEB cost, the percentage of annual cost contributed to the plan and the net OPEB obligation for the years ended June 30, 2012, 2011 and 2010 are shown in the following table:

Fiscal Year Ending	Annual OPEB Cost	Percentage of OPEB Contributed	Net OPEB Obligation
6/30/2010	$ 118,200	3.51%	$ 114,047
6/30/2011	$ 126,999	4.51%	$ 235,321
6/30/2012	$ 135,999	6.07%	$ 363,061

Funded Status – The funded status of the Plan as of June 30, 2009, the most recent actuarial valuation date, was as follows:

Actuarial accrued liability	$ 733,600
Actuarial value of plan assets	-
Unfunded actuarial accrued liability	$ 733,600
Funded ratio	0%
Covered payroll	$ 5,026,100
Unfunded actuarial accrued liability as a percentage of covered payroll	14.6%

The schedule of funding progress, presented as required supplementary information following the notes to the financial statements, is intended to present multiyear trend information about whether the actuarial value of plan assets is increasing or decreasing over time relative to the actuarial accrued liabilities for benefits.

Actuarial methods and assumptions – Actuarial valuations involve estimates of the value of reported amounts and assumptions about the probability of events far into the future. Actuarially determined amounts are subject to continual revision as actual results are compared to past expectations and new estimates are made about the future. Calculations are based on the types of benefits provided under the terms of the substantive plan at the time of each valuation and the pattern of sharing of costs between the employer and plan members to that point. Consistent with the long-term perspective of actuarial calculations, actuarial methods and assumptions used included techniques that are designed to reduce short-term volatility in actuarial accrued liabilities for benefits.

The following is a summary of the actuarial assumptions and methods:

Valuation date	June 30, 2009
Actuarial cost method	Entry age normal cost method
Amortization method	Level percent of payroll amortization on a closed basis
Remaining amortization period	28 years as of the valuation date
Actuarial assumptions:	
Investment rate of return	4.25% (net of 2% of administrative expenses)
Projected salary increase	3.25% (depending upon age, service and type of employment)
Inflation – discount rate	3.00%
Healthcare cost trend rate	4.50% (PEMHCA minimum)

Note 7. RISK MANAGEMENT JOINT POWERS AUTHORITY

The District participates in the property, liability and workers' compensation program and risk management services organized by the Special District Risk Management Authority (the Authority). The Authority is a Joint Powers Authority (JPA) created to provide an insurance program and risk management services to public agencies in the State of California. The JPA is not a component unit of the District for financial purposes, as explained below.

The Authority provides liability, property and workers' compensation insurance and risk management services for the District, which is one of over 750 participating agencies, for losses in excess of the members' specified self-insurance retention levels. Individual claims (and aggregate public liability and property claims) in excess of specified levels are covered by excess insurance policies purchased from commercial carriers. The Authority is governed by a board composed of members from participating agencies. The board controls the operations of the Authority, including selection of management and approval of operating budgets, independent of any influence by the members from beyond their representation on the board. Each member shares financial surpluses and deficiencies proportionately to its participation in the Authority.

Based on audited financial statements, at June 30, 2012 the Authority had total assets, liabilities and net assets of $102,675,963, $43,880,783 and $58,795,180 respectively. The District paid premiums of $249,498 to the Authority for property, general liability and workers' compensation insurance during the year ended June 30, 2012.

The self-insurance retention level covered under the Authority program for property, liability and workers' compensation is $100,000, $500,000 and $250,000, respectively, per claim and would be paid from the assets of the Authority. Assistance with disposition of claims within the self-insured retentions is provided through the Authority. The District had no outstanding claims under the Authority and no liabilities relating to outstanding claims (including estimates for incurred but not reported claims) were recorded as of June 30, 2012.

Note 8. STATE WATER PROJECT

In 1963, the Ventura County Flood Control District contracted with the State of California (State) for 20,000 acre-feet per year of water from the State Water Project (SWP). The SWP conveys water from Northern California to Southern California through a system of reservoirs, canals, pump stations and power generation facilities. In 1971, the administration of the Water Supply Contract with the State was assigned to Casitas Municipal Water District (Casitas). The District has contracted with Casitas for an annual entitlement of 5,000 acre-feet of SWP water. As consideration for water delivery entitlement, the District is obligated through the year 2036 to pay, without regard to the quantity of water received, its share of SWP capital construction costs, ongoing operating, maintenance, power and replacement costs, and certain other costs (collectively referred to as "ongoing operations and maintenance costs") to ensure the future availability of water.

The District has recorded a liability for its share of capital construction costs (see Note 9). The District's share of ongoing operations and maintenance costs is determined annually by the State. Estimates provided by the State of future costs are as follows:

Year Ending June 30	Governmental Activities
2013	$ 518,000
2014	539,946
2015	545,931
2016	561,305
2017	563,172
2018-2022	2,804,723
2023-2027	2,811,137
2028-2032	2,663,401
2033-2036	1,800,969
Total	$ 12,808,584

The above estimates are based upon a number of assumptions, are contingent upon future events, and are subject to significant variations over time. The District accounts for such ongoing operations and maintenance costs as expenditures in the periods in which they are billed to the District.

Note 9. LONG-TERM LIABILITIES

State Water Project - This long-term liability represents the District's share of capital construction costs of the State Water Project (See Note 8). The total principal amount outstanding as of June 30, 2012 is estimated by the State to be $1,353,665 and has a fixed interest rate of 4%, payable in various installments, due December 2035.

Year Ending	State Water Project Construction Costs Governmental Activities	
June 30	Principal	Interest
2013	$ 92,202	$ 51,408
2014	96,061	48,096
2015	99,038	44,985
2016	100,886	40,948
2017	99,249	36,485
2018-2022	336,973	126,525
2023-2027	212,668	68,503
2028-2032	205,543	19,570
2033-2036	111,045	(11,113)
Total	$ 1,353,665	$ 425,407

2001B Revenue Bonds - In August 2001, the District entered into an Installment Purchase Agreement with the California Statewide Communities Development Authority (the Authority), a joint exercise of powers agency, in order to provide for the financing for certain public capital improvements and water system maintenance. The Authority, under a pooled financing program, issued $12,495,000 Water and Wastewater Revenue Bonds, Series 2001B. The District is a participant in the Series 2001B program. The District's portion of the Water and Wastewater Revenue Bonds amounted to $2,550,000. The bonds require semi-annual payments, with interest ranging from 3.25% to 5.13%, through October 2021. The payments are secured by a pledge of the District's net revenues. The total principal amount outstanding as of June 30, 2012 is $1,185,000 with remaining interest ranging from 4.10% to 5.13%.

Year Ending	2001B Revenue Bonds			
	Governmental Activities		Business-type Activities	
June 30	Principal	Interest	Principal	Interest
2013	$ 17,438	$ 10,209	$ 77,563	$ 45,409
2014	18,355	9,421	81,645	41,904
2015	19,273	8,565	85,727	38,095
2016	20,191	7,647	89,809	34,013
2017	21,109	6,666	93,891	29,649
2018-2022	121,144	16,107	538,855	71,651
Total	$ 217,510	$ 58,615	$ 967,490	$ 260,721

2005B Revenue Bonds - In July 2005, the District entered into an Installment Purchase Agreement with the California Statewide Communities Development Authority (the Authority), a joint exercise of powers agency to provide for the financing for certain public capital improvements. The Authority, under a pooled financing program, issued $11,840,000 Water and Wastewater Revenue Bonds, Series 2005B. The District is a participant in the Series 2005B program. The District's portion of the Water and Wastewater Revenue Bonds amounted to $9,620,000. The bonds require semi-annual payments, with interest ranging from 2.50% to 4.50%, for 20 years through October 2025 and for 30 years through October 2035. The payments are secured by a pledge of the District's net revenues. The total principal amount outstanding as of June 30, 2012 is $7,820,000 with remaining interest from 3.10% to 4.50%.

2005B Revenue Bonds

Year Ending	Governmental Activities		Business-type Activities	
June 30	Principal	Interest	Principal	Interest
2013	$ 225,160	$ 256,118	$ 59,840	$ 62,123
2014	233,104	248,555	61,896	60,114
2015	244,843	240,366	65,157	57,937
2016	252,787	231,531	67,213	55,587
2017	260,731	222,157	69,269	53,096
2018-2022	1,457,673	948,352	387,327	222,320
2023-2027	1,588,781	610,197	411,219	132,709
2028-2032	1,024,859	341,588	210,141	70,041
2033-2036	995,814	92,050	204,186	18,874
Total	$ 6,283,752	$ 3,190,914	$ 1,536,248	$ 732,801

2006A Revenue Bonds - In March 2006, the District entered into an Installment Purchase Agreement with the California Statewide Communities Development Authority (the Authority), a joint exercise of powers agency, in order to provide for the financing for certain public capital improvements, and to refund certain outstanding obligations of the District (1996 Certificates of Participation issue). The Authority, under a pooled financing program, issued $21,560,000 Water Revenue Bonds, Series 2006A. The District is a participant in the Series 2006A program. The District's portion of the Water Revenue Bonds amounted to $8,470,000. The bonds require semi-annual payments, with interest ranging from 3.00% to 4.50%, through April 2016. The payments are secured by a pledge of the District's net revenues. The total principal amount outstanding as of June 30, 2012 is $2,100,000 with remaining interest ranging from 3.50% to 4.5%.

2006A Revenue Bonds

Year Ending	Governmental Activities		Business-type Activities	
June 30	Principal	Interest	Principal	Interest
2013	$ 485,592	$ 33,077	$ 719,408	$ 45,311
2014	54,485	6,488	235,515	28,218
2015	54,695	4,445	240,305	19,386
2016	58,143	2,327	251,857	10,074
Total	$ 652,915	$ 46,337	$ 1,447,085	$ 102,989

2009 Certificates of Participation Bonds – Certificates of Participation (COP), in the amount of $15,465,000 were issued in December 2009 to provide funds for the purchase of (1) acquisition of approximately 231 acres of land of $13,542,400 and for (2) improvements related to the Lake Piru Recreation facilities for $750,000. The certificates are payable solely from certain installment payments to be made by the District pursuant to the 2009 Installment Purchase Contract, dated December 1, 2009 by and between the District and the United Water Conservation District Public Facilities Financing Corporation. The 2009 Installment Payments are a special obligation of the District payable from and secured by a pledge of the net revenues of the District's water system. The bonds require semi-annual payments, with interest ranging from 2.00% to 5.00% for 30 years through June 2040. The total principal amount outstanding as of June 30, 2012 is $11,820,000 with remaining interest ranging from 3.00% to 5.00%.

Year Ending	2009 Certificates of Participation Governmental Activities	
June 30	Principal	Interest
2013	$ 395,000	$ 534,356
2014	415,000	518,156
2015	435,000	501,156
2016	450,000	483,456
2017	465,000	465,156
2018-2022	2,025,000	2,049,216
2023-2027	1,515,000	1,715,338
2028-2032	1,910,000	1,300,500
2033-2037	2,435,000	759,875
2038-2040	1,775,000	135,875
Total	$ 11,820,000	$ 8,463,084

In December 2009, the District entered into an agreement with the City of Oxnard (City) for the purchase of supplemental water. In the event the District makes available supplemental water to the City and the City utilizes these water supplies, the City could potentially make payments up to $5,850,000 to the District beginning in January 2010 and continuing through June 2019. The District received $1,212,506 and $1,925,000 from the City for supplemental water during the years ended June 30, 2012 and 2011, respectively. The District has committed to utilize these revenues to assist in making the 2009 Certificates of Participation debt service payments.

Long-term liability activity for the year ended June 30, 2012 was as follows:

	Balance June 30, 2011	Additions	Retirements	Balance June 30, 2012	Due within One Year
Governmental activities:					
Obligation under State Water Project	$ 1,429,356	$ 12,052	$ (87,743)	$ 1,353,665	$ 92,202
Bonds payable:					
2001B Revenue bonds	235,430	-	(17,920)	217,510	17,438
2005B Revenue bonds	6,505,118	-	(221,366)	6,283,752	225,160
2006A Revenue bonds	1,121,039	-	(468,124)	652,915	485,592
2009 Certificates of Participation	13,650,000	-	(1,830,000)	11,820,000	395,000
Plus deferred amounts of bond premium	105,114	-	(5,098)	100,016	5,101
Less deferred amounts for issuance discounts	(59,452)	-	2,516	(56,936)	(2,517)
Less deferred amounts on refundings	(2,332)	-	501	(1,831)	(499)
Total bonds payable	21,554,917	-	(2,539,491)	19,015,426	1,125,275
Compensated absences	519,163	242,811	(236,506)	525,468	276,287
Post employment benefits other than pensions	119,667	70,511	(4,282)	185,896	-
Other	200	16,391	(200)	16,391	16,391
Governmental activity long-term liabilities	$ 23,623,303	$ 341,765	$ (2,868,222)	$ 21,096,846	$ 1,510,155
Business-type activities:					
Bonds payable:					
2001B Revenue bonds	$ 1,109,570	$ -	$ (142,080)	$ 967,490	$ 77,563
2005B Revenue bonds	1,594,882	-	(58,634)	1,536,248	59,840
2006A Revenue bonds	2,138,961	-	(691,876)	1,447,085	719,408
Plus deferred amounts of bond premium	13,072	-	(2,752)	10,320	2,752
Less deferred amounts for issuance discounts	(20,871)	-	1,263	(19,608)	(1,262)
Less deferred amounts on refundings	(160,811)	-	34,459	(126,352)	(34,460)
Total bonds payable	4,674,803	-	(859,620)	3,815,183	823,841
Compensated absences	295,288	130,065	(135,878)	289,475	161,265
Post employment benefits other than pensions	115,658	65,484	(3,977)	177,165	-
Business-type activity long-term liabilities	5,085,749	195,549	(999,475)	4,281,823	985,106
Total long-term liabilities	$ 28,709,052	$ 537,314	$ (3,867,697)	$ 25,378,669	$ 2,495,261

For governmental activities, compensated absences and other post employment benefits are generally liquidated by the general fund.

Note 10. MAJOR CUSTOMERS

The District has four customers whose water charges represent a significant portion of water revenue. Revenue from these four customers represented 33%, 10%, 7% and 6% respectively, of water revenue during the fiscal year ended June 30, 2012.

Note 11. RISK MANAGEMENT

The District is exposed to potential losses from claims arising from its business operations. Significant losses are covered by commercial insurance. There have been no significant reductions in insured coverage. Settlement amounts have not exceeded insurance coverage for the current year or the three prior years.

Note 12. RELATED PARTY TRANSACTIONS

Three of the seven-member Board of Directors have business concerns within the District boundaries and purchased water from the District. The amounts received, for the year ended June 30, 2012, from Board members in sales revenue was $156,645.

Note 13. JOINT VENTURE

On September 17, 2002, the District entered into a Joint Exercise of Powers agreement with the City of Oxnard to create the Oxnard Plain/RiverPark Reclamation and Groundwater Recharge Authority (Authority), a public entity set up to secure grant funding and other public and private funding to reclaim mining pits for water recharge purposes, to implement the Recharge Program and Reclamation Plan, and to undertake other groundwater recharge, groundwater quality, and water supply programs. Each of the parties may be required to make contributions of funds or use its personnel, equipment or property. At June 30, 2012, the Authority had total assets, liabilities and net assets of $1,024,021, $0, and $1,024,021 respectively. The financial information on the Authority may be obtained by contacting its Treasurer/Auditor, City of Oxnard, Finance Director, 300 West Third Street, Oxnard, CA 93003.

Note 14. COMMITMENTS

The District leases office space from a third party under a long-term operating lease, which expires on June 30, 2017. The future minimum rental payments due under the lease are as follows:

Year ending 30-Jun	Rental Payments
2013	$ 37,968
2014	39,107
2015	40,280
2016	41,489
2017	42,733
	$ 201,577

There was no rent expense for the year ended June 30, 2012.

Note 15. CONTINGENCIES

Santa Felicia Dam and HydroElectric Plant - The Federal Energy Regulatory Commission (FERC) relicense for the operation of the District's Santa Felicia Dam and Hydroelectric Plant is financed by a combination of District groundwater extraction rates and property taxes. The District's original FERC license expired in 2004 and the District began the relicensing process in FY 2001-2002. Through June 30, 2012, the District has spent or encumbered costs of $3,475,598 on the relicense process. On September 12, 2008, FERC issued to the District a new, 40 year FERC license. The new license requires that the

District meet specific conditions. Many of these conditions arise from the Biological Opinion (BiOp), which National Marine Fisheries Service (NMFS) issued to FERC concerning impacts to the Southern California steelhead, an endangered Distinct Population Segment (an endangered species of fish) under the federal Endangered Species Act (ESA). NMFS found that the issuance of the FERC license would jeopardize the continued existence of steelhead and identified a Reasonable and Prudent Alternative (RPA) made up of three elements that the District must implement to reduce the effects to steelhead such that it is no longer a jeopardy situation. The RPA includes requirements that the District undertake actions, such as water releases, that are operational changes that would potentially reduce the water-yield of the project. The RPA requires the District to prepare and implement a number of plans, in consultation with NMFS and other agencies, to address the effect of the District's activities on water flows, geomorphic conditions, and fish passage. In addition to the RPA, the biological opinion also contains measures that the District must implement to generally minimize the effects of certain activities on steelhead. These measures include requiring that the District develop plans that evaluate ramping rates for water releases. Since the license was issued, the District has been working with NMFS on developing and implementing the required plans. At the same time, the District requested a rehearing on several license elements including items for steelhead effects. On December 17, 2009, FERC denied the District's request for a rehearing. The District filed an appeal in the U.S. Court of Appeals for the D.C. Circuit on February 12, 2010, while continuing to work with NMFS on the various plans. The District's brief was filed with the court on August 24, 2010. Because significant progress was being made on the most critical of the necessary plans, NMFS, FERC and the District requested that the court proceedings be held in abeyance. The court ordered the abeyance on September 29, 2010. The order requires reports each 60-day period and the first report was filed on November 29, 2010. The District is in compliance with this reporting requirement and continues to report each 60-day period. To date, four of the eight BiOp required plans have been approved by FERC. The District has completed implementation of one, the study plan of geomorphic effects. Two other required plans have been developed to understand and evaluate the relationship between flows and water depths of lower Piru Creek. The District is using these results to inform its water release ramping rates. The District has not yet begun implementation of the other FERC-approved plan, a study plan for assessing the feasibility of providing fish passage at Santa Felicia Dam. In its approval, FERC stated that the District must obtain NMFS' agreement on that plan before it can initiate implementation. The District is currently working to obtain NMFS' agreement. Of the remaining four plans, one, the water release plan, has been completed and the District is in the process of seeking to amend its license with this plan as required by FERC. This process is expected to be completed by December 2013. In FY 2012-13, the District expects to complete two (water release monitoring/implementation and adaptive management plans) of the four remaining plans and file them with FERC for approval. A third plan (habitat improvement plan) will be completed and filed with FERC early in the following fiscal year. The remaining plans will contain the results obtained from implementation of the passage feasibility study plan. At this time, the earliest the District expects that plan to be completed is June 2015. The development and implementation of the plans require the District to undertake specific actions (e.g., including water releases) for the lifetime of the license. This will continue to involve staff time and outside consulting services to manage and carry out and will likely have a negative effect on water resources over the term of the license (40 years). In addition to the required plans, the District is required to meet other conditions as part of the FERC licensing process. At this time, the cost of complying with the additional requirements associated with steelhead is not known. The District is continuing to work with NMFS/FERC in an effort to finalize and implement these remaining plans to satisfy the license requirements while minimizing the impact on the District's operations and limited water resources. The District and NMFS successful collaboration on the development of acceptable plans has demonstrated to FERC that progress is being made. Based on these efforts, FERC has not, to date, imposed any penalties on the District for non-compliance of the license requirements. However, the District is still in technical violation due to the delay in filing of the final required plans and could be subject to penalty costs of $11,000 per day for each violation. FERC has made it clear to the District that it could be subject to up to the $11,000 per day penalty, for each infraction, going back to the date in which the District first went out of compliance with any required action(s) deadline. Because the District has been making positive headway in complying with all the license requirements, it does not believe any penalty costs will be assessed by FERC. If FERC concludes at some point that the District is not making enough progress in meeting its requirements, in a timely manner, it could assess up to the maximum amount of the $11,000 per day penalty since the required deadline set for any required action(s). The financial impact to the District, if FERC takes such a position, could be significant. It should be understood though, that it appears that FERC's intent is not to assess and collect penalties from the District but instead to use the possible penalties to keep the District focused on coming into compliance with the license requirements.

Santa Felicia Dam - Under the District's dam safety program, a structural analyses study was performed to determine the seismic adequacy of the Santa Felicia Dam outlet works. The final results of the analyses have not been received; however, preliminary reports indicate that two structures of the outlet works are insufficient to withstand the largest credible earthquake as defined by the study. The outlet works include the intake tower, a standing pipe under the lake with its opening above the lake bottom sediment. Water flows into the intake tower and is channeled through the penstock, a steel

pipe supported inside of a tunnel built under the dam. The purpose of the outlet works is to convey water from upstream of the dam and release it downstream of the dam. The intake tower was modified in the late 1970's and it is believed that the modification will not withstand a large seismic activity such as an earthquake. The failure of the intake tower could prevent water releases from the reservoir, affecting the District's mission of recharging the aquifers. In addition, it has also been determined that the penstock will most likely not withstand a significant seismic event. A failure of the penstock could drain the reservoir and might cause serious damage to the dam. Because of the seismic insufficiency of the intake tower (and silting issues) and penstock, the District is working on the design of a project to replace both structures. Once all technical options have been thoroughly considered and a final decision is made by the Board of Directors, a detailed cost analysis will be prepared. It is anticipated that the rehabilitation of the two structures could have a significant financial impact on the District. At this time, the estimated cost to design and construct the rehabilitation of the two structures is in the order of $13 to $30 million.

The Freeman Diversion - The District's Freeman Diversion was completed in 1991. The Freeman Diversion diverts water released from Lake Piru and natural runoff from the Santa Clara River. In 1997, the Southern California steelhead was listed as an endangered Distinct Population Segment (DPS) in accordance with the ESA. The District must comply with the ESA for this listed DPS with respect to the District's operation of the Freeman Diversion. As part of an ESA Section 7 process, NMFS in 2008 issued a Jeopardy Biological Opinion to the Bureau of Reclamation for the effects of the operations at the Freeman Diversion on steelhead. NMFS's Jeopardy Biological Opinion contained a Reasonable and Prudent Alternatives (RPA) to be undertaken by the District. The RPA consisted of several elements including increased bypass flows for fish, and interim and long-term physical modifications to the Freeman Diversion. The cost of complying with the conditions of the Biological Opinion was unknown. However, such costs were expected to have a significant effect on the financial position and cash flows of the District. The U.S. Bureau of Reclamation withdrew from the process after NMFS issued the Biological Opinion. Accordingly, the Section 7 Jeopardy Biological Opinion issued by NMFS is no longer valid. However, the District must still comply with the ESA in protecting the endangered steelhead. To minimize effects of ongoing operations on steelhead, the District has developed and is implementing modified operations, including diversions, of the Freeman Diversion. However, the District still needs incidental take authorization for the operation of the diversion. To obtain this authorization, the District is preparing a Habitat Conservation Plan (HCP) in accordance with Section 10 of the ESA. Through June 30, 2012, the District has spent or encumbered costs of $1,144,668 on the habitat conservation plan. That process is expected to take from two to five years to complete.

During the fiscal year ending June 30, 2009, a lawsuit was filed by an environmental group alleging unauthorized take of Southern California steelhead by the District at the Freeman Diversion Dam and seeking compliance by the District and Bureau with the terms of the 2008 Biological Opinion. By mutual agreement in August 2009, the District and the environmental group reached a settlement agreement in order to resolve the lawsuit and to avoid future costs and uncertainties of further litigation. The District recognized an extraordinary item of $827,682 in fiscal year ending June 30, 2009 which included settlement costs. Pursuant to the settlement agreement, the District agreed to undertake several measures, including modifying certain operations, evaluating bypass flows, and forming an independent panel of experts to evaluate fish passage at the Freeman Diversion. The District is in compliance with all requirements of the settlement agreement. The independent panel issued a final report with its recommendations for improving the fish passage at the Freeman Diversion on September 15, 2010. Based on that panel's conclusions and in compliance with the settlement agreement, the District is pursuing the design and implementation of a new fish passage facility at the Freeman Diversion. This fish passage facility will be included as a conservation measure in the HCP. The design, permitting, construction, and maintenance of this new fish passage facility could have a significant effect on the financial position and cash flows of the District. At this time, the estimated cost to construct the facility is in the order of $24 to $30 million. The District's current goal is to complete the HCP and all other permitting and environmental compliance such that construction of the fish passage facility can begin in March 2015. Through June 30, 2012, the District has spent or encumbered costs of $761,208 to evaluate the fish passage.

Probable Maximum Precipitation/Flood Studies – Standard engineering practices require that dams be able to safely pass the largest discharges that they might encounter. This discharge is conjectural and is called the Probable Maximum Flood (PMF). The PMF is calculated from a conjectural large rainfall distribution. The standard rainfall employed is typically derived from the National Weather Service (NWS) computer model(s). In 2008, new PMF's were calculated for both the District's Santa Felicia Dam and California Department of Water Resources (DWR) Pyramid Dam on Piru Creek with the revised NWS rainfall model. Both dams were found to have issues with safely passing the new conjectural flows. The discharges at either dam are intended to be conveyed over engineered spillways. Accordingly, should a discharge which

exceeds existing capacity need to be passed, some enlargement or modification to the dam's spillway becomes necessary. The higher the increased flood discharge, the larger and more costly the necessary retrofit. The recent NWS rainfall model discharges represented large increases from earlier PMF discharges. In order to verify and refine the PMF values for retrofit design, dam owners are allowed to utilize hydrology techniques specifically tailored to the specific watershed characteristics. The Federal Energy Regulatory Commission (FERC) and the California Division of Safety of Dams (DSOD) in their regulatory capacities, require that the site-specific PMF considerations be reviewed by an independent Board of Consultants. The District and DWR teamed to perform a Piru Watershed site specific PMF. DWR developed and funded the site-specific Probable Maximum Precipitation/Flood study and the District secured and funded a Board of Consultants that was responsible to review and approve the Probable Maximum Precipitation/Flood study results generated by the agencies for their respective facilities. These tasks were largely accomplished during FY 2010-11. The findings of the site-specific Probable Maximum Precipitation/Flood report resulted in reduced Probable Maximum Precipitation/Flood values. The draft results of the site specific rainfall study pointed to rainfall amounts that are substantially lower than those suggested by the NWS model, and if approved, would result in eliminated or significantly reduced modifications to the dam and spillway. FERC verbally reported that they intended to reject the new methodology, but agreed with the District's assertion that the current NWS methodology was flawed. This new policy will be issued in a written joint FERC-DSOD document. The District has not received this document to date. Additional studies may be required by any future FERC and DSOD policy document. A new methodology may result in higher rainfall findings which could lead to greater design changes to the dam and spillway at significant expense to the District. If the new methodology or additional studies suggests the need for modifications to the dam and spillway, the design and construction of those modifications may have a significant financial impact on the District. Through June 30, 2012, the District has spent or encumbered costs of $389,729 on the Probable Maximum Precipitation/Flood study.

Note 16. CLAIMS

The District has been named a real party in interest in a lawsuit filed by California Trout, Inc. and Friends of the River against the State Water Resources Control Board (SWRCB). The lawsuit is a petition for writ of mandate challenging, on California Environmental Quality Act (CEQA) grounds, a SWRCB water quality certification pertaining to a reduction of in stream flows in middle Piru Creek allegedly adversely impacting native trout and other aquatic species. The District was named a party in interest because the District currently contracts with the State of California (via an agreement with Casitas Municipal Water District) to receive 5,000 acre-feet of Table A State Water Project water annually. The District receives a portion of its State Water via deliveries from Pyramid Lake down middle Piru Creek into its Lake Piru. The impact, if any, upon the District's operations at Lake Piru is unknown. The District does not anticipate that these proceedings will result in a material adverse change relating to the operations or financial position of the District.

In August 2011, the City of San Buenaventura (City) filed a petition for writ of mandate, petition for writ of administrative mandate, complaint for declaratory relief, and complaint for determination of invalidity (reverse validation) against the District seeking, among other things, to invalidate FY 2011-12 water rates adopted by the District in June 2011. The City alleges that the rates do not comply with California constitutional, statutory and common law requirements. The District is vigorously defending the action. The District has filed an answer and a cross-complaint for declaratory relief. Other parties have additionally intervened in the action. In August 2012, the City of San Buenaventura (City) filed a second similar petition for writ of mandate, petition for writ of administrative mandate, complaint for declaratory relief, and complaint for determination of invalidity (reverse validation) against the District seeking, among other things, to invalidate FY 2012-13 water rates adopted by the District in June 2012. A unfavorable outcome to these lawsuits could potentially invalidate the District's water rates placed into effect as of July 1, 2011 and July 1, 2012, which in turn could materially affect cash flows and the financial position of the District. The two actions have been consolidated for trial purposes and the trial date in Santa Barbara Superior Court is set for April 30, 2013. At this time, it is unknown if the final outcome, if any, could materially affect cash flows or the financial position of the District.

Note 17. SUBSEQUENT EVENTS

In August 2012, the City of San Buenaventura (City) filed a second petition for writ of mandate, petition for writ of administrative mandate, complaint for declaratory relief, and complaint for determination of invalidity (reverse validation) against the District seeking, among other things, to invalidate FY 2012-13 water rates adopted by the District in June 2012 (See Note 16).

The District has evaluated subsequent events through December 19, 2012, the date which the financial statements were available to be issued.

Note. 18. EFFECT OF NEW GOVERNMENTAL ACCOUNTING STANDARDS BOARD PRONOUNCEMENTS

In November 2010, the GASB issued Statement No. 60, *Accounting and Financial Reporting for Service Concession Arrangements.* This statement establishes recognition, measurement, and disclosure requirements for service concession arrangements for both transferors and governmental operators. This statement is effective for the District's 2013 fiscal year. The District has not yet determined the effects of GASB No. 60 on its financial position.

In November 2010, the GASB issued Statement No. 61, *The Financial Reporting Entity: Omnibus – an amendment of GASB Statements No. 14 and No. 34.* This statement results in financial reporting entity financial statements being more relevant by improving guidance for including, presenting, and disclosing information about component units and equity interest transactions of a financial reporting entity. This statement is effective for the District's 2013 fiscal year. The District has not yet determined the effects of GASB No. 61 on its financial reporting.

In December 2010, the GASB issued Statement No. 62, *Codification of Accounting and Financial Reporting Guidance Contained In Pre-November 30, 1989 FASB and AICPA Pronouncements.* This statement will codify all sources of generally accepted accounting principles for state and local governments so that they derive from a single source. This statement is effective for the District's 2013 fiscal year. The District has not yet determined the effects of GASB No. 62 on its financial reporting.

In June 2011, the GASB issued Statement No. 63, *Financial Reporting of Deferred Outflows of Resources, Deferred Inflows of Resources, and Net Position.* This statement standardizes the presentation of deferred outflows of resources and deferred inflows of resources and their effects on a government's net position. This statement is effective for the District's 2013 fiscal year. The District has not yet determined the effects of GASB No. 63 on its financial position.

In March 2012, the GASB issued Statement No. 65, *Items Previously Reported as Assets and Liabilities.* This statement establishes accounting and financial reporting standards that reclassify, as deferred outflows of resources or deferred inflows of resources, certain items that were previously reported as assets and liabilities and recognizes, as outflows of resources or inflows of resources, certain items that were previously reported as assets and liabilities. This statement is effective for the District's 2014 fiscal year. The District has not yet determined the effects of GASB No. 65 on its financial position.

In March 2012, the GASB issued Statement No. 66, *Technical Corrections – 2012 – an amendment of GASB Statements No. 10 and No. 62.* This statement is to improve accounting and financial reporting for a governmental financial reporting entity by resolving conflicting guidance that resulted from the issuance of two pronouncements, Statements No. 54. Fund Balance Reporting and Governmental Fund Type Definitions, and No. 62, Codification of Accounting and Financial Reporting Guidance contained in pre-November 30, 1989 FASB and AICPA Pronouncements. This statement is effective for the District's 2014 fiscal year. The District has not yet determined the effects of GASB No. 66 on its financial position.

In June 2012, the GASB issued Statement No. 68, *Accounting and Financial Reporting for Pensions – an amendment of GASB Statement No 27.* This statement is to improve accounting and financial reporting by state and local governments for pensions. It also improves information provided by state and local governmental employers about financial support for pensions that is provided by other entities. This statement replaces the requirements of State No. 27, *Accounting for Pensions by State and Local Governmental Employers*, as well as the requirements of Statement No. 50, *Pension Disclosures*, as they relate to pensions that are provided through pension plans administered as trusts or equivalent arrangements. This statement is effective for the District's 2015 fiscal year. The District has not yet determined the effects of GASB No. 68 on its financial position.

Required Supplementary Information

Required Supplementary Information
United Water Conservation District
California Public Employees' Retirement System

Schedule of Funding Progress - Pool

Valuation Date	Accrued Liability	Actuarial Value of Assets	Unfunded Liability	Funded Ratio	Annual Covered Payroll	UL as a % of Payroll
6/30/2009	$ 1,834,424,640	$ 1,493,430,831	$ 340,993,809	81.4%	$ 355,150,151	96.0%
6/30/2010	$ 1,972,910,641	$ 1,603,482,152	$ 369,428,489	81.3%	$ 352,637,380	104.8%
6/30/2011	$ 2,135,350,204	$ 1,724,200,585	$ 411,149,619	80.8%	$ 350,121,750	117.4%

UWCD - Side Fund

Valuation Date	Side Fund	Amortization Period
6/30/2009	$ (2,605,054)	10
6/30/2010	$ (2,514,360)	9
6/30/2011	$ (2,407,128)	8

See the notes to the required supplementary information.

Required Supplementary Information
United Water Conservation District
California Public Employees' Retirement System
Other Post Employment Benefits

Schedule of Funding Progress

Valuation Date	Actuarial Accrued Liability (AAL)	Actuarial Value of Assets	Unfunded Actuarial Liability (UAAL)	Funded Ratio	Annual Covered Payroll	UAAL as a % of Payroll
6/30/2009	$ 733,600	$ -	$ 733,600	0.0%	$ 4,714,700	15.6%
6/30/2010	$ 733,600	$ -	$ 733,600	0.0%	$ 4,867,900	15.1%
6/30/2011	$ 733,600	$ -	$ 733,600	0.0%	$ 5,026,100	14.6%

See the notes to the required supplementary information.

Required Supplementary Information
United Water Conservation District
Budgetary Comparison Schedule
General Fund
For the Year Ended June 30, 2012

	Budgeted Amounts				Variance with Final Budget-
	Original	Final	Actual (Budgetary)		Positive (Negative)
Revenues					
Taxes	$ 1,952,600	$ 1,952,600	$ 2,016,499		$ 63,899
Water delivery	1,943,146	1,943,146	1,664,468		(278,678)
Groundwater	6,042,000	6,042,000	5,838,933		(203,067)
Supplemental Water	1,212,506	1,212,506	1,212,506		-
Concessions	119,975	119,975	118,982		(993)
Grants	153,750	233,750	223,460		(10,290)
Rents and leases	85,123	85,123	87,420		2,297
Interest	19,956	19,956	8,173		(11,783)
Other revenue	638,580	638,580	285,292		(353,288)
Total revenues	12,167,636	12,247,636	11,455,733		(791,903)
Expenditures					
Personnel costs	3,807,852	3,807,852	3,738,089		69,763
Contractual services	1,868,320	2,511,369	1,587,909		923,460
Office expense	74,277	81,248	47,709		33,539
Travel, meetings and training	56,510	56,510	40,599		15,911
Gasoline and diesel fuel	70,450	70,450	64,282		6,168
Insurance	78,936	78,936	73,195		5,741
Utilities	132,822	132,822	76,962		55,860
Safety, supplies, clothing	53,390	54,893	37,382		17,511
Water treatment chemicals	16,500	16,500	7,651		8,849
Maintenance	372,240	417,319	319,217		98,102
Small tools and equipment	58,840	75,716	54,952		20,764
Permits and licenses	35,900	45,291	60,207	(1)	(14,916)
Water quality services	42,000	42,000	27,622		14,378
Rents and leases	198,970	136,080	24,450		111,630
Miscellaneous	62,893	86,843	82,589		4,254
Total operating expenses	6,929,900	7,613,829	6,242,815		1,371,014
General and administrative	1,332,980	1,384,899	1,230,677		154,222
Principal	2,537,409	2,537,409	2,537,409		-
Interest	896,840	896,840	896,836		4
Bond fees and expenses	8,085	8,085	7,020		1,065
Total debt service	3,442,334	3,442,334	3,441,265		1,069
Capital outlay	1,055,571	4,093,369	925,051		3,168,318
Total expenditures	12,760,785	16,534,431	11,839,808		4,694,623
Net change in fund balance	(593,149)	(4,286,795)	(384,075)		3,902,720
Budgetary fund balance - July 1, 2011	5,026,303	6,725,594	6,725,594		-
Budgetary fund balance - June 30, 2012	$ 4,433,154	$ 2,438,799	$ 6,341,519		$ 3,902,720

Net change in fund balance - budgetary	$ (384,075)
Budgetary change in fund balance is different from GAAP change in fund balance because:	
Encumbrances for supplies and services ordered but not received are reported in the year ordered for budgetary purposes, but in the year the supplies are received for financial reporting purposes.	402,036
Net change in fund balance - Statement of revenues, expenditures, and changes in fund balances - Governmental funds	$ 17,961

Explanation of difference:

(1) Overage based on costs of the cancelled Seawater Intrusion Barrier project that were expensed versus planned capitalization.

See the notes to the required supplementary information.

Required Supplementary Information
United Water Conservation District
Budgetary Comparison Schedule
State Water Import Fund
For the Year Ended June 30, 2012

	Budgeted Amounts			Variance with Final Budget-
	Original	Final	Actual (Budgetary)	Positive (Negative)
Revenues				
Taxes	$ 1,000,000	$ 1,000,000	$ 1,084,910	$ 84,910
Interest	5,698	5,698	7,114	1,416
Other	-	-	3,784	3,784
Total revenues	1,005,698	1,005,698	1,095,808	90,110
Expenditures				
State Water Import Costs	1,091,094	1,118,751	676,953	441,798
Miscellaneous	4,725	4,725	3,403	1,322
Total operating expenses	1,095,819	1,123,476	680,356	443,120
Principal	88,005	88,005	87,743	262
Interest	54,499	54,499	54,544	(45)
Total debt service	142,504	142,504	142,287	217
Total expenditures	1,238,323	1,265,980	822,643	443,337
Net change in fund balance	(232,625)	(260,282)	273,165	533,447
Budgetary fund balance - July 1, 2011	1,260,238	1,503,544	1,503,544	-
Budgetary fund balance - June 30, 2012	$ 1,027,613	$ 1,243,262	$ 1,776,709	$ 533,447

See the notes to the required supplementary information.

Note 1. PENSION PLAN

A method change was adopted by the CalPERS Board in June 2009. CalPERS is in the third year of a 3-year temporary change to the asset smoothing method and the amortization of gains and losses in order to phase in the impact of the -24% investment loss experienced by CalPERS in fiscal year 2008-2009.

In the most recent actuarial valuation as of June 30, 2011, the CalPERS Board of Administration adopted updated actuarial assumptions to be used beginning with the June 30, 2011 valuation. The inflation rate changed from 3% to 2.75% and the discount rate changed from 7.75% to 7.5%. In addition, a temporary modification to their method of determining the actuarial value of assets and the amortization of gains and losses was implemented for the valuations as of June 30, 2009 through June 30, 2011. The effect of those modifications continues in their valuation.

In 2003, mandatory pooling was required for plans with less than 100 active members. At the time of joining the pool, a Side Fund was created to account for the difference between the funded status of the pool and the funded status of the District's plan. The District's negative Side Fund will cause the required employer contribution rate to be increased by the amortization of the Side Fund.

Note 2. OTHER POST EMPLOYMENT BENEFITS

The most recent actuarial valuation is June 30, 2009.

Note 3. BUDGETS AND BUDGETARY ACCOUNTING

On or before June 30, the annual budget is adopted by the Board of Directors after holding a public hearing and provides for the general operation of the District. The operating budget includes proposed expenditures and the means of financing them. The Board of Directors has the legal authority to amend the budget for all funds at any time during the fiscal year. The appropriated budget is prepared by fund and activity. The legal level of budgetary control is at the fund level. Unbudgeted expenditures over $10,000 require the approval of the Board of Directors.

Encumbrance accounting is employed in the governmental funds. Encumbrances (i.e., purchase orders, contracts) outstanding at year-end are carried forward and added to the subsequent year's appropriation. The unencumbered balance of each appropriation lapses at year-end and reverts to the respective fund from which it was appropriated and becomes available for future appropriation.

Statistical Section

This section represents statistical data to help a reader understand how the District's financial position has changed over time, sources of revenues, debt capacity, economic environment in which financial activities take place and the services and activities the District performs.

Contents: **Pages:**

Financial Trends

These schedules contain trend (year to year) information to understand how the District's financial position has changed over time. 72-76

Revenue Capacity

These schedules contain information on the District's revenue sources and expenses by function, district-wide groundwater production (extraction) and pipeline deliveries, groundwater rates and water delivery (pipeline) charges and 10 largest customers by revenues. 77-84

Debt Capacity

These schedules present information to assess the affordability to the District's current levels of outstanding debt and future debt capacity. 85-87

Demographic and Economic Information

This schedule offers demographic and economic indicators to understand the environment within which the District's financial activities takes place. 88-90

Operating Information

These schedules contain service and infrastructure information to understand the services of the District and the activities it performs. 91-94

United Water Conservation District
Net Assets by Component
Last Ten Fiscal Years
(accrual basis of accounting)
(amounts expressed in thousands)
(Unaudited)

	2011-12	2010-11	2009-10	2008-09	2007-08	2006-07	2005-06	2004-05	2003-04	2002-03
Governmental activities:										
Invested in capital assets, net of related debt	$ 19,661	$ 18,747	$ 16,924	$ 12,747	$ 9,418	$ 9,193	$ 8,488	$ 9,581	$ 7,882	$ 6,814
Restricted	1,777	1,504	989	1,496	724	1,303	1,678	1,528	1,026	695
Unrestricted	4,411	3,157	4,072	3,222	3,870	4,174	3,415	2,129	2,704	2,940
Total governmental activities net assets	$ 25,849	$ 23,408	$ 21,985	$ 17,465	$ 14,012	$ 14,670	$ 13,581	$ 13,238	$ 11,612	$ 10,449
Business-type activities:										
Invested in capital assets, net of related debt	$ 39,019	$ 39,124	$ 38,310	$ 37,477	$ 38,388	$ 36,283	$ 35,500	$ 35,423	$ 34,270	$ 32,680
Restricted	-	-	261	260	963	898	895	903	883	861
Unrestricted	6,748	5,006	4,513	4,028	4,117	4,927	4,168	3,695	4,396	3,252
Total business-type activities net assets	$ 45,767	$ 44,130	$ 43,084	$ 41,765	$ 43,468	$ 42,108	$ 40,563	$ 40,021	$ 39,549	$ 36,793
Total government										
Invested in capital assets, net of related debt	$ 58,680	$ 57,871	$ 55,234	$ 50,224	$ 47,806	$ 45,476	$ 43,988	$ 45,004	$ 42,152	$ 39,494
Restricted	1,777	1,504	1,250	1,756	1,687	2,201	2,573	2,431	1,909	1,556
Unrestricted	11,159	8,163	8,585	7,250	7,987	9,101	7,583	5,824	7,100	6,192
Total government net assets	$ 71,616	$ 67,538	$ 65,069	$ 59,230	$ 57,480	$ 56,778	$ 54,144	$ 53,259	$ 51,161	$ 47,242

United Water Conservation District
Changes in Net Assets
Last Ten Fiscal Years
(accrual basis of accounting)
(amounts expressed in thousands)
(Unaudited)

	2011-12	2010-11	2009-10	2008-09	2007-08	2006-07	2005-06	2004-05	2003-04	2002-03
Expenses										
Governmental activities:										
Water conservation	$ 7,518	$ 7,033	$ 5,498	$ 5,379	$ 4,862	$ 4,182	$ 4,392	$ 3,634	$ 3,391	$ 2,874
Lake Piru recreation facilities	816	755	705	1,135	-	-	-	-	-	-
State Water Project importation	766	765	1,203	709	817	695	387	862	518	874
Interest on long-term debt	931	1,009	754	455	477	474	472	254	269	285
Total governmental activities expenses	10,031	9,562	8,160	7,678	6,156	5,351	5,251	4,750	4,178	4,033
Business-type activities:										
Freeman Diversion facility	1,492	1,575	1,787	1,785	1,361	1,422	1,368	1,255	1,226	1,242
Water delivery and treatment facilities	4,531	4,709	5,144	4,942	5,501	4,845	4,248	3,946	4,246	4,540
Lake Piru recreation facilities	-	-	-	-	1,595	1,635	1,673	1,374	1,308	1,215
Total business-type activities expenses	6,023	6,284	6,931	6,727	8,457	7,902	7,289	6,575	6,780	6,997
Total government expenses	$ 16,054	$ 15,846	$ 15,091	$ 14,405	$ 14,613	$ 13,253	$ 12,540	$ 11,325	$ 10,958	$ 11,030
Program Revenues										
Governmental activities:										
Charges for services:										
Water conservation	$ 8,826	$ 7,005	$ 5,812	$ 4,719	$ 3,735	$ 3,761	$ 3,299	$ 3,019	$ 2,194	$ 1,335
Lake Piru recreation facilities	123	114	127	148	-	-	-	-	-	-
State Water Project importation	1,096	1,503	595	1,574	273	252	459	1,284	830	583
Operating grants and contributions	100	-	-	44	28	179	680	839	176	700
Capital grants and contributions	44	281	-	-	-	154	-	492	1,002	-
Total governmental activities program revenues	10,189	8,903	6,534	6,485	4,036	4,346	4,438	5,634	4,202	2,618
Business-type activities:										
Freeman Diversion facility	2,757	2,602	3,087	2,751	2,535	2,487	2,210	2,125	2,329	2,079
Water delivery and treatment facilities	4,840	4,655	5,077	5,237	5,283	5,313	4,478	3,614	4,031	3,596
Lake Piru recreation facilities	-	-	-	-	579	1,141	1,039	790	877	835
Capital grants and contributions	-	-	-	-	-	-	-	14	1,810	207
Total business-type activities program revenues	7,597	7,257	8,164	7,988	8,397	8,941	7,727	6,543	9,047	6,717
Total government program revenues	$ 17,786	$ 16,160	$ 14,698	$ 14,473	$ 12,433	$ 13,287	$ 12,165	$ 12,177	$ 13,249	$ 9,335

United Water Conservation District
Changes in Net Assets
Last Ten Fiscal Years
(accrual basis of accounting)
(amounts expressed in thousands)
(Unaudited)

	2011-12	2010-11	2009-10	2008-09	2007-08	2006-07	2005-06	2004-05	2003-04	2002-03
Net (expense)/revenue										
Governmental activities	$ 158	$ (659)	$ (1,626)	$ (1,193)	$ (2,120)	$ (1,005)	$ (813)	$ 884	$ 24	$ (1,415)
Business-type activities	1,574	973	1,233	1,261	(60)	1,039	438	(32)	2,267	(280)
Total government net expense	$ 1,732	$ 314	$ (393)	$ 68	$ (2,180)	$ 34	$ (375)	$ 852	$ 2,291	$ (1,695)
General Revenues and Other Changes in Net Assets										
Governmental activities:										
Property taxes	$ 2,016	$ 1,950	$ 2,090	$ 2,090	$ 2,000	$ 1,896	$ 1,127	$ 984	$ 1,366	$ 1,260
Unrestricted investment earnings	8	18	21	110	364	414	312	21	20	57
Miscellaneous	259	114	86	151	210	125	143	80	104	48
Extraordinary item - claim settlement	-	-	-	(828)	-	-	-	-	-	-
Transfers	-	-	-	3,122	(1,112)	(341)	(427)	(343)	(335)	(208)
Donated capital asset	-	-	3,949	-	-	-	-	-	-	-
Total governmental activities	2,283	2,082	6,146	4,645	1,462	2,094	1,155	742	1,155	1,157
Business-type activities:										
Unrestricted investment earnings	63	73	86	159	308	403	265	161	138	188
Extraordinary item - loss on impaired assets	-	-	-	-	-	(238)	(588)	-	-	-
Transfers	-	-	-	(3,122)	1,112	341	428	343	335	208
Total business-type activities	63	73	86	(2,963)	1,420	506	105	504	473	396
Total government	$ 2,346	$ 2,155	$ 6,232	$ 1,682	$ 2,882	$ 2,600	$ 1,260	$ 1,246	$ 1,628	$ 1,553
Change in Net Assets										
Governmental activities	$ 2,441	$ 1,423	$ 4,520	$ 3,452	$ (658)	$ 1,089	$ 342	$ 1,626	$ 1,179	$ (258)
Business-type activities	1,637	1,046	1,319	(1,702)	1,360	1,545	543	472	2,740	116
Total government	$ 4,078	$ 2,469	$ 5,839	$ 1,750	$ 702	$ 2,634	$ 885	$ 2,098	$ 3,919	$ (142)

United Water Conservation District
Fund Balances of Governmental Funds
Last Ten Fiscal Years
(modified accrual basis of accounting)
(amounts expressed in thousands)
(Unaudited)

	2011-12	2010-11*	2009-10	2008-09	2007-08	2006-07	2005-06	2004-05	2003-04	2002-03
General Fund										
Restricted/Reserved	$ 1,796	$ 3,104	$ 5,255	$ 4,809	$ 5,715	$ 6,353	$ 7,673	$ 248	$ 941	$ 288
Unrestricted/Unreserved	4,947	3,621	3,519	3,211	3,983	4,326	3,151	2,106	1,917	2,680
Total general fund	$ 6,743	$ 6,725	$ 8,774	$ 8,020	$ 9,698	$ 10,679	$ 10,824	$ 2,354	$ 2,858	$ 2,968
All Other Governmental Funds										
Restricted/Reserved	$ 1,777	$ 1,504	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Unrestricted/Unreserved reported in:										
Special revenue funds	-	-	988	1,496	724	1,303	1,678	1,528	1,026	695
Debt Service funds	-	-	-	-	-	-	-	-	-	-
Capital projects funds	-	-	-	-	-	-	-	-	-	-
Total all other governmental funds	$ 1,777	$ 1,504	$ 988	$ 1,496	$ 724	$ 1,303	$ 1,678	$ 1,528	$ 1,026	$ 695

*June 30, 2011 reflects the first year of GASB Statement No. 45 implementation. Fiscal years 2002 through 2010 have not been restated based on these new classifications.

United Water Conservation District
Changes in Fund Balances of Governmental Funds
Last Ten Fiscal Years
(modified accrual basis of accounting)
(amounts expressed in thousands)
(Unaudited)

	2011-12	2010-11	2009-10	2008-09	2007-08	2006-07	2005-06	2004-05	2003-04	2002-03
Revenues										
Taxes	$ 3,101	$ 3,443	$ 2,674	$ 3,642	$ 2,215	$ 2,064	$ 1,523	$ 2,239	$ 2,187	$ 1,824
Charges for services	8,949	7,119	5,939	4,867	3,735	3,761	3,299	3,019	2,194	1,335
Earnings on investments	15	27	29	128	419	493	372	49	29	75
Grants	145	281	-	44	28	334	680	1,331	1,178	700
Other revenues	263	114	89	155	214	129	147	80	104	48
Total revenues	$ 12,473	$ 10,984	$ 8,731	$ 8,836	$ 6,611	$ 6,781	$ 6,021	$ 6,718	$ 5,692	$ 3,982
Expenditures										
Salaries and benefits	$ 3,628	$ 3,275	$ 2,776	$ 2,836	$ 2,098	$ 1,838	$ 1,742	$ 1,537	$ 1,304	$ 1,121
Professional fees	1,252	932	790	995	493	523	734	739	640	603
Maintenance	995	1,275	1,356	932	1,346	706	753	1,295	537	857
Utilities	77	102	101	108	106	44	30	33	26	21
Materials and supplies	488	454	440	469	421	389	362	331	342	240
General and administrative	1,218	1,153	1,074	1,136	714	808	606	564	519	513
Debt Service										
Principal	2,625	2,743	742	752	691	666	598	383	368	347
Interest	952	1,023	601	461	481	487	477	257	273	285
Bond issuance costs	7	6	221	6	6	6	303	-	-	-
Capital Outlay	952	1,554	16,119	1,273	731	769	367	1,306	1,089	239
Total expenditures	$ 12,194	$ 12,517	$ 24,220	$ 8,968	$ 7,087	$ 6,236	$ 5,972	$ 6,445	$ 5,098	$ 4,226
Excess of revenues over (under) expenditures	$ 279	$ (1,533)	$ (15,489)	$ (132)	$ (476)	$ 545	$ 49	$ 273	$ 594	$ (244)
Other financing sources (uses)										
Proceeds of refunding bonds	-	-	-	-	-	-	2,814	-	-	-
Proceeds of long-term capital-related debt	-	-	-	-	28	62	9,018	68	-	-
Proceeds from financing	12	-	15,631	-	-	-	-	-	-	-
Bond Premium	-	-	104	-	-	-	16	-	-	-
Bond Discount	-	-	-	-	-	-	(82)	-	-	-
Payment to bond refunding escrow agent	-	-	-	-	-	-	(2,768)	-	-	-
Extraordinary item - claim settlement	-	-	-	(828)	-	-	-	-	-	-
Transfers in	-	-	-	54	-	24	-	3	-	-
Transfers out	-	-	-	-	(1,112)	(1,151)	(427)	(346)	(373)	(208)
Total other financing sources (uses)	12	-	15,735	(774)	(1,084)	(1,065)	8,571	(275)	(373)	(208)
Net change in fund balances	$ 291	$ (1,533)	$ 246	$ (906)	$ (1,560)	$ (520)	$ 8,620	$ (2)	$ 221	$ (452)
Debt service as a percentage of noncapital expenditures	31.8%	34.4%	16.6%	15.8%	18.4%	21.1%	19.2%	12.5%	16.0%	15.9%

United Water Conservation District

General Governmental Revenues by Source and
Expenditures by Function
Last Ten Fiscal Years
(Unaudited)

Revenue:

Fiscal Year	Charges for Services	Taxes	Grant Revenue	Earnings on Investments	Other Revenues	Total
2002-03	$ 1,335,189	$ 1,824,170	$ 699,865	$ 74,651	$ 47,803	$ 3,981,678
2003-04	$ 2,193,859	$ 2,187,196	$ 1,178,130	$ 28,919	$ 104,069	$ 5,692,173
2004-05	$ 3,018,900	$ 2,239,093	$ 1,330,763	$ 49,616	$ 80,286	$ 6,718,658
2005-06	$ 3,299,382	$ 1,522,625	$ 680,102	$ 371,806	$ 147,224	$ 6,021,139
2006-07	$ 3,761,106	$ 2,064,499	$ 333,538	$ 493,098	$ 128,865	$ 6,781,106
2007-08	$ 3,735,433	$ 2,214,637	$ 27,794	$ 418,770	$ 213,786	$ 6,610,420
2008-09	$ 4,866,810	$ 3,642,073	$ 44,100	$ 127,978	$ 155,346	$ 8,836,307
2009-10	$ 5,939,275	$ 2,673,878	$ -	$ 28,741	$ 89,267	$ 8,731,161
2010-11	$ 7,118,940	$ 3,443,492	$ 281,156	$ 27,264	$ 113,836	$ 10,984,688
2011-12	$ 8,948,539	$ 3,101,409	$ 144,815	$ 15,288	$ 262,846	$ 12,472,897

Expenditures:

Fiscal Year	Water Conservation	Lake Piru Recreation Facilities (1)	State Water Import	Capital Outlay	Debt Service	Total
2002-03	$ 2,632,644	$ -	$ 721,799	$ 238,123	$ 632,340	$ 4,224,906
2003-04	$ 3,146,179	$ -	$ 365,651	$ 1,089,156	$ 641,133	$ 5,242,119
2004-05	$ 3,782,963	$ -	$ 716,403	$ 1,306,956	$ 639,518	$ 6,445,840
2005-06	$ 4,286,876	$ -	$ 243,438	$ 367,097	$ 1,074,440	$ 5,971,851
2006-07	$ 3,761,465	$ -	$ 554,080	$ 768,484	$ 1,152,260	$ 6,236,289
2007-08	$ 4,434,180	$ -	$ 743,086	$ 730,501	$ 1,178,210	$ 7,085,977
2008-09	$ 4,951,967	$ 889,362	$ 635,420	$ 1,273,057	$ 1,219,147	$ 8,968,953
2009-10	$ 4,925,944	$ 482,476	$ 1,129,031	$ 16,118,830	$ 1,563,946	$ 24,220,227
2010-11	$ 5,974,358	$ 524,794	$ 691,290	$ 1,554,477	$ 3,772,435	$ 12,517,354
2011-12	$ 6,430,332	$ 535,883	$ 692,408	$ 951,648	$ 3,583,552	$ 12,193,823

(1) Effective July 1, 2008, the Lake Piru Recreation facilities (an enterprise fund) was eliminated and all assets, liabilities and net assets were transferred to the General Fund.

United Water Conservation District

Enterprise Funds Revenue and Non-Operating Revenue by Source
and Expenses by Function
Last Ten Fiscal Years
(Unaudited)

Revenue:

Fiscal Year	Charges for Services	Other Operating Revenue	Interest Income	Inter-governmental Revenue	Total
2002-03	$ 6,415,562	$ 94,768	$ 188,630	$ 207,362	$ 6,906,322
2003-04	$ 7,078,931	$ 158,496	$ 137,972	$ 1,810,057	$ 9,185,456
2004-05	$ 6,453,663	$ 75,431	$ 160,927	$ 14,031	$ 6,704,052
2005-06	$ 7,590,024	$ 136,943	$ 265,094	$ -	$ 7,992,061
2006-07	$ 8,413,387	$ 527,255	$ 403,284	$ -	$ 9,343,926
2007-08	$ 8,240,307	$ 156,058	$ 308,114	$ -	$ 8,704,479
2008-09	$ 7,893,985	$ 94,092	$ 158,890	$ -	$ 8,146,967
2009-10	$ 8,039,952	$ 123,629	$ 86,835	$ -	$ 8,250,416
2010-11	$ 7,154,324	$ 102,611	$ 72,577	$ -	$ 7,329,512
2011-12	$ 7,527,205	$ 70,480	$ 62,991	$ -	$ 7,660,676

Expenses:

Fiscal Year	Salaries and Benefits	Contractual Services	Materials and Supplies	General and Administrative	Depreciation	Total
2002-03	$ 1,560,578	$ 188,676	$ 2,150,655	$ 989,084	$ 1,326,912	$ 6,215,905
2003-04	$ 1,722,503	$ 141,200	$ 1,733,865	$ 1,019,948	$ 1,396,281	$ 6,013,797
2004-05	$ 1,702,218	$ 169,613	$ 1,532,627	$ 1,068,769	$ 1,414,649	$ 5,887,876
2005-06	$ 2,000,523	$ 203,255	$ 1,850,369	$ 1,094,443	$ 1,411,898	$ 6,560,488
2006-07	$ 2,065,313	$ 356,764	$ 2,187,617	$ 1,236,189	$ 1,393,333	$ 7,239,216
2007-08	$ 2,180,252	$ 172,500	$ 2,943,316	$ 1,193,356	$ 1,461,467	$ 7,950,891
2008-09	$ 1,584,257	$ 177,046	$ 2,213,498	$ 1,089,253	$ 1,231,606	$ 6,295,660
2009-10	$ 1,693,762	$ 333,840	$ 2,302,070	$ 1,068,756	$ 1,207,821	$ 6,606,249
2010-11	$ 1,588,572	$ 257,358	$ 1,847,998	$ 1,085,471	$ 1,211,584	$ 5,990,983
2011-12	$ 1,570,750	$ 91,067	$ 1,766,259	$ 1,131,106	$ 1,228,982	$ 5,788,164

United Water Conservation District
Water Production for Last Ten Fiscal Years
(in Acre Feet)
(Unaudited)

July 1 - June 30	Water Pumped from Wells Agricultural	Water Pumped from Wells Non-agricultural	Water Deliveries Agricultural	Water Deliveries Non-agricultural
2002-03	122,419	24,750	13,395	13,844
2003-04	136,086	33,721	15,874	11,724
2004-05	111,099	34,967	15,330	7,739
2005-06	111,073	35,902	21,431	9,276
2006-07	140,141	33,644	23,478	14,852
2007-08	139,045	29,219	19,613	18,915
2008-09	138,459	42,930	26,134	16,029
2009-10	128,888	44,930	23,533	15,524
2010-11	120,858	41,751	19,439	10,982
2011-12	125,033	39,651	22,802	11,424

United Water Conservation District
Groundwater Pumping by Zone (Acre Foot)
Last Ten Fiscal Years
(Unaudited)

Fiscal Year	Zone A	Zone B	Zone C	District Total
2002-03	73,954	68,720	4,495	147,169
2003-04	94,853	71,992	2,961	169,806
2004-05	77,236	63,699	5,131	146,066
2005-06	80,973	59,641	6,361	146,975
2006-07	98,399	67,171	8,215	173,785
2007-08	96,090	64,566	7,608	168,264
2008-09	91,602	81,196	8,591	181,389
2009-10	86,033	79,402	8,383	173,818
2010-11	81,508	73,779	7,322	162,609
2011-12	84,781	79,903	-	164,684

Zone A - 100% District-wide pump charge / 0% Freeman pump charge
Zone B - 100% District-wide pump charge / 100% Freeman pump charge
Zone C - 100% District-wide pump charge / 33% Freeman pump charge

* In FY 2011-12, the District eliminated Zone C.

United Water Conservation District
Ground Water Charge Rates
Last Ten Fiscal Years
(Charge per Acre Foot)
(Unaudited)

Fiscal Year	Zone	Pumped water used for agricultural purposes	Pumped water used for purposes other than agriculture
2002-03	A	$ 5.15	$ 15.45
	B	$ 20.15	$ 60.45
	C	$ 10.15	$ 30.45
2003-04	A	$ 7.45	$ 22.35
	B	$ 22.45	$ 67.35
	C	$ 12.45	$ 37.35
2004-05	A	$ 11.25	$ 33.75
	B	$ 26.25	$ 78.75
	C	$ 16.25	$ 48.75
2005-06	A	$ 11.65	$ 34.95
	B	$ 26.65	$ 79.95
	C	$ 16.65	$ 49.95
2006-07	A	$ 11.65	$ 34.95
	B	$ 26.65	$ 79.95
	C	$ 16.65	$ 49.95
2007-08	A	$ 11.65	$ 34.95
	B	$ 26.65	$ 79.95
	C	$ 16.65	$ 49.95
2008-09	A	$ 16.45	$ 49.35
	B	$ 34.45	$ 103.35
	C	$ 22.45	$ 67.35
2009-10	A	$ 16.45	$ 49.35
	B	$ 34.45	$ 103.35
	C	$ 22.45	$ 67.35
2010-11	A	$ 19.50	$ 58.50
	B	$ 37.50	$ 112.50
	C	$ 25.50	$ 76.50
2011-12	A	$ 28.50	$ 85.50
	B	$ 46.50	$ 139.50

Zone A District-wide pump charges - 100%

Zone B District-wide pump charges - 100%
Freeman Diversion pump charge - 100%

Zone C District-wide pump charges - 100%
Freeman Diversion pump charge - 33%

* In FY 2011-12, the District eliminated Zone C.

United Water Conservation District

Oxnard Hueneme Pipeline Deliveries per Acre Foot and Rate Charge

Last Ten Fiscal Years

(Unaudited)

July 1 - June 30	Water delivered (acre feet)	Pipeline variable* water charge per acre foot Municipal & Industrial (1) Customer	Pipeline marginal ** water charge per acre foot Municipal & Industrial (1) Customer	Pipeline variable* water charge per acre foot Agricultural (2) Customer	Pipeline marginal ** water charge per acre foot Agricultural (2) Customer	Fixed Charge *** per unit of peak (3) capacity
2002-03	15,127	$ 178.95	$ 139.61	$ 138.65	$ 99.31	$ 22,528.00
2003-04	13,156	$ 197.40	$ 150.40	$ 152.50	$ 105.50	$ 25,460.00
2004-05	8,901	$ 216.15	$ 166.80	$ 163.65	$ 114.30	$ 25,460.00
2005-06	10,235	$ 217.35	$ 168.00	$ 164.05	$ 114.70	$ 25,651.00
2006-07	15,954	$ 226.70	$ 163.20	$ 173.40	$ 109.90	$ 25,635.00
2007-08	20,256	$ 224.70	$ 161.20	$ 171.40	$ 107.90	$ 26,653.00
2008-09	17,596	$ 248.10	$ 184.60	$ 179.20	$ 115.70	$ 26,653.00
2009-10	16,806	$ 248.10	$ 184.60	$ 179.20	$ 115.70	$ 26,653.00
2010-11	12,091	$ 272.00	$ 197.35	$ 197.00	$ 122.35	$ 23,252.00
2011-12	12,606	$ 292.50	$ 227.50	$ 199.50	$ 134.50	$ 24,178.00

(1) Municipal and Industrial customer shall mean water used for domestic, industrial, commercial, urban, incidental irrigation or fire protection purposes.

(2) Oxnard Hueneme Pipeline Agriculutural customer (Oceanview) shall mean Oxnard Hueneme Pipeline water used primarily for agricultural irrigation purposes.

(3) The peak capacity in the OH Pipeline is 53.0 cubic feet per second (cfs).

* Variable Costs = (up to 75% of customer sub-allocation). Variable costs shall mean the rate required per acre foot of water delivered and charged to individual customers up to 75% of their 1985-89 historical sub-allocation.

** Marginal costs = (over 75% of customer sub-allocation). Marginal costs shall mean the rate charged to individual customers for every acre foot delivered once their deliveries from the Oxnard Hueneme Pipeline exceed 75% of their 1985-89 historical sub-allocation.

*** Fixed charge represents per unit of peak capacity, all other rates per acre foot delivered. The above annual fixed charge shown is in addition to the variable/marginal rate charged as applies per individual customer. Charge is allocated over 12 monthly payments.

This schedule is subject to all other terms and conditions per the "Water Supply Agreement for delivered water through the Oxnard/Hueneme Pipeline" that may not be represented in this schedule.

United Water Conservation District
Pleasant Valley and Pumping Trough Pipeline Deliveries per Acre Foot and Rate Charge
Agricultural Customers
Last Ten Fiscal Years
(Unaudited)

Pleasant Valley Pipeline Deliveries per Acre Foot and Rate Charge

July 1 - June 30	Water delivered (acre feet)	Pipeline water charge per acre foot Agricultural Customer	Saticoy Well * Field Pump Charge per acre feet
2002-03	4,507	$ 30.15	
2003-04	6,249	$ 42.45	
2004-05	6,399	$ 56.25	$11.00
2005-06	12,376	$ 56.65	$11.00
2006-07	13,081	$ 51.65	$17.00
2007-08	8,807	$ 51.65	$15.00 **
2008-09	14,529	$ 59.45	$15.00
2009-10	13,077	$ 59.45	$30.00
2010-11	10,482	$ 72.50	$30.00
2011-12	12,858	$ 81.50	$30.00

Pumping Trough Pipeline Deliveries per Acre Foot and Rate Charge

July 1 - June 30	Water delivered (acre feet)	Pipeline water charge per acre foot Agricultural Customer	Saticoy Well * Field Pump Charge per acre feet
2002-03	7,605	$ 107.65	
2003-04	8,194	$ 127.45	
2004-05	7,769	$ 131.25	$11.00
2005-06	8,096	$ 131.65	$11.00
2006-07	9,295	$ 137.65	$17.00
2007-08	9,465	$ 137.65	$15.00 **
2008-09	10,038	$ 143.45	$15.00
2009-10	9,174	$ 143.45	$30.00
2010-11	7,848	$ 166.50	$30.00
2011-12	8,762	$ 175.50	$30.00

* Pump charge is in addition to water charge per acre foot when the District pumps from the Saticoy Well Field in lieu of surface water.

** GMA Pump charge of $4.00 effective as of January 1, 2008 for Saticoy Well Field and PTP Pipeline.

United Water Conservation District
10 Largest Customers by Revenues
Fiscal Year Ended June 30, 2012 and Nine Years Ago
(Unaudited)

Fiscal Year 2011-2012

Customer	Groundwater consumed (acre-feet)	Groundwater charge per acre foot	Water delivered by pipeline (acre-feet)	Pipeline water charge per acre foot	Total water purchased (acre-feet)	Fixed annual charge	Well Repl. Charge	Supplemental Water	Revenue
City of Oxnard	7,099	$139.50	8,824	$292.50/$227.50 & $199.50/$134.50	15,923	$ 646,762	$ 94,680	$ 1,212,506	$ 5,415,580
PHWA	-	-	3,360	$292.50/$227.50	3,360	537,961	48,814	-	$ 1,569,633
PVCWD	3,916	$46.50	12,637	$81.50	16,553	-	-	-	$ 1,212,036
City of San Buenaventura	8,509	$139.50/$85.50	-		8,509	-	-	-	$ 1,038,129
City of Santa Paula	5,617	$28.50/$85.50	-		5,617	-	-	-	$ 423,344
Farmers Irrigation Co	9,222	$28.50	-		9,222	-	-	-	$ 262,836
CA Dept of Fish & Game	8,297	$28.50	-		8,297	-	-	-	$ 236,458
Hiji Brothers	3,153	$46.50	479	$175.50/$205.50/$50	3,632	-	-	-	$ 233,941
City of Fillmore	2,207	$85.50	-		2,207	-	-	-	$ 188,703
Southland Sod Farms	3,530	$46.50	59	$175.50/$205.50/$50	3,589	-	-	-	$ 175,171
	51,550		25,359		76,909	$1,184,723	$ 143,494	$ 1,212,506	$ 10,755,831

Fiscal Year 2002-2003

Customer	Groundwater consumed (acre-feet)	Groundwater charge per acre foot	Water delivered by pipeline (acre-feet)	Pipeline water charge per acre foot	Total water purchased (acre-feet)	Fixed annual charge	Well Repl. Charge	Supplemental Water	Revenue
City of Oxnard	5,105	$60.45	9,315	$178.95/$139.61	14,420	$ 489,984	$ -	$ -	$ 1,793,136
PHWA	-	$60.45	4,016	$178.95/$139.61	4,016	501,248	-	-	$ 696,677
PVCWD	9,365	$20.15	4,390	$30.15	13,755	-	-	-	$ 321,097
City of San Buenaventura	7,095	$60.45/$30.45/$15.45	-		7,095	-	-	-	$ 170,356
Southland Sod Farms	4,791	$20.15	-		4,791	-	-	-	$ 96,554
City of Santa Paula	6,321	$5.15/$15.45	-		6,321	-	-	-	$ 84,791
Del Norte Water Co	2,468	$20.15/$60.45	-		2,468	-	-	-	$ 51,696
CA Dept of Fish & Game	9,646	$5.15/$15.45	-		9,646	-	-	-	$ 49,677
City of Fillmore	2,608	$5.15/$15.45	-		2,608	-	-	-	$ 39,893
Farmers Irrigation Co	5,964	$5.15	-		5,964	-	-	-	$ 30,716
	53,363		17,721		71,084	$ 991,232	$ -	$ -	$ 3,334,593

Source: United Water Conservation District's internal water delivery and groundwater extraction reports.

United Water Conservation District
Ratios of Outstanding Debt by Type
Last Ten Fiscal Years
(amounts expressed in thousands except for population and per capita amount)
(Unaudited)

	Governmental Activities			Business-Type Activities										
Fiscal Year	Special Assessment Contract (1)	Revenue-backed Bonds	Certificates of Participation	General Obligation Debt (2)	Revenue-backed Bonds	Loans	Contracts	Certificates of Participation	Total Government	Assessed Valuations (3)	Percentage of Assessed Valuations (4)	Population (5)	Per Capita
2002-2003	$ 1,778	$ 267	$ 3,686	$ 8,539	$ 2,997	$ 2,414	$ 303	$ 6,065	$ 26,049	$ 19,988,985	0.13%	789,367	$ 33.00
2003-2004	$ 1,726	$ 345	$ 3,391	$ 7,539	$ 2,670	$ 2,147	$ 290	$ 5,626	$ 23,734	$ 21,990,695	0.11%	795,046	$ 29.85
2004-2005	$ 1,732	$ 331	$ 3,084	$ 6,512	$ 2,430	$ 1,871	$ 276	$ 5,170	$ 21,406	$ 24,390,390	0.09%	796,867	$ 26.86
2005-2006	$ 1,736	$ 11,815	$ -	$ 5,493	$ 8,159	$ 1,586	$ 261	$ -	$ 29,050	$ 27,265,071	0.11%	801,225	$ 36.26
2006-2007	$ 1,730	$ 10,410	$ -	$ 4,409	$ 8,113	$ 1,290	$ 246	$ -	$ 26,198	$ 30,708,931	0.09%	805,911	$ 32.51
2007-2008	$ 1,686	$ 9,793	$ -	$ 3,294	$ 7,226	$ 984	$ -	$ -	$ 22,983	$ 33,316,302	0.07%	812,028	$ 28.30
2008-2009	$ 1,582	$ 9,156	$ -	$ 2,128	$ 6,307	$ -	$ -	$ -	$ 19,173	$ 34,199,233	0.06%	818,546	$ 23.42
2009-2010	$ 1,668	$ 8,492	$ 15,569	$ 928	$ 5,508	$ -	$ -	$ -	$ 32,165	$ 32,845,989	0.10%	825,378	$ 38.97
2010-2011	$ 1,429	$ 7,808	$ 13,747	$ -	$ 4,675	$ -	$ -	$ -	$ 27,659	$ 32,826,901	0.08%	830,215	$ 33.32
2011-2012	$ 1,354	$ 7,101	$ 11,914	$ -	$ 3,815	$ -	$ -	$ -	$ 24,184	$ 32,865,630	0.07%	834,109	$ 28.99

(1) California State Water Project Contract
(2) Loan from Bureau of Reclamation
(3) Source - County Auditor-Controller Ventura County - also refer to Demographic and Economic Statistics for detailed breakdown.
(4) Assessed valuation used as other economic base versus personal income.
(5) California Department of Finance Ventura County July 1st of each year.

Note: Details regarding the District's outstanding debt can be found in the notes to the financial statements.

The above data are alternative indicators that are considered relevant to United Water Conservation District.

United Water Conservation District
Ratios of General Bonded Debt Outstanding
Last Ten Fiscal Years
(amounts expressed in thousands except for population and per capita amount)
(Unaudited)

Fiscal Year	General Obligation Bonds	Total General Obligation Bonds	Total Assessed Valuations	Percentage of Total Assessed Valuations (1)	Population (2)	Per Capita
2002-2003	$ 8,539	$ 8,539	$ 19,988,985	0.04%	789,367	$ 10.82
2003-2004	$ 7,539	$ 7,539	$ 21,990,695	0.03%	795,046	$ 9.48
2004-2005	$ 6,512	$ 6,512	$ 24,390,390	0.03%	796,867	$ 8.17
2005-2006	$ 5,493	$ 5,493	$ 27,265,071	0.02%	801,225	$ 6.86
2006-2007	$ 4,409	$ 4,409	$ 30,708,931	0.01%	805,911	$ 5.47
2007-2008	$ 3,294	$ 3,294	$ 33,316,302	0.01%	812,028	$ 4.06
2008-2009	$ 2,128	$ 2,128	$ 34,199,233	0.01%	818,546	$ 2.60
2009-2010	$ 928	$ 928	$ 32,845,989	0.00%	825,378	$ 1.12
2010-2011	$ -	$ -	$ 32,826,901	0.00%	830,215	$ -
2011-2012	$ -	$ -	$ 32,865,630	0.00%	834,109	$ -

(1) Source - County Auditor-Controller Ventura County.
(2) California Department of Finance Ventura County July 1st of each year.

The above data are alternative indicators that are considered relevant to United Water Conservation District.

United Water Conservation District Water System
Summary of Historic Operating Results and Pledged-Revenue and non Pledged Debt Service Coverage
Fiscal Year Ended June 30
(Unaudited)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Revenues										
Water delivery charges	$ 4,622,189	$ 5,094,058	$ 4,553,421	$ 5,660,844	$ 6,544,073	$ 7,102,327	$ 7,626,111	$ 8,167,953	$ 8,304,773	$ 8,451,933
Groundwater charges	2,278,994	3,341,330	3,998,730	4,024,600	4,297,195	4,108,102	4,855,486	5,465,530	5,648,726	7,575,270
Less allowance for uncollectables	-	-	-	-	-	-	(19,690)	9,688	(876)	(9,527)
Taxes	1,259,400	1,366,114	983,234	1,126,876	1,895,896	2,000,078	2,089,854	2,089,881	1,949,647	2,016,499
Interest	243,947	157,573	181,694	576,758	813,667	665,160	264,128	107,155	90,699	69,737
Other	877,381	395,775	418,664	521,977	1,058,254	376,730	283,952	202,191	190,912	530,332
Total revenues	9,281,911	10,354,850	10,135,743	11,911,055	14,609,085	14,252,397	15,099,841	16,042,398	16,183,881	18,634,244
Operating expenditures (1)										
Salaries	1,588,617	1,694,540	1,738,614	1,982,344	2,159,346	2,456,084	2,659,544	2,824,241	3,079,085	3,212,930
Employee benefits	488,046	781,127	760,348	885,289	942,866	1,041,956	1,273,509	1,327,087	1,438,154	1,622,051
Utilities	1,133,349	781,425	713,631	616,356	914,815	1,315,366	1,167,901	1,171,421	998,711	926,083
Maintenance	663,790	698,613	515,113	815,951	861,452	1,055,420	947,493	1,110,982	1,167,225	723,718
Professional fees	745,156	739,123	636,949	842,885	802,397	590,711	1,129,739	1,094,790	1,168,058	1,326,488
Miscellaneous	526,139	587,016	541,929	605,749	712,306	1,156,124	859,491	722,595	730,926	880,862
General and administrative	1,294,192	1,324,686	1,401,138	1,415,957	1,768,320	1,639,077	1,949,131	2,073,257	2,164,448	2,275,837
Total operating expenditures	6,439,289	6,606,530	6,307,722	7,164,531	8,161,502	9,254,738	9,986,808	10,324,373	10,746,607	10,967,969
Net revenues	$ 2,842,622	$ 3,748,320	$ 3,828,021	$ 4,746,524	$ 6,447,583	$ 4,997,659	$ 5,113,033	$ 5,718,025	$ 5,437,274	$ 7,666,275
Debt Service:										
Principal	$ 1,188,100	$ 1,252,049	$ 1,296,307	$ 1,580,887	$ 1,780,799	$ 1,846,047	$ 2,573,612	$ 1,495,000	$ 3,370,000	$ 3,430,001
Interest	746,178	698,758	648,537	861,861	809,207	772,813	713,971	790,036	1,185,358	1,085,538
Total Parity debt service (2)	$ 1,934,278	$ 1,950,807	$ 1,944,844	$ 2,442,748	$ 2,590,006	$ 2,618,860	$ 3,287,583	$ 2,285,036	$ 4,555,358	$ 4,515,539
Coverage of system net revenues to parity debt service	1.47	1.92	1.97	1.94	2.49	1.91	1.56	2.50	1.19	1.70
Debt Service:										
Principal	$ 987,194	$ 1,014,011	$ 1,040,884	$ 1,069,815	$ 1,099,809	$ 1,360,751	$ 1,166,000	$ 1,200,000	$ 928,000	$ -
Interest	218,456	256,896	209,511	276,164	213,834	118,660	88,581	36,309	28,885	-
Total debt service on other debt payable from net revenues	$ 1,205,650	$ 1,270,907	$ 1,250,395	$ 1,345,979	$ 1,313,643	$ 1,479,411	$ 1,254,581	$ 1,236,309	$ 956,885	$ -
Coverage on all debt payable from net revenues	0.91	1.16	1.20	1.25	1.65	1.22	1.13	1.62	0.99	1.70

(1) Excludes depreciation, capital expenditures and debt service
(2) Includes 2001, 2005, 2006 Revenue Bonds, 2009 Certificates of Participation bond contracts and note payable to the State Department of Water Resources
Does not include other obligations of the District not secured by an express pledge of water revenues

United Water Conservation District
Demographic and Economic Statistics
Last Ten Fiscal Years
(amounts expressed in thousands)
(Unaudited)

Fiscal Year	Utility Valuations	Secured Valuations	Unsecured Valuations	Total Assessed Valuations (1)	Population (2)
2002-2003	$ 17,080	$ 19,198,232	$ 773,673	$ 19,988,985	789,367
2003-2004	$ 117,882	$ 21,074,070	$ 798,743	$ 21,990,695	795,046
2004-2005	$ 229,718	$ 23,364,998	$ 795,674	$ 24,390,390	796,867
2005-2006	$ 216,409	$ 26,177,424	$ 871,238	$ 27,265,071	801,225
2006-2007	$ 193,060	$ 29,586,144	$ 929,727	$ 30,708,931	805,911
2007-2008	$ 157,264	$ 32,206,250	$ 952,788	$ 33,316,302	812,028
2008-2009	$ 132,246	$ 33,082,922	$ 984,065	$ 34,199,233	818,546
2009-2010	$ 106,785	$ 31,652,196	$ 1,087,008	$ 32,845,989	825,378
2010-2011	$ 119,468	$ 31,673,871	$ 1,033,562	$ 32,826,901	830,215
2011-2012	$ 106,617	$ 31,672,936	$ 1,086,077	$ 32,865,630	834,109

(1) Source - County Auditor-Controller Ventura County.
(2) California Department of Finance Ventura County July 1st of each year.

The above data are alternative indicators that are considered relevant to United Water Conservation District.

United Water Conservation District
Demographic and Economic Statistics
Last Ten Calendar Years
(amounts expressed in thousands or acre foot as indicated)
(Unaudited)

Calendar Year	Gross Value of Crops (1)	Leading Commodity Value Strawberrys (1)	Acres of Agricultural of Farm Land (2)
2002	$ 1,117,628	$ 300,746	N/A
2003	$ 1,389,452	$ 363,646	128,061
2004	$ 1,255,109	$ 325,567	N/A
2005	$ 1,508,174	$ 366,310	124,959
2006	$ 1,549,988	$ 366,428	N/A
2007	$ 1,613,247	$ 393,507	122,492
2008	$ 1,600,000	$ 394,000	N/A
2009	$ 1,623,857	$ 515,406	96,316
2010	$ 1,859,151	$ 542,127	N/A
2011	$ 1,844,260	$ 625,509	96,340

(1) Source: Farm Bureau of Ventura County
(2) Source: Farm Bureau of Ventura County calculated by the California Department of Conservation's Farmland Mapping and Monitoring Program and excludes grazing land.

The above data are alternative indicators that are considered relevant to United Water Conservation District.

United Water Conservation District
Demographic and Economic Statistics
Fiscal Year Ended June 30, 2012 and Nine Years Ago
(Unaudited)

	2011-12			2002-03		
Principal Employers	Employees	Rank	Percentage of Total County Employment	Principal Employers	Rank	Percentage of Total County Employment
United States Naval Base	17,000	1	5.71%	16,481	1	5.40%
County of Ventura	8,431	2	2.83%	8,317	2	2.73%
Amgen, Inc.	5,995	3	2.01%	5,800	3	1.90%
WellPoint Inc.	3,033	4	1.02%	3,707	5	1.22%
Simi Unified School District	2,250	5	0.76%	2,400	7	0.79%
Community Memorial Hospital	2,006	6	0.67%	1,540	13	0.50%
Conejo Valley Unified School District	2,004	7	0.67%	2,143	9	0.70%
Ventura Unified School District	1,819	8	0.61%	2,500	6	0.82%
Ventura Community College District	1,682	9	0.56%	2,201	8	0.72%
Los Robles Regional Medical Center	1,500	10	0.50%	1,391	14	0.46%
	45,720		15.35%	46,480		15.24%

Source: California Economic Forecast, Santa Barbara, California (February Report for Ventura County)

The above data are alternative indicators that are considered relevant to the County of Ventura.

United Water Conservation District
Operating Information
Year Ended June 30, 2012
(Unaudited)

Full time equivalent positions as assigned by Function/Program:

Fiscal Year	Water Conservation	Facility Operations and Improvements	Recreation Facilities	General and Administrative	Total District Employees
2002-2003	5	22	6	12	45
2003-2004	5	22	6	12	45
2004-2005	5	22	6	12	45
2005-2006	6	23	6	12	47
2006-2007	8	22	7	12	49
2007-2008	9	23	8	12	52
2008-2009	10	27	4	13	54
2009-2010	9	27	2	14	52
2010-2011	10	28	2	13	54
2011-2012	9	25	2	12	48

General and administrative employees compensation allocated to water conservation and facilities based on an agreed upon in-direct cost allocation methodology.

United Water Conservation District
Operating Information - Continued
Year Ended June 30, 2012
(Unaudited)

Data on Pumping Wells:

Well No.	Well Depth In Feet	Well Capacity Gallons Per Minute
The Oxnard-Hueneme Pipeline has twelve active pumping wells:		
2A	320	2,500
4	303	2,500
5	303	2,500
6	301	2,500
7	326	2,500
8	314	2,500
11	360	3,400
12	1,112	2,500
13	1,418	2,500
14	1,470	3,500
15	330	3,000
16	340	2,500
The Pumping Trough Pipeline has five deep aquifer irrigation pumping wells:		
1	1,113	2,500
2	1,418	2,500
3	1,410	2,000
4	1,565	3,000
5	1,499	3,000

The Pumping Trough Pipeline also has one Booster Pump with pumping capacity of 6,700 gallons per minute.

The Saticoy Well Field has four upper aquifer irrigation pumping wells:		
1	375	3,000
2	330	2,900
3	360	2,800
4	280	2,800

United Water Conservation District
Operating Information - Continued
Year Ended June 30, 2012
(Unaudited)

District Facilities: United Water Conservation District operates a series of water conservation facilities within the watershed of the Santa Clara River. The facilities are used to store water run-off, divert water, recharge aquifers through the use of spreading ponds and deliver water to municipalities and agricultural growers. The District has over 1,132 active water wells within the District's service area. The District estimates these wells are owned by approximately 694 individuals. A listing of some of the major facilities is as follows:

Santa Felicia Dam	An earthen dam constructed in 1954 with a maximum height of 200 feet. The main purpose of the dam is to catch water run-off from Piru Creek.

Lake Piru	Created by the Santa Felicia Dam. The main purpose of the Lake is to store water run-off and release, in controlled amounts, water to replenish several groundwater basins and supply surface water for irrigation to agricultural areas of the District. Capacity: maximum 87,200 acre feet to a minimum pool of 20,000 acre feet.

Piru Diversion and Spreading Grounds	Constructed in 1931. Percolating Capacity: 150 acre-feet per day Average Annual Spreading: 5,700 acre feet

Ferro Rose Basins	231 acre Ferro Basin 117 acre Rose Basin Acquired in 2009 Not presently connected to the District's recharge system

Noble Basin	Converted from an aggregate mining pit in 1994 132 acre Noble Basin Basin dividers: 3 cells separated by 15 to 20 foot earthen berms Initial capacity: 375 cfs

Mugu Lateral	Pipeline to Point Mugu Naval Air Station Leased long term to Port Hueneme Water Agency

Freeman Diversion	Construction completed in 1991. A concrete structure spanning the Santa Clara River with water diversion of 375 cfs. Diverts water released from Lake Piru and natural runoff from the Santa Clara River. Flows via canal and pipelines to a 44 acre desilting basin. From the desilting basin water flows via canals and pipelines to spreading grounds and other water delivery systems. Average annual diversion: 80,900 acre feet

United Water Conservation District
Operating Information - Continued
Year Ended June 30, 2012
(Unaudited)

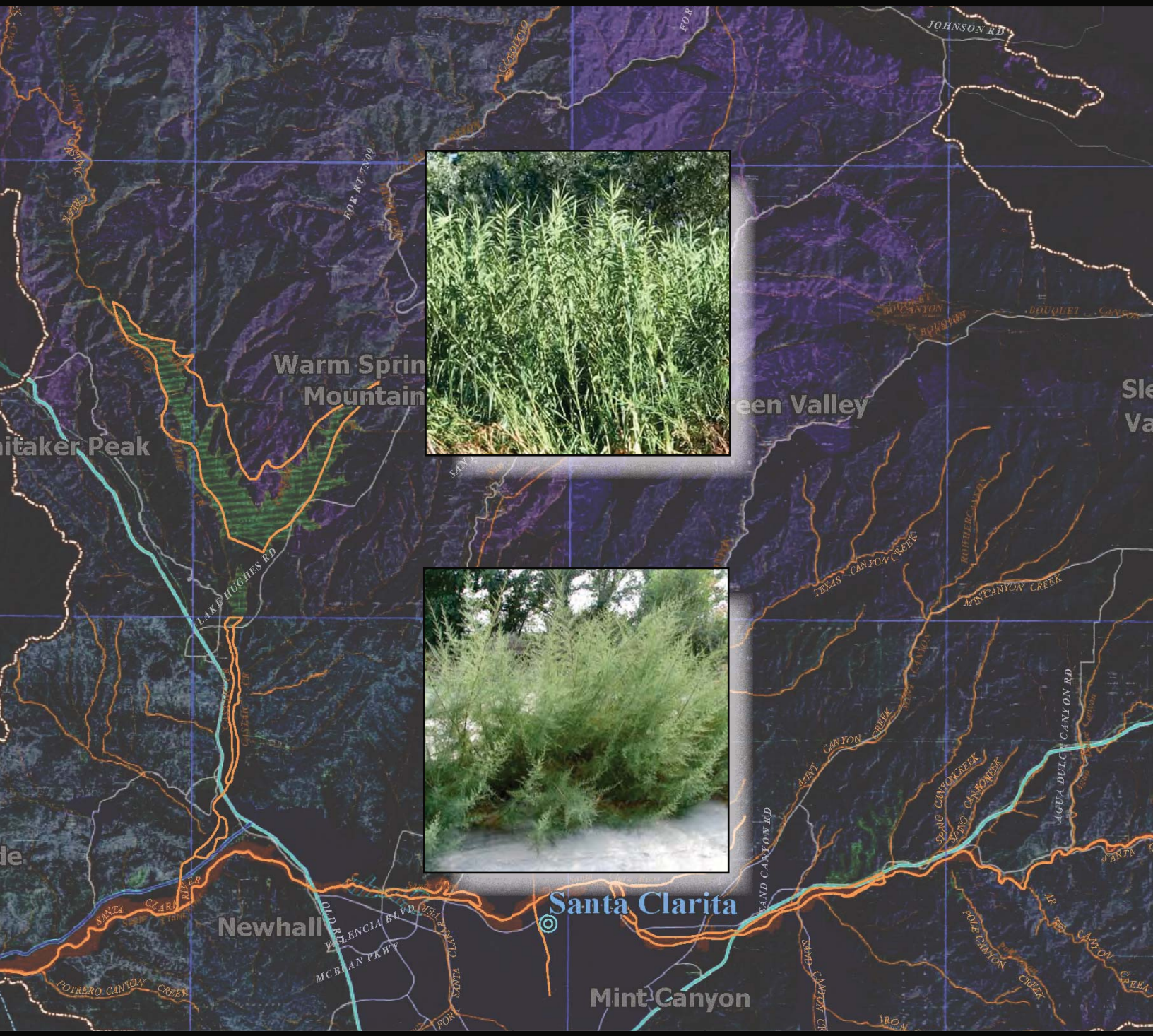
Saticoy Spreading Grounds	Headworks and canal capacity: 375 cfs Number of basins: 15 including desilting basin Wetted area: 133 acres Basin dividers: 6 to 8 foot earth dikes Percolating capacity: 450 acre-feet per day Annual average spreading: 26,500 acre feet

El Rio Spreading Grounds	Saticoy to El Rio pipeline capacity: 150 cfs Number of basins: 10 Wetted area: 100 acres Basin dividers: 6 to 8 foot earth dikes Percolating capacity: 300 acre-feet per day Annual average spreading: 31,300 acre feet

Municipal Delivery Systems: **Oxnard-Hueneme Pipeline**	Consists of: 12 wells located at the El Rio spreading grounds and Rose Avenue 2 8 million gallon clearwells 1 chloramination facility 1 booster plant 12 miles of distribution pipeline Delivery: 53 cfs of potable water to customers 13 turnouts and servicing agent for 53 turnouts. Includes City of Oxnard, Port Hueneme Water Agency that provides service to the City of Port Hueneme, Point Mugu and Port Hueneme Navel bases and 4 mutual water companies
Agricultural Delivery Systems: **Pumping Trough Delivery System**	Construction completed in 1986 consisting of: 5 wells 1 reservoir 1 booster station Serves 4,000 acres of farmland Average delivery capacity of approximately 12,000 acre feet of water per year 15 miles of distribution pipeline. 62 turnouts
Pleasant Valley Delivery System	Completed approximately 1958. The primary purpose is to sell diverted river water to the Pleasant Valley County Water District (PVCWD) to offset pumping of wells in the PVCWD area. Serves 12,000 acres of farmland The pipeline is 25,600 feet long and 54 inches in diameter. 4 turnouts Design capacity: 75 cfs 2 150 acre foot reservoirs Average surface water delivery is 8,700 acre feet per year.
Saticoy Well Field	Construction completed in 2005 4 wells The purpose is to increase storage in the upper aquifer by pumping at the Saticoy spreading grounds and delivering excess water to the Oxnard Plain to relieve pumping in the lower aquifer system.

Upper Santa Clara River Watershed
Arundo and Tamarisk Removal Program

Long-Term Implementation Plan



Ventura County Resource Conservation District

June 2006

Funding for this project has been provided in full through an Agreement with the State Water Resources Control Board (SWRCB) pursuant to the Costa-Machado Water Act of 2000 (Proposition 13) and any amendments hereto for the implementation of California's Nonpoint Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the SWRCB, nor does mention of trade names or commercial products constitute endorsement of recommendation of use.

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List of Acronyms

Acronym	Definition
°C	degrees Celsius
af	acre-feet
BMP	best management practices
Cal-IPC	California Invasive Plant Council
CDFA	California Department of Food and Agriculture
CDFG	California Department of Fish and Game
CA Parks/Rec	California Department of Parks and Recreation
CDPR	California Department of Pesticide Regulations
CESA	California Endangered Species Act
CLWA	Castaic Lake Water Agency
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
CWA	Clean Water Act
DWR	California Department of Water Resources
FSCR	Friends of the Santa Clara River
FESA	Federal Endangered Species Act
I-5	Interstate 5
LADPW	Los Angeles County Department of Public Works
LBV	least Bell's vireo
MBTA	Migratory Bird Treaty Act
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
msl	mean sea level
NGO	Non-governmental organization
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
QAPP	Quality Assurance Project Plan
RGP	Regional General Permit
RWQCB	Regional Water Quality Control Board
SARMB	Santa Ana River Mitigation Bank
SCARP	Santa Clara River Arundo and Tamarisk Removal Program
SCREMP	Santa Clara River Enhancement Management Plan
SMSLRWMA	Santa Margarita and San Luis Rey Watershed Weed Management Area
SWFC	Southwestern willow fly-catcher
TADN	Team Arundo del Norte
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UWCD	United Water Conservation District
VCRCD	Ventura County Resource Conservation District
VCWPD	Ventura County Watershed Protection District

1.0 Introduction

The Santa Clara River, its tributaries and the associated riparian or streamside habitats comprise one of the largest natural river systems remaining in Southern California. From its headwaters in the San Gabriel Mountains southeast of the town of Acton, the Santa Clara River flows for 84 miles through Los Angeles and Ventura Counties terminating at the Pacific Ocean. The 45-mile-long portion of the Santa Clara River and its associated tributaries within Los Angeles County are referred to as the upper Santa Clara River. Along this 45-mile course, the Santa Clara River crosses national forest land, large areas of moderately developed private rural lands, the growing City of Santa Clarita, and then large tracts of rural farmland extending west to the county line. The Santa Clara River and this wide range of adjacent land uses comprise the upper Santa Clara River watershed, which consists of approximately 680 square miles (409,703 acres). This area is the focus of this plan (Fig. 1).

The Santa Clara River system and its associated riparian habitats provide major benefits to the surrounding communities including groundwater recharge, urban and agricultural water supplies, flood conveyance, visual relief, and recreational opportunities. In addition, the types of habitat found in the Santa Clara River's riparian areas are some of the most valuable wildlife habitat in the state, in terms of both species diversity and abundance, and provide habitat for some of the state's most threatened and endangered wildlife. This is especially important since as much as 90 percent of California's streamside riparian plant communities have been eliminated by urban and agricultural development within the last 150 years.

Many threats to the values provided by the Santa Clara River and its tributaries exist, including encroaching development, increased urban runoff, and the spread of invasive, non-native plant species. According to the National Invasive Species Council, an "invasive species" is one that is a) non-native (or alien) to the ecosystem under consideration and b) whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

In particular, the widespread establishment of two invasive plant species, arundo or giant reed (*Arundo donax*) and tamarisk or salt cedar (*Tamarix* spp.), severely threaten many of the benefits described above. Arundo and tamarisk have spread throughout the Santa Clara River and most of its tributaries such that their presence has become an important issue for the surrounding communities. Major stands of arundo dominate large sections of the Santa Clara River in northeast Los Angeles County and are even more prevalent throughout its reaches in Ventura County. Although less prevalent than arundo, tamarisk is also a major problem in some portions of the central and upper watershed.

1.1 Project Goals and Scope

The Upper Santa Clara River Watershed Arundo/Tamarisk Removal Plan (SCARP) provides guidance to stakeholders for implementing procedures to remove invasive, non native plants. The primary objective of the plan is to guide and facilitate the implementation of arundo and/or tamarisk removal projects within the upper Santa Clara River watershed of Los Angeles County. The SCARP is a living document and will be updated periodically as new technologies become available, regulations change, or new resources/issues are identified. The project focus is on approximately 16,300 acres of land within the 500 year floodplain of the Santa Clara River and its primary, secondary, and tertiary tributaries. These floodplain lands, particularly within the banks and channel of the Santa Clara River and tributaries, are where arundo and tamarisk infestations are primarily contained and where the bulk of removal activities would occur. However, additional activities such as access, equipment staging and storage, transport, and disposal may occur outside of the 500-year floodplain.

The SCARP has been prepared to provide local landowners, municipalities, environmental groups, and other stakeholders with a broad menu of available techniques for removal of arundo and tamarisk and guidance in obtaining proper permits and approval for removal. The SCARP also provides best management practices (BMP) needed to minimize impacts during removal projects. The following factors have been researched and considered in the development of this SCARP:

- Potential eradication methods
- Degree of infestation
- Existing habitats
- Presence of threatened and/or endangered species
- Access
- Land use
- Current work being conducted or planned
- Pre-existing environmental agency restrictions and permits
- Funding mechanisms in place and strategies for future funding

Taken together, these factors provide a framework for a long term eradication program and associated monitoring to facilitate removal of arundo and tamarisk from the upper Santa Clara River watershed and the restoration and maintenance of natural, economic and community values provided by these riparian corridors.

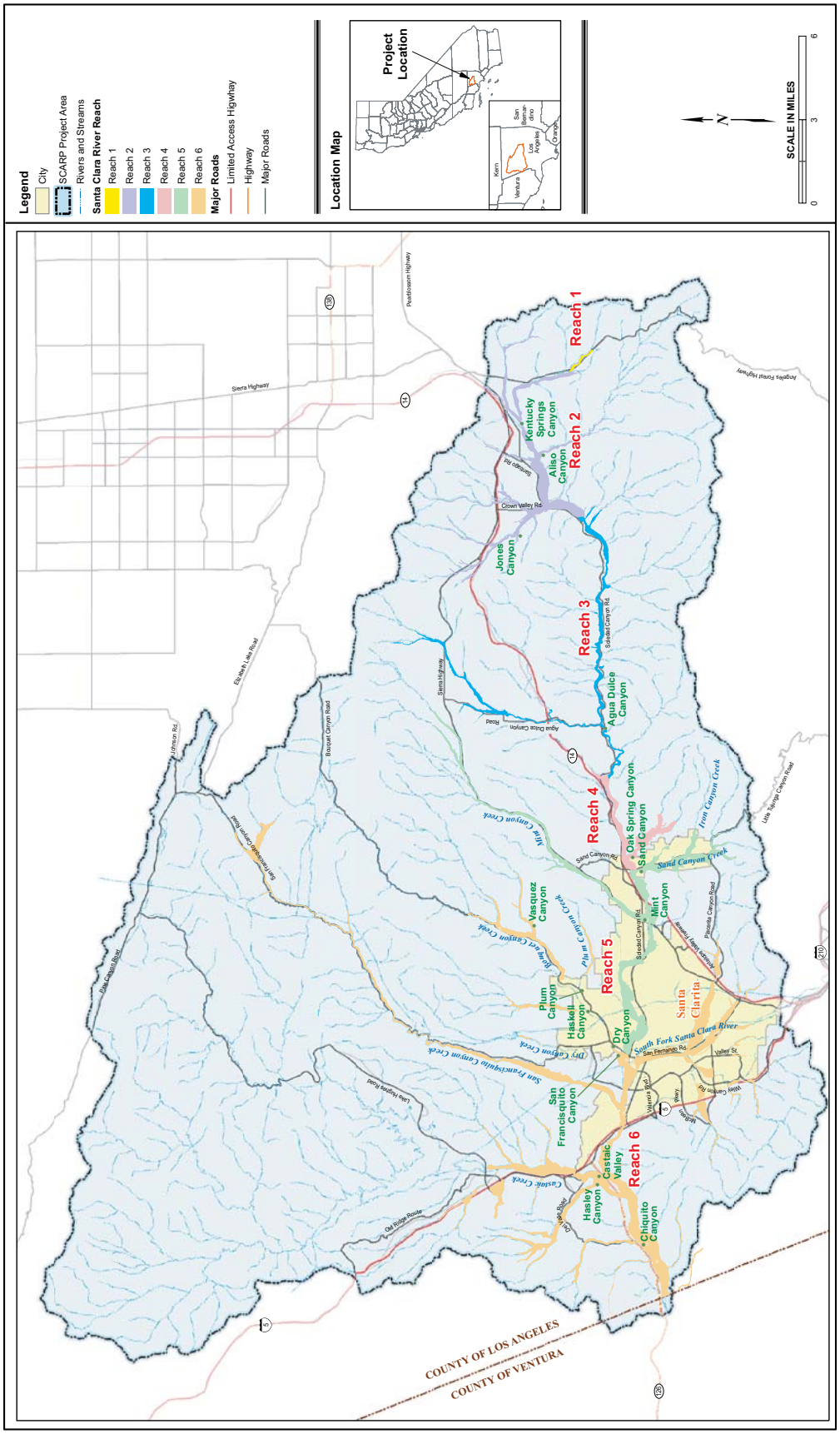
1.2 Project Partnerships

The lead agency directing this effort is the Ventura County Resource Conservation District (VCRCD). The VCRCD is one of 104 resource conservation districts in California and is a special district of the state, which receives funding primarily through grants. The VCRCD manages a diversity of programs including soil and water conservation projects, wildlife habitat enhancement and restoration, control of invasive plants species, and environmental education. The VCRCD has developed a Memorandum of Understanding (MOU) to show support for the SCARP project. The agencies and organizations, which have completed MOUs, are listed below and copies of these memoranda are included in Appendix 1:

- Antelope Valley Resource Conservation District (AVRCD)
- U.S. Forest Service (USFS)
- U.S. Fish and Wildlife Service (USFWS)
- Los Angeles County Department of Public Works (LADPW)
- Los Angeles Agricultural Commissioner's Office
- Los Angeles County Weed Management Area (LAWMA)
- City of Santa Clarita
- Friends of the Santa Clara River (FSCR)
- UC Cooperative Extension

A SCARP Working Group was also created to collaborate with the various organizations and agencies within the upper Santa Clara River watershed. There are many other local agencies and organizations assisting in various ways with the SCARP development such as the U.S. Army Corps of Engineers (USACE), the California Department of Fish and Game (CDFG), the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), the Los Angeles Regional Water Quality Control Board (RWQCB), the Ventura County Arundo Task Force, and the Ventura County Watershed Protection District (VCWPD).

Figure 1: SCARP Project Location and Associated River Reaches



Upper Santa Clara River Sub-Watershed – Santa Clara River Reaches

SCARP

2.0 Invasive Plant Species in the Santa Clara River

The primary focus of this program is the eradication of arundo and tamarisk from the upper Santa Clara River watershed. These species and the issues involving them are described in detail in this section. However, the SCARP recognizes that arundo and tamarisk are not the only non-native invasive plant species present in the upper Santa Clara River watershed. Other species that have been identified within the project area are listed at the end of this chapter. While the removal methods described in Chapter 10 are primarily listed for their use in eradicating arundo and tamarisk, they may also be used to remove other non-native invasive species that are encountered during an individual eradication project.

2.1 Background on Arundo

Arundo is native to the Mediterranean region. It was introduced to the western United States by Spanish settlers in the early 1800s and became abundant in the Los Angeles River by the 1820s. It was historically used as a windbreak, soil stabilizer, fodder, and for making reeds for woodwind instruments. Material from this plant was also commonly woven into mats and used as building material. It is no longer widely used or harvested for these traditional products, but is still used in landscaping.

Arundo is a tall, perennial grass that can reach up to 30 feet in height. It is light to dark green in color and has long, broad blades, with large plume-like flowers. Arundo is one of the fastest growing plants in the world and grows quickly in response to elevated nitrogen levels. This plant is tolerant of both drought and flooding, and can survive extended periods of salinity exposure. Arundo reproduces vegetatively from rhizomes (underground stems) and stem segments. Stem segments usually need two nodes or points for both roots and shoots to grow, but shoots have been observed on stem segments with a single node. Once introduced, arundo has the capability to spread rapidly, forming extensive rhizome systems that out-compete native riparian vegetation and require human intervention to remove. A single clump typically has hundreds of stems that grow very closely together and very rapidly, up to several inches per day during the spring and summer months. Arundo does not usually spread from seed.

Arundo thrives in warm, tropical environments and is most often invasive in coastal riparian areas, where it forms dense monocultures. The invasiveness of arundo substantially affects water quality, water conservation, native biological resources, flooding, erosion hazards, and wildfire risks. Arundo uses at least twice the amount of water as native riparian plants, and can use as much as 17.3 liters/m^2 per day, which is nearly 20 times the amount used by native vegetation (Hendrickson and McGaugh 2005). Arundo is extremely flammable throughout most of the year and is highly adapted to fire. The height of arundo growth spreads fires to tree canopies and the dense growth in the river channels spread fires up and down the river system. The rhizomes also respond quickly after fires, sending up new shoots, and quickly outgrow native species that may have otherwise taken root or sprouted in a burned site (Bell 1997).

2.2 Background on Tamarisk

Similar to arundo, tamarisk is a native of south Eurasia and may have been introduced by Spanish settlers. It was present in California by the early 1900s. Tamarisk was historically, and is currently, used for windbreaks, firewood, shade, and in landscaping. There are currently five known species of tamarisk in California including *Tamarix ramosissima*, *T. parviflora*, *T. gallica*, *T. aphylla*, and *T. chinensis*. Tamarisk is found in rivers, streams, wetlands, desert alkali sinks, playas, and springs throughout Southern and Central California and the western United States.

Although currently less of a problem than arundo in this watershed, tamarisk may be spreading and has potential to cause substantial long-term effects on the water quality, water conservation, native biological resources, flood control, and fire hazards. Tamarisk is a hardy, perennial shrub or small to medium-sized tree, which under favorable circumstances can reach 30 to 40 feet in height. Tamarisk foliage is light to dark green, with small, alternate scale-like leaves. The bark varies from smooth to rough and is reddish-brown. The plants are able to flower after one year of growth.

Tamarisk spreads by seed dispersal and vegetative reproduction. Full-grown mature trees can produce

500,000 seeds per year. These seeds remain viable up to five weeks after being produced and some may survive to the next spring (DiTomaso 2003). These seeds are extremely small with a terminal tuft of exposed fibers that allows them to travel greater distances via wind or water. Unlike arundo, seed dispersal is tamarisk's primary form of reproduction and spreading. However, under favorable moist conditions, tamarisk can also become easily established from stem and root segments.

Tamarisk is an aggressive invasive plant that has a long taproot capable of extending down to the water table. Because of this long taproot, tamarisk is capable of obtaining water in inhospitable and fluctuating groundwater environments, which allows it to out-compete native vegetation. In particular, tamarisk displaces native woody species, such as cottonwood, willow, and mesquite, especially in disturbed areas. Tamarisk consumes at least twice the amount of water that native vegetation uses, or about 3.3 liters/m^2 per day (Hendrickson and McGaugh 2005). Tamarisk further impacts the environment by its ability to concentrate soil salts. Tamarisk leaves collect salt brought up from the soil by the roots. As leaf litter accumulates under the plant, the surface soil can become highly saline, thereby impeding future colonization by many native understory plant species (Carpenter 1998). In addition, dense stands of tamarisk can be highly flammable and tamarisk is likely to persist following fire and expand its dominance with repeated burning of low-elevation riparian plant communities (Busch 1995).

2.3 *Long-term Effects of Arundo and Tamarisk Invasion*

Both arundo and tamarisk are officially recognized as undesirable invasive plants. Both plants are listed as 'A-1' invaders (the most invasive and widespread wildland pest plants) by the California Invasive Plant Council (Cal-IPC) [formerly known as California Exotic Pest Plant Council] and as noxious weeds by the California Department of Food and Agriculture (CDFA). While the degree and specifics of problems associated with these species vary, general negative effects associated with the establishment of arundo and tamarisk within the watershed.

2.3.1 Water Quality and Supply

Both arundo and tamarisk consume large amounts of water, which negatively affects both instream and groundwater availability. Reduced water availability also adversely affects water-dependent plants and wildlife, and reduces the water available for beneficial urban and agricultural uses. Although native riparian plants have similar transpiration rates per unit of surface area to arundo and tamarisk, arundo and tamarisk have approximately two or more times greater leaf surface area. Therefore, they transpire more water than native plants (Kelly 2003). Water consumption by these species is so high that dense infestations can desiccate riparian areas (seeps, springs, rivers) in arid habitats (Egan and Walker 2000; Dudley 2000). Major arundo infestations can cause an overall increase in water temperature by reducing shade in riparian areas. Increased water temperature can ultimately lead to a reduction of dissolved oxygen, making the water unsuitable for aquatic organisms (Bell 1997). In addition, increased light exposure and temperature may encourage algal blooms, and consequently increase pH levels and severely reduce available habitat for aquatic organisms (Adamus et al. 1997). Increased pH also facilitates the conversion of usable ammonia to a toxic byproduct, which degrades water quality. All of these changes can adversely affect wildlife, including rare and sensitive species.

2.3.2 Flooding and Erosion

Both arundo and tamarisk are known to increase flood hazards and the potential for erosion of adjacent lands, particularly for farmland along the Santa Clara River. Both plants can alter stream geomorphology by trapping and stabilizing sediment, which narrows stream channels, widens floodplains, and causes increased flooding (Carpenter 1998; Lovich 2000; Zouhar 2003). Large stands of arundo and tamarisk may also obstruct flows and shunt floodwaters into areas that historically have not experienced water flow. This can exacerbate bank erosion problems and lead to an unnatural increase in the loss of adjacent public and private property that is often valuable farmland. Arundo provides less protection for steam banks from erosion, because its dense but shallow root masses are more easily undercut than

deep-rooted native riparian vegetation. In addition to increasing flood magnitudes, arundo and tamarisk debris may accumulate downstream of the infestations, trapping sediments, and impeding natural water flow. Arundo debris can create new establishments downstream and on the beach. In many cases, costly clean up efforts or repairs are required.

2.3.3 Fire Hazards

Both arundo and tamarisk contribute to increased fire hazards. Under natural conditions, riparian areas act as firebreaks, but as they are overcome by invasive species, they not only enable wildfires to spread more rapidly, but they can also become sites where fires may originate. Arundo, in particular, is highly flammable and burns more intensely than native riparian vegetation even when green (Bell 1997; Dudley 2000). Because arundo is able to grow to substantial heights, it can act as a ladder fuel, effectively carrying, fire into tree canopies, thereby causing "crown fires" that increase tree mortality. Further, fire disturbance encourages regrowth of arundo. Burned areas also favor tamarisk regrowth, generating a positive feedback loop which is ultimately destructive to native habitat and dangerous to human developments (Bell 1997). Tamarisk leaf litter is also highly flammable, and because both plants are more flammable than native riparian vegetation, fires may occur more frequently and contribute to the eventual exclusion of native plant species (Bell 1997; Carpenter 1998; Lovich 2000).

2.3.4 Native Habitats and Wildlife

Arundo and tamarisk threaten native riparian habitats and the wildlife that depends upon these habitats by excluding native plants from water resources, growing space, and sunlight. Arundo often forms dense monocultures that exclude native vegetation by monopolizing water resources, shading, and altering flood regimes critical to the establishment of native riparian vegetation (Bell 1997; Dudley 2000). The salt-laden leaf litter of tamarisk also precludes such native understory from establishing. Both plants do not offer the same amount of shade as native vegetation (Carpenter 1998). Both arundo and tamarisk reduce habitat quality and food supply for native wildlife, including insects and bird species (Bell 1997; Dudley 2000; Herrera 2003). Insects and other grazers are not able to use arundo as a food source due to the noxious chemicals it contains and its defensive cellular structure (Bell 1997). This is particularly important for federal and state listed species, such as least Bell's vireo, southwestern willow flycatcher, and yellow-billed cuckoo, which utilizes insects as a food source. Documented decreases in wildlife usage of riparian areas have occurred due to massive stands of arundo (Dudley 2000).

2.4 Other Invasive Species

In addition to arundo and tamarisk, perennial pepperweed is a third significant threat to the watershed. Once established, it is very difficult to remove, and the monocultures it creates effectively displace native flora and fauna. Similar to tamarisk, perennial pepperweed also has the ability to concentrate salts near the ground surface (Renz 2000). The following list contains additional noxious and invasive plant species, which may be treated when encountered. The Cal IPC and CDFA also have lists of noxious and invasive plant species. The removal project manager, in coordination with the resource agencies, will make a determination regarding the level of effort that should be exerted in removing each species. For example, mustard may only require treatment if it occurs in stands greater than 0.25 acre at greater than 50-percent cover. Table 1 below lists additional invasive plant species.

Table 1: Invasive Plant Species

Scientific Name	Common Name
Ageratina adenophora	eupatory
Ailanthus altissima	tree of heaven
Aptenia spp.	iceplant
Atriplex semibaccata	Australian saltbush
Avena spp.	non-native grasses
Bassia hyssopifolia	five hook bassia
Brassica spp.	mustard species
Bromus spp.	non-native grasses
Cardaria chalepensis or *C. draba*	hoary cress, white top
Carduus pycnocephalus	Italian thistle
Carpobrotus spp.	iceplant
Centaurea melitensis	tocalote
Centaurea solstitialis	yellow starthistle
Cirsium arvense	Canada thistle
Cirsium vulgare	bull thistle
Conium maculatum	poison hemlock
Cortaderia jubata or *C. selloana*	pampas grass
Cynara cardunculus	artichoke thistle
Cynodon spp.	non-native grasses
Cytisus scoparius	scotch broom
Erodium cicutarium	red stem filaree
Eucalyptus spp.	eucalyptus
Foeniculum vulgare	fennel
Genista monosperma	bridal veil broom
Hedera helix	English ivy
Lepidium latifolium	pepper weed
Linaria dalmatica	dalmation toadflax
Mesembryanthemum spp.	iceplant
Nerium oleander	oleander
Nicotiana glauca	tree tobacco
Phoenix canariensis	canary island palm
Ricinus communis	castor bean
Robinia pseudoacacia	black locust
Salsola spp.	Russian thistle
Schinus spp.	pepper trees
Silybum marianum	milk thistle
Washingtonia spp.	fan palm

3.0 Description of Project Area Reaches

This section provides specific details on the physical and environmental characteristics for each of the upper Santa Clara River's six designated reaches and discussion of future removal program issues and recommendations. The same general analysis is also provided for each of the upper Santa Clara River's ten major tributary systems. In some reaches, removal work may have been conducted prior to the development of the SCARP. The goal of this background information and analysis is to facilitate an understanding among and between future removal project applicants and concerned state and federal resource agencies about the issues surrounding arundo and tamarisk removal proposals. An additional goal is to set the stage for resource agencies such as CDFG, USFWS, and USACE to issue programmatic permits, which will facilitate future removal projects while still protecting critical resources. Reach discussions are generally organized from east to west; with Reach 1 beginning upstream at the eastern project boundary, and Reach 6 ending downstream at the western project boundary.

The upper Santa Clara River's ten main tributaries are grouped based on their hydrological connections to one another and their point of intersection with the mainstem. Eight of these tributaries are located on the north side of the watershed and extend into USFS land. Two tributaries are located on the south side of the watershed. Tables 2 and 2a list the reaches and tributaries within the upper Santa Clara River watershed. The location of the project area is shown in Figure 1. Mainstem and tributary surveys performed by AMEC are described in the text, however detailed tributary surveys conducted by Condor Environmental are included as a separate document in the Appendices. Additional information for each reach and its respective tributaries such as summary tables for reach characteristics, channel cover, and sensitive species can be found in Appendix 6.

Table 2: Reach Descriptions

Reach	Location (east to west)	Length of Reach (miles)	Arundo Coverage (acres)	Tamarisk Coverage (acres)
Reach 1	Eastern Project Boundary to the Angeles Forest Highway	3.6	0	0
Reach 2	Angeles Forest Highway to Acton	8.0	0	2.5
Reach 3	Acton to Spring Canyon	11.4	111	30
Reach 4	Spring Canyon to Sand Canyon	3.9	70.7	21.3
Reach 5	Sand Canyon to Bouquet Canyon	7.9	98.7	202.5
Reach 6	Bouquet Canyon to the Los Angeles County Line	11.0	464.3	190.3

Table 2a: Tributary Descriptions

Reach	Tributary Name	Length of Reach (miles)	Arundo Coverage Greater than 50% (acres)	Tamarisk Coverage Greater than 50% (acres)
Reach 1	No tributaries	n/a	0	0
Reach 2	Jones Canyon Tributaries	9.0	0	0
	Soledad	6.87	0	0
	Aliso Canyon	3.02	0	0
	Escondido Canyon	6.41	0	0
	Santiago Road	n/a	0	0
Reach 3	Aqua Dulce Canyon Tributary	4.7	0	0.15
Reach 4	Oak Spring	5.13	0	0
Reach 5	Sand Canyon Creek	8.5	0	0
	Mint Canyon Creek	13.6	3	0
Reach 6	Bouquet Canyon Creek	25.0	0	0
	South Fork Tributaries	7.5	0	0
	San Francisquito Canyon Creek	21.7	5	0
	Castaic Creek	23.5	3	2
	Hasley Canyon	5.4	0	0
	Chiquito Canyon Tributary	4.9	0	0
	Potrero	3.61	0	0
	Salt	7.24	0	0
	San Martinez Grande	3.22	0	0

3.1 Reach 1: Eastern Project Boundary to Angeles Forest Highway

Characteristics

Extending 3.6 miles, Reach 1 comprises the headwaters of the Santa Clara River which are located in Soledad and Kentucky Springs Canyons; and the river flows through Soledad Canyon for many of the following reaches. Kentucky Springs Canyon is fed by several small streams originating in the San Gabriel Mountains. Reach 1 lies entirely within the Angeles National Forest, although there are several private in-holdings. Reach 1 is an ephemeral stream, where surface water is present only after major storm events. The stream channel within this reach is narrow and steep due to surrounding topography. The 500-year floodplain of Reach 1 ranges between 250 and 500 feet in width and has primarily natural streambanks.

The vegetation in Reach 1 is dominated by big sagebrush and chamise. The remainder of the floodplain is dominated by juniper and walnut woodlands. Sensitive species including the coast horned lizard (state candidate for listing) and the short-joint beavertail cactus (state species of concern) have been reported in Reach 1 (CDFG 2004). This reach's high quality habitat may support other sensitive species; however, this area has only been partially surveyed.

Target Species

No known infestations of arundo, tamarisk, or other invasive plant species have been observed in Reach 1 and therefore no eradication projects are currently anticipated. Although this reach is not threatened or highly suitable for arundo or tamarisk, this reach should be monitored for development of arundo and tamarisk colonies, as presence of these species can lead to infestations downstream.

3.2 Reach 2: Angeles Forest Highway to Acton

Characteristics

Reach 2 begins where Angeles Forest Highway crosses the Santa Clara River at its intersection with BP & L Road and extends eight miles towards the town of Acton. Tributaries draining into the reach include Jones, Acton, and Aliso Canyons. Reach 2 contains substantial acreage of low-level development associated with the town of Acton. Low-density development is present throughout the reach, although it is primarily concentrated around the town of Acton and toward the western end of the reach. This development includes residential housing, ranches, campgrounds, recreation fields, and recreational vehicle parks. The channel within Reach 2 is an open, often shallow, low-gradient wash. The 500-year floodplain is relatively wide near the reach's western boundary, varying between 350 feet in width near its eastern extent and 2,250 feet near Acton.

Vegetation in this reach gradually shifts from dense brush to sparse scrub, with pinyon-juniper woodland in the east transitioning into high desert scrub in the west. Sensitive species in Reach 2 include the coast horned lizard and Mason's neststraw (CNPS List 1B), both known to occur within the 500-year floodplain of the reach (CDFG 2004). As with Reach 1, the lack of reported sensitive species may be due the lack of area surveys.

Target Species

No arundo infestation has been reported within the 500-year floodplain of Reach 2. However, tamarisk occurs in a few small stands at low densities within one mile of the western boundary of the reach.

3.2.1 Acton, Jones, and Kashmere Canyon Tributaries

Characteristics

The Jones Canyon tributaries are located north of the mainstem and connect with the Santa Clara River in Acton. These tributaries include Acton, Jones, and Kashmere Canyons. These canyons consist primarily of private land and scattered rural residences are located in the upper sections of these canyons. These tributaries tend to be arid washes with little or no surface flow of water except under high rain conditions. All three are dominated by desert vegetation and scrub. Sightings of coast horned

lizard have been recorded in these tributaries.

Target Species

Neither tamarisk nor arundo have been recorded in these tributaries. However, the tributaries are susceptible to infestation from ornamental landscaping by proximate private landowners. Therefore, residents in the area should be educated about arundo and tamarisk and the area should be monitored for possible future infestations.

3.2.2 Aliso Canyon Tributary

Characteristics

Aliso Canyon is located south of the mainstem in Reach 2. Aliso Canyon is also an arid wash, except in high rain conditions. Scattered rural residences and areas of agricultural production exist along portions of the canyon. Similar to the Jones Canyon tributaries, Aliso Canyon is characterized by desert vegetation and scrub and coast horned lizards have been sighted.

Target Species

Neither tamarisk nor arundo have been recorded in these tributaries. However, they are also susceptible to infestation from ornamental landscaping by proximate private landowners. Therefore, residents in the area should be educated about arundo and tamarisk and the area should be monitored for possible future infestations.

3.3 Reach 3: Acton to Spring Canyon

Characteristics

Reach 3 is the longest reach in the project area and extends for 11.4 miles from Acton to Spring Canyon. The only major tributary draining into Reach 3 is Agua Dulce Canyon, entering the mainstem from the north about two miles east of Spring Canyon. Development within the floodplain totals approximately 141 acres, including rural-residential housing, recreational vehicle parks, and campgrounds. Reach 3 traverses deep, narrow Soledad Canyon for nearly its entire length. The river channel is correspondingly narrow, with the 500-year floodplain generally limited to 200 and 500 feet in width. The stream channel is broad and often dry at its eastern border, transitioning into a steep narrow canyon for virtually its entire 11-mile extent. The majority of Reach 3 is bounded by natural banks that rise sharply from the channel, with minor areas of concrete hard bank protection.

This reach provides large areas of relatively high quality native riparian habitat Cottonwood woodland dominates this reach, occupying 329 acres of the floodplain, with 119 acres of open unvegetated channel breaking up these expanses of woodlands. These woodlands and associated habitats, such as the mixed willow and big sage, provide several uninterrupted one to two mile stretches of high value native habitat, particularly in the central portions of this reach. This area supports known resident populations of the federal and state endangered arroyo toad, unarmored threespine stickleback, and slender-horned spineflower. Potential suitable breeding habitat for the federal and state endangered least Bells' vireo and southwestern willow flycatcher also exist.

Target Species

There are only a few minor stands of arundo or tamarisk in the eastern five miles of Reach 3. Dense arundo stands occupy a total of 111 acres along this reach. With dense stands occurring approximately one mile both upstream and downstream of the confluence with Agua Dulce Creek. Tamarisk infestation occurs at low-to-moderate densities with approximately 30 acres of the reach's total area. Tamarisk is located in the same general areas of dense arundo stands, including upstream from Indian Springs Road, one mile upstream and downstream of the Agua Dulce tributary intersection, and near Capra Road.

3.3.1 Agua Dulce Canyon

Characteristics

Agua Dulce Canyon is a narrow canyon on the north side of the mainstem with headwaters near Vasquez Rocks County Park. It passes through steep rock walls and intersects with the mainstem in Reach 3 approximately four miles downstream from the headwaters. Near the headwaters, the stream channel is wash-like and has only seasonal surface flow. This section of the

canyon is used for rural residences and small ranches. As the canyon approaches the mainstem, it narrows and becomes steeper, especially downstream near the canyon's intersection with the mainstem. The only development in the base of the canyon is Agua Dulce Road.

The vegetation in Agua Dulce Canyon is dominated by mixed riparian vegetation and some desert species. There is no single dominant plant assemblage within Agua Dulce Canyon. Small cottonwood stands occur throughout the creek, as well as other riparian tree species. Sparse mule fat and other riparian scrub species occur within the creek, as well as scattered desert species such as juniper. Sensitive wildlife species that may be present in the canyon include the arroyo toad, coast horned lizard, and unarmored threespine stickleback.

Target Species

Arundo occurs in scattered, but dense stands along the streambed and on the banks of Agua Dulce Canyon. Due to the narrow nature of this tributary, many of the stands are smaller in size (approximately 5 meters in diameter), except for elbows in the tributary where some larger stands exist. Tamarisk occurs primarily in one stand mid-way to the headwaters off Agua Dulce Road, but additional stands may exist. Surrounding ranches provide sources of arundo and tamarisk.

3.4 Reach 4: Spring Canyon to Sand Canyon

Characteristics

Reach 4 extends 3.9 miles from Spring Canyon to Sand Canyon through the eastern extent of the City of Santa Clarita. The communities of Pine Tree and Canyon Country lie north of the Santa Clara River in this reach, while the communities of Lang and Sulfur Springs extend south from the Santa Clara River. Reach 4 is composed mainly of residential and mining development (91 acres) among sparsely scattered great basin and riparian vegetation. The 500-year floodplain through Reach 4 varies in width from 1,500 feet at its eastern border to 350 feet near Shadow Pines Boulevard and widening to 1,800 feet near Sand Canyon Road. Sand mining in the area near Spring Canyon has lowered the channel approximately 40 feet from its historic elevation.

Reach 4 is dominated by open channel, particularly in its central sections. Great basin and coastal scrub communities total 131 acres of the floodplain along this reach. At the reach's east end, stands of cottonwood woodland are intermixed with the scrub habitats. Sensitive species reported from Reach 4 are limited to coast horned lizard (state species of concern) from the northern margin of the east end of the reach. The two-striped garter snake (state species of concern) has been observed to the south and may occur when water is present in the floodplain area (CDFG 2004). The endangered slender-horned spineflower may also grow along the stream bank in the upstream portions of Reach 4, but its presence has not been confirmed (AMEC 2004).

Target Species

Arundo infestations range from low-to-high density throughout the 500-year floodplain, occupying approximately 71 acres. There are two extensive arundo stands located at the reach's east end, near the private River's End Campground (located in Reach 3). A one-mile section starts at the vicinity of Lang Station Road. Tamarisk is present on 21 acres of the floodplain in generally medium-to-low densities. With the exception of a small patch at the western end of Reach 4, tamarisk concentration within the 500-year floodplain is limited to the area between Lang Station Road and Poppy Meadows Street.

3.4.1 Oak Spring Tributary

Characteristics

Oak Spring Canyon feeds into the western extent of Reach 4. The golf course at the mouth of Oak Spring Canyon has contoured the channel throughout the golf course. Sensitive species reported in these tributaries include the two-striped garter snake.

Target Species

Neither tamarisk nor arundo have been recorded in these tributaries. However, they are also susceptible to infestation from ornamental landscaping by proximate private landowners. Therefore, residents in the area should be educated about arundo and tamarisk and the area should be monitored for possible future infesta-

tions.

3.5 Reach 5: Sand Canyon to Bouquet Canyon

Characteristics

Reach 5 extends 7.9 miles from Sand Canyon Road downstream to Bouquet Canyon Road. The majority of this reach falls within the City of Santa Clarita. Major tributaries to Reach 5 include those from Sand Canyon joining the mainstem from the south at the junction between Reaches 4 and 5, and Mint Canyon flowing into the Santa Clara River from the north approximately two miles downstream from this junction. Approximately 360 acres of the 500-year floodplain is developed along Reach 5, which is mostly within the City of Santa Clarita. The 500-year floodplain in Reach 5 varies in width from 500 feet by the Sierra Highway bridge to nearly 2,500 feet in the developed area off Oak Avenue.

Open channel dominates this reach, occupying 404 acres of the floodplain, with great basin plant communities concentrated along the east and west ends of the reach. The channel is heavily braided. Native vegetation communities are dominated by scalebroom and big sagebrush. Although there are scattered groves of cottonwoods and willows along the channel margins in the western portion of this reach, the riparian vegetation consists primarily of mule fat. This reach has limited native vegetation and only sparse data on sensitive species are available. However, the western spadefoot toad (state species of concern), arroyo chub (state species of concern), and the endangered unarmored threespine stickleback, federal threatened California red-legged frog have reported observations in Reach 5. Others that may be present are the coast horned lizard (state species of concern) and western whiptail (state candidate). Similarly, sensitive plant species have not been observed, but the floodplain in Reach 5 has the potential to support the endangered slender-horned spineflower and federally threatened spreading navarretia.

Target Species

Arundo and tamarisk occupy 302 acres together in low-to-moderate densities throughout this reach. Arundo is established on approximately 203 acres. Large stands of low-density arundo extend downstream for approximately 3.5 miles from the eastern boundary of Reach 4. Within the mainstem, one source of arundo is one mile west of the conservation camp near the stream channel. The Angeles National Forest cleared one-mile of the channel in 1995 downstream of the conservation camp. A large, high-density stand of arundo is also located downstream from where the Los Angeles aqueduct crosses the river. Additional large areas of low- and medium-density infestations are heavily intermixed with high-quality habitat at the western boundary. Tamarisk occupies approximately 99 acres. Dense stands occur one mile east of Bouquet Canyon Road, and are scattered throughout the eastern portion of the reach. Other invasive plant species identified in Reach 5 included tree tobacco, black locust, and pepper tree.

3.5.1 Sand Canyon Tributaries

Characteristics

The Sand Canyon tributaries are located on the south side of the mainstem and include Sand Canyon and Iron Canyon. Sand Canyon joins the mainstem at the intersection between Reaches 4 and 5. Iron Canyon joins Sand Canyon approximately two miles upstream from the mainstem. Channels of Sand Canyon tributaries tend to be narrow with seasonal surface water flows. Rural residences surround the majority of the Sand Canyon tributaries, many of which are sited in the 500-year floodplain. The headwaters of these tributaries are generally surrounded by protected open space. The Sand Canyon tributaries support scattered mule fat within the channel and live oaks near the stream banks. This stream channel supports only seasonal surface flow. Sensitive species reported in these tributaries include the western spadefoot toad reported in Sand Canyon.

Target Species

Arundo and tamarisk have not yet been identified in any of these tributaries; however, introductions may occur due to landscaping of rural residences.

3.5.2 Mint Canyon Tributaries

Characteristics

The Mint Canyon tributaries are located on the north

side of the Santa Clara River and join the mainstem about two miles downstream from the Reach 4 boundary. These tributaries include Mint and Rowher Canyons. The 500-year floodplain in Mint Canyon varies between 300 and 1,000 feet wide at its mouth. The streambed is narrow and channelized for 3.5 miles upstream from the mainstem. Surface water is seasonal within Mint Canyon.

Scattered mule fat and great basin scrub communities dominate the stream channel. In some areas, robust cottonwood-willow groves are also present. Southern sycamore-alder riparian forest is also found in a minor tributary near the headwaters of Mint Canyon. Slender-horned spineflower and slender mariposa lily have been reported within Mint Canyon. These occurrences were in the 3.5-mile stretch extending downstream from the intersection of Sand Canyon Road to the mainstem, and species may have since been extirpated by recent development.

Target Species

Tamarisk is present in moderate levels and arundo is present at low to moderate levels within and adjacent to the stream channel throughout Mint Canyon. Much of these infestations are associated with residences using arundo and tamarisk as landscaping plants, which now grow wild in stands. Pepper trees are also present within the stream corridor and are beginning to establish within Mint Canyon.

3.6 Reach 6: Bouquet Canyon to Ventura County Line

Characteristics

Reach 6 begins in Santa Clarita where Bouquet Canyon drains into the mainstem and stretches west 11 miles to the Ventura County line. Six main tributaries drain into Reach 6: Bouquet Canyon, South Fork, San Francisquito Canyon, Castaic Creek, Hasley Canyon, and Chiquito Canyon. Interstate 5 (I-5) divides Reach 6 into two characteristically distinct sections at the western border of Santa Clarita. The land surrounding this reach east of I-5 within Santa Clarita is heavily developed with residential, commercial, and industrial land uses. A public recreational path borders Reach 6 for its entire length between Bouquet Canyon Road and the South River Village Apartment Complex. The width of the 500-year floodplain on this part of the reach ranges between 700 to 1,000 feet. West of I-5, with the exception of the Six Flags Magic Mountain Theme Park (located adjacent to the Santa Clara River just west of I-5), the Santa Clara River is bordered by agricultural and other undeveloped open land. The majority of the land here is under the ownership of the Lennar-LNR. From I-5 to the Ventura County line, Reach 6 traverses a broad open valley, with a 500-year floodplain of ranging between 1,800 and 3,000 feet in width.

Water flow within Reach 6 is braided and subsidized year-round by effluent from two wastewater treatment plants: the Saugus Wastewater Treatment Plant and the Valencia Water Reclamation Plant. Over 600 acres of Reach 6 is currently open un-vegetated channel. The perennial water flows, cottonwood woodlands, and associated habitats such as mixed willow, mule fat, and big sage provide high quality habitat for several sensitive species. In particular, this reach includes the only known occurrences along the mainstem of the Santa Clara River for breeding of endangered least Bells' vireo. Further, these riparian habitats provide extensive suitable breeding habitat for the endangered southwestern willow flycatcher. This reach also supports known populations of the endangered arroyo toad and unarmored threespine stickleback. Declining sensitive aquatic species such as the western pond turtle (state species of concern) and the two-striped garter snake (state species of concern) are also present.

Target Species

The environmentally sensitive habitats along Reach 6 are also the section of the upper Santa Clara River watershed most heavily infested with arundo. Tamarisk is present to a lesser extent. Large areas of arundo and tamarisk occur at a low density infestation range of about 355 acres. An additional 176 acres of arundo occurs at densities of high density infestation range.

3.6.1 Bouquet Canyon Tributaries

Characteristics

The Bouquet Canyon tributaries are located on the north side of the mainstem and include Bouquet

Canyon, Dry Canyon, Haskell Canyon, Texas Canyon, Vasquez Canyon, and Plum Canyon. Land use surrounding Bouquet Canyon transitions from a highly urbanized area near the confluence to residential and rural residential upstream, before Bouquet Canyon enters Angeles National Forest. Land currently developed is used for campgrounds or rural residences. The length of the tributary that flows from the intersection of Plum Canyon and Bouquet Canyon through Santa Clarita to the mainstem is channelized. Above Plum Canyon, Bouquet Creek is often confined to a narrow natural channel. Scattered groves of cottonwood, oaks, and willows intermixed with mule fat are located throughout this section of the reach. Upstream, past the USFS boundary, cottonwood woodland transitions to dense live oak woodland. Portions of several of Bouquet Canyon's tributaries, notably the lower portions of Plum, Haskell, Vasquez, and Texas Canyons, contain 500-year floodplains that fall within the project boundary. These canyons vary from broad floodplain supporting scrub habitats with scattered cottonwoods to areas with higher quality riparian habitats. Some areas have been subject to extensive development and the streams are largely channelized.

Target Species

Bouquet Canyon exhibits heavy arundo infestation throughout the lower reaches of the canyon, and lacks public access to the tributary in some of the most heavily infested areas. Once beyond the channelized portion of the tributary, Bouquet Canyon is heavily infested with arundo. Arundo is also present north of the Angeles National Forest boundary. These infestations are smaller and are closely associated with private properties. No tamarisk was observed within Bouquet Canyon. Scattered stands of eucalyptus, pine trees, and pampas grass are located throughout Bouquet Canyon.

3.6.2 South Fork Tributaries

Characteristics

The South Fork of the Santa Clara River is a system of major tributaries, passing through the City of Santa Clarita. Tributaries include South Fork, Pico Canyon, Newhall Creek, and Placerita Creek. These tributaries are mostly contained within the limits of urban development. With the exception of Placerita Creek, the streams are channelized throughout much of South Fork system. The waterways therefore tend to be fairly degraded, with little or no vegetation growing within most of the channels. However, the four mile section of the South Fork tributary just prior to where it enters the mainstem is wider and contains more native vegetation, including scattered great basin scrub and mule fat. The channel has seasonal flow, which may be supplemented by urban runoff.

Target Species

Arundo is present in Placerita Creek, near its intersection with South Fork. Due to the channelization of the remaining waterways, there is little potential for invasive species to establish.

3.6.3 San Francisquito Canyon

Characteristics

San Francisquito Canyon is a large tributary of the Santa Clara River, stretching nearly 22 miles from headwaters on the northeastern boundary of the watershed to the mainstem. It enters the mainstem from the north in Santa Clarita near McBean Parkway. Much of the northern portion of the canyon is located within Angeles National Forest. As with Bouquet Canyon, land use surrounding San Francisquito Creek transitions from highly urban at the confluence to rural residential in the middle reaches and protected open space in the upstream half of the canyon. The 500-year floodplain of the San Francisquito Canyon ranges between 700 and 1,200 feet in the lower portion of the canyon. Most of San Francisquito Canyon has a wide, shallow stream channel with low velocity water flow, although some upstream sections are narrow and undeveloped, particularly near the headwaters in Angeles National Forest. San Francisquito Canyon provides large areas of relatively high value natural habitat, including sage scrub, cottonwood forest, mixed willow forest, sycamore and alder forest, coast live oak woodland.

Target Species

Arundo occurs at moderate to high densities throughout San Francisquito Canyon and presents a

threat to both resources in this tributary and the Santa Clara River's mainstem. Moderate density arundo infestations exist at and downstream of the Los Angeles County Fire Station. Small infestations were observed as high in the watershed as Bee Canyon. No infestations were observed beyond Bee Canyon. No tamarisk was identified within San Francisquito Canyon.

San Francisquito Canyon has had continuing efforts for arundo removal since 1995, which were initiated by the Angeles National Forest Service. The program was expanded in 1999 to include the LADWP property. During 2000 and 2001, the lowest 2.5 miles of San Francisquito were treated for mitigation as a result of a bridge construction and bank stabilization project. Other areas on San Francisquito have been treated by commercial property companies as mitigation for development impacts.

3.6.4 Castaic Creek Tributaries

Characteristics

The Castaic Creek tributaries are located on the northern side of the mainstem. Castaic Creek tends to be low velocity. Water flow may be subsurface throughout much of the year. The streambed is wide at the mouth of the creek, and is constrained by a barrier fence and agricultural lands on either side. Most of the adjacent land in this area is agricultural with a small amount of recreational open space. Water availability in the downstream section of the Castaic Creek is regulated by dam releases from Castaic Lake. Castaic Lake creates an artificial disjunct in the streambed geomorphology, which is broad with low velocity flow downstream and narrow and deeply incised upstream. Most of the land upstream of Castaic Lake is protected USFS land and is outside of the project area.

Target Species

Tamarisk and arundo are present in the area of Castaic Creek near where Commerce Center Drive meets Highway 126 and upstream of Castaic Lake on USFS property.

3.6.5 Hasley Canyon Tributary

Characteristics

Hasley Canyon is a small tributary that drains north from Castaic Creek. In general, the channel tends to have little vegetation, but contains some intermittent coastal scrub and live oaks. The channel has been contoured and directed by residents within much of the canyon. A large construction effort has widened the stream channel near the intersection of Hasley Canyon Road and Commerce Center Drive. Rural residential land surrounds most of Hasley Canyon, although the mouth of the tributary does pass through an unincorporated urbanized area.

Target Species

No arundo or tamarisk was identified within Hasley Canyon. The majority of other invasive species in the canyon persist as an artifact of private landscaping. Eucalyptus and pepper trees have sprouted outside private yard areas and are colonizing the canyon in areas. Sensitive species, which have been reported in Hasley Canyon, include the San Fernando Valley spineflower, the Los Angeles sunflower, and the Santa Ana sucker.

3.6.6 Chiquito Canyon Tributaries

Characteristics

The Chiquito Canyon tributaries consist of Chiquito Canyon and San Martinez Grande Canyon. In general, these tributaries are heavily affected by surrounding rural residences, with many landscaping plants encroaching on the stream channel. The stream channels tend to be narrow, and are sometimes paved-over at road crossings and other areas to avoid erosion. In general, there is little water, except for that introduced via runoff and over watering. However, higher amounts of water are present after heavy rain events. Rural residential areas and open space surround the Chiquito Canyon tributaries.

Great basin sagebrush and limited cottonwoods are present within the stream channel although in most areas the stream channel has no vegetation. Disturbed oak savanna, which appears to have been grazed historically, is present along downstream portions of the tributaries. The headwaters are dominated by high-quality coastal sage scrub. The San Fernando Valley spineflower is the only sensitive species known to be present in these

tributaries.

Target Species

There is little to no arundo within the Chiquito Canyon tributaries. Tamarisk is present at moderate densities within the Chiquito Canyon tributaries as individual plants have escaped residential cultivation and have become established along the stream bank. San Martinez Grande Canyon tends to have more tamarisk than Chiquito Canyon. Landscaping plants and non-native grass are the primary invasive species within the Chiquito Canyon tributaries. Liquid amber trees and pepper trees are also present within and along the stream channel.

4.0 Biological Resources

The upper Santa Clara River drains an area that extends from the mountainous areas along the western edge of the Mojave Desert in the east and north of the watershed, west to the inland extent of areas that are typically dominated by coastal habitat associations. The habitats present along the Santa Clara River itself and in the surrounding areas reflect the Santa Clara River's transit of habitats ranging from high desert and montane associations in the inland areas to coastal valley associations near the project area's western boundary. A similar transition from high desert or montane also occurs along many of the Santa Clara River's larger tributaries. Mapping has been completed for the mainstem and tributaries of the upper Santa Clara River watershed (Appendices 6 and 7). A plant and wildlife species list was compiled during these surveys and is included in Appendix 5.

Special status plant and wildlife species are recognized by the California Native Plant Society, CDFG, or USFWS because these species have limited populations. It is important to recognize these species and avoid impacts to them because of various regulatory restrictions as discussed in Chapter 9.

4.1 Special Status Plant Species

A total of 19 special status plant species with the potential to occur within the project area were identified (Table 3). The potential for these species to occur in the study area is based on a review of historical sensitive plant species locations identified in the CNDDB (CDFG 2002).

4.2 Special Status Wildlife Species

A total of 21 special status wildlife species with the potential to occur within the project area were identified (Table 4). The potential for these species to occur in the study area is also based on a review of historical wildlife species locations identified in the CNDDB), and a review of pertinent literature. Of these 21 species, eight are federally listed under the Federal Endangered

Table 3: Special Status Plant Species

Scientific Name	Common Name	Status[1]	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low, and Why)
Allium howellii var. *clokeyi*	Mt. Pinos onion	List 1B	Pinyon and juniper woodlands and Great Basin scrub; 4,265-6,000 feet above msl.	Potential to occur in Reaches 1 and 2 and all tributaries. Known to occur in Castaic Creek tributaries.	Low: The project area elevation is 4,265 feet at its highest point. This plant does not grow in the riparian flood channel where weed removal will occur.
Arenaria macradenia var. *kuschei*	Kusche's sandwort	List 1B	Granitic openings in chaparral; 4,000- 5,700 feet above msl.	Potential to occur in Reaches 1, 2, and 3 and all tributaries.	Low: The elevation for this plant is close to the highest elevation for the project (4,265 feet). This plant does not grow in the riparian flood channel where weed removal will occur.
Berberis nevinii	Nevin's barberry	SE, FE, List 1B	Chaparral, cismontane woodland, coastal scrub, riparian scrub/sandy or gravelly soils; 1,000-2,700 feet above msl.	Potential to occur in Reaches 2 though 6 and all tributaries. Known to occur in San Francisquito Canyon.	High: This plant grows in habitats (e.g., riparian scrubs) that could be impacted during weed removal and in habitats where access roads may need to be built.
Calochortus clavatus var. *gracilis*	Slender mariposa lily	List 1B	Chaparral and coastal sage scrub; 1,100-3,200 feet above msl.	Potential to occur in Reaches 3 though 6 and all tributaries. Known to occur in Mint Canyon Tributaries and in San Francisquito Canyon.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Calochortus plummerae	Plummer's mariposa lily	List 1B	Chaparral, cismontane woodland, coastal scrub, lower montane coniferous forest, valley and foothill grassland in rocky habitats; 330-5,600 feet above msl.	Potential to occur in all reaches and tributaries. Known to occur in Agua Dulce Canyon and in the South Fork Tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Castilleja gleasonii	Mt. Gleason Indian paintbrush	SR, List 1B	Lower montane coniferous forests and pinyon and juniper woodlands; 3,800-7,100 feet above msl.	Potential to occur in Reaches 1, 2, and 3 and all tributaries.	Low: The elevation for this plant is close to the highest elevation for the project (4,265 feet). This plant does not grow in the riparian flood channel where weed removal will occur.
Centromadia parryi var. *australis*	Southern tarplant	List 1B	The margins of marshes and swamps, valley and foothill grasslands, and vernal pools; 0-1,400 feet above msl.	Potential to occur in Reaches 5 and 6 and all tributaries.	High: This plant grows in habitats (e.g., margins of marshes and swamps) that could be impacted during weed removal and where access roads may need to be built.
Chorizanthe parryi var. *fernandina*	San Fernando Valley spineflower	SC, FC, List 1B	Sandy soils in coastal scrub; 500-4,000 feet above msl.	Potential to occur in Reaches 3 though 6 and all tributaries. Known to occur in Reach 6 and in Castaic Creek and Chiquito Canyon Tributaries	Medium: This plant grows in coastal sage and alluvial scrub habitats.

Scientific Name	Common Name	Status[1]	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low, and Why)
Dodecahema leptoceras	Slender-horned spineflower	SE, FE, List 1B	Sandy soils in chaparral, cismontane woodland, and coastal scrub (alluvial fans); 650-2,500 feet above msl.	Potential to occur in Reaches 2 though 6 and all tributaries. Known to occur in Reaches 3 and 5 and in Mint Canyon, South Fork, and Halsey Canyon Tributaries.	High: This plant grows in habitats (e.g., alluvial fans) that could be impacted during weed removal and in habitats where access roads may need to be built.
Erodium macrophyllum	Round-leaved filaree	List 2	Clay soils in cismontane woodland, valley and foothill grassland; 50-4,000 feet above msl.	Potential to occur in all reaches and tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Galium grande	San Gabriel bedstraw	List 1B	Broadleaved upland forest, chaparral, cismontane woodland, lower montane coniferous forest; 1,400-5,000 feet above msl.	Potential to occur in all reaches and tributaries. Known to occur in Castaic Creek Tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Helianthus nuttallii ssp. *parishii*	Los Angeles sunflower	List 1A	Coastal salt and freshwater marshes and swamps; 30-1,600 feet above msl.	Potential to occur in Reaches 3 through 6 and all tributaries. Known to occur in Reach 6.	High: This plant grows in habitats (e.g., marshes and swamps) that could be impacted during weed removal.
Lilium parryi	Lemon lily	List 1B	Mesic areas in lower montane coniferous forest, meadows and seeps, riparian scrub, upper montane coniferous forest; 4,300-8,600 feet above msl.	Potential to occur in Reaches 1 and 2 and all tributaries.	Low: The project area elevation is 4,265 feet at its highest point. This plant does not grow in the riparian flood channel where weed removal will occur.
Malacothamnus davidsonii	Davidson's bush mallow	List 1B	Chaparral, cismontane woodland, coastal scrub, riparian woodland; 600-2,800 feet above msl.	Potential to occur in Reaches 2 though 6 and all tributaries.	High: This plant grows in habitats (e.g., riparian woodland) that could be impacted during weed removal and in habitats where access roads may need to be built.
Navarretia fossalis	Spreading navarretia	FT, List 1B	Chenopod scrub, marshes and swamps (assorted shallow freshwater), playas, vernal pools; 100-4,300 feet above msl.	Potential to occur in all reaches. Known historically in Reach 5 and the Plum Canyon Tributary.	High: This plant grows in habitats (e.g., marshes and swamps) that could be impacted during weed removal and in habitats where access roads may need to be built.
Opuntia basilaris var. *brachyclada*	Short-joint beavertail	List 1B	Chaparral, Joshua tree woodland, Mojavean desert scrub, pinyon and juniper woodlands; 1,400-5,900 feet above msl.	Potential to occur in all reaches and tributaries. Known to occur in Reach 1 and in Bouquet Canyon and South Fork Tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.

Scientific Name	Common Name	Status[1]	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low, and Why)
Orcuttia californica	California Orcutt grass	List 1B	Vernal pools; 50-2,200 feet above msl.	Potential to occur in Reaches 3 though 6 and all tributaries. Known to occur in Bouquet Canyon and in South Fork Tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Senecio aphanactis	Rayless ragwort	List 2	Alkaline areas in chaparral, cismontane woodland, coastal scrub; 50-2,600 feet above msl.	Potential to occur in Reaches 2 though 6 and all tributaries. Known to occur in the South Fork Tributaries.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.
Stylocline masonii	Mason's neststraw	List 1B	Sandy soils in chenopod scrub, pinyon, and juniper woodlands; 330-4,000 feet above msl.	Potential to occur in all reaches and tributaries. Known to occur in Reach 2.	Low: This plant does not grow in the riparian flood channel where weed removal will occur.

[1]FC: federal candidate
FE: federally listed as endangered
FT: federally listed as threatened
SC: state candidate
SR: state listed as rare
ST: state listed as threatened
CNPS List 1A: plant species are presumed extinct in California
CNPS List 1B: plant species are rare, threatened, or endangered in California and elsewhere
CNPS List 2: plants species are rare, threatened, or endangered in California, but more common elsewhere

Table 4: Special Status Wildlife Species

Scientific Name	Common Name	Status	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low) and Why
Mammals					
Neotoma lepida intermedia	San Diego desert woodrat	SC, SSC	Pinyon-Juniper in association with rocky outcrops, including burrows of ground squirrels and woodrats.	Upstream and middle reaches of project area.	Medium potential to occur since it is not a riparian species. Uplands surrounding riparian zone have greater potential for this species.
Perognathus alticola inexpectatus	Tehachapi pocket mouse	SSC	Prefers open, sandy upland habitats, with friable soils.	Potentially found in adjacent upland habitats in all reaches and tributaries.	Low potential since this species is primarily associated with upland habitats.
Taxidea taxus	American badger	SSC	Prefers open, sandy upland habitats.	Potentially found in adjacent upland habitats in all reaches and tributaries.	Medium potential to occur, but seldom seen due to its fossorial ecology. Not usually associated with riparian habitats, but found in adjacent upland habitats.
Birds					
Accipiter cooperii	Cooper's Hawk	SSC	Found in a variety of habitats, including riparian and uplands, as well as urban areas.	Found in all reaches and tributaries.	High potential to occur, for breeding, roosting, and foraging.
Athene cunicularia	Burrowing owl	SC, SSC	Typically found in open scrub habitats in uplands.	Potentially found in high-quality upland habitats in all reaches and tributaries.	Low potential, since this species does not typically inhabit riparian zones.
Coccyzus americanus occidentalis	Western yellow-billed cuckoo	SE	Prefers dense riparian habitats, including willow-cottonwood.	Potentially found in all reaches, although the species is very rare.	Low potential given the scarcity of this species, but it could be found in any reach with an overstory of riparian hardwoods.
Dendroica petechia brewsteri	Yellow warbler	SSC	Prefers willow riparian and associated habitats.	Potentially found throughout all reaches and tributaries.	Medium potential since this species will occur disjunctly throughout appropriate habitats.
Empidonax traillii extimus	Southwestern willow flycatcher	FE, SE	Riparian scrub, willow and mule fat, including arundo stands.	Known in Reaches 3 and 6.	High potential to occur in downstream reaches, below Soledad Canyon where high quality riparian habitat is prevalent.
Pilioptila californica californica	Coastal California gnatcatcher	FT, SSC	Coastal sage scrub	Known in Plum and Placerita Canyons.	Low potential, since this species does not typically inhabit riparian zones.

Scientific Name	Common Name	Status	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low) and Why
Gymnogyps californianus	California condor	FE, SE	Montane and cliff habitats, primarily limited to Sespe Wilderness area and adjacent lands.	Potentially found in all reaches, although the species is very rare.	Low potential to occur since no breeding sites are located within the project area, although this species has large home ranges and could potentially forage within the project area.
Icteria virens	Yellow-breasted chat	SSC	Riparian scrub, willow and mule fat, including arundo stands.	Likely to be found in all reaches with willow riparian habitat	High potential to occur in downstream reaches, below Soledad Canyon where high quality riparian habitat is present.
Toxostoma lecontei	Le Conte's thrasher	SSC	Open desert scrub, primarily found in habitats dominated by common saltbush.	Potentially found in Real 1 and 2.	Medium potential to occur in scrub habitats areas.
Vireo bellii pusillus	Least Bell's vireo	FE, SE	Riparian scrub, willow and mule fat, including arundo stands.	Most likely to be encountered in the downstream reaches, but possibly occurs throughout the Santa Clara River.	High potential to occur in downstream reaches, below Soledad Canyon.
Reptiles					
Aspidoscelis tigris stejnegeri	Coastal western whiptail lizard	SC	Chaparral, riparian scrub.	Can be found in open riparian scrub, but chiefly associated with upland habitats.	High potential to occur in appropriate habitats throughout The Santa Clara River.
Phrynosoma coronatum blainvillei	Coast horned lizard	SC, SSC	Chamise chaparral.	This species is unlikely to occur in riparian habitats in the project area, but can be found in uplands.	High potential to occur in appropriate habitats throughout the Santa Clara River.
Thamnophis hammondii	Two-striped garter snake	SC, SSC	Riparian habitat.	May be found throughout project area.	High potential to occur throughout project area. Forages widely, and usually active during the day on highly vegetated stream banks.
Amphibians					
Bufo californicus	Arroyo toad	FE, SE	Sandy alluvial stream courses and adjacent uplands.	Possible throughout project area. Known in Reaches 3 and 6 and Castaic and San Francisquito Creeks.	Medium potential to occur since the species will be locally abundant in the few areas it is found, and thorough surveys of the entire project area are lacking.
Rana muscosa	Mountain yellow-legged frog	FE	Montane streams at higher elevations.	None	Species does not occur in the project area.

Scientific Name	Common Name	Status	Habitat	Potential to Occur in Each Reach/Tributary	Potential to Occur (High, Medium, Low) and Why
Scaphiopus hammondii	Western spadefoot toad	SC, SSC	Upland and riparian habitat. Breeds in ephemeral pools.	Potential to occur throughout the project area.	High potential to occur, where intact native upland habitat contacts riparian areas.
Rana aurora draytonii	California red-legged frog	FT, SSC	Prefers permanent water with vegetated edges.	Known only from remnant population in San Francisquito Creek, but could occur elsewhere.	High potential in San Francisquito Creek where current population exists, low potential elsewhere.
Fishes					
Catostomus santaanae	Santa Ana sucker	FT	Swift flowing stretches of Santa Clara River.	Primarily in upstream reaches, but can be found elsewhere during high flows.	High potential to occur when water is present, but low detectability in the absence of trapping/netting surveys.
Gasterosteus aculeatus williamsoni	Unarmored threespine stickleback	FE, SE, DFG: Fully Protected	Typically in slow moving water with vegetated edges.	Possible throughout entire project area.	High potential to occur when water is present, but low detectability in the absence of trapping/netting surveys.
Gila orcutti	Arroyo chub	SC, SSC	Prefers slow water with sand or mud bottom.	Possible throughout project area.	High potential to occur when water is present, but low detectability in the absence of trapping/netting surveys.

FE: federally listed as endangered
FT: federally listed as threatened
SC: state candidate
SE: state listed as endangered
SSC: state species of special concern
ST: state listed as threatened
DFG Fully Protected: The Fish and Game Codes sections dealing with Fully Protected species state that these species "...may not be taken or possessed at any time and no provision of this code or any other law shall be construed to authorize the issuance of permits or licenses to take any fully protected" species, although take may be authorized for necessary scientific research. This language arguably makes the "Fully Protected" designation the strongest and most restrictive regarding the "take" of these species. In 2003, the code sections dealing with fully protected species were amended to allow the Department to authorize take resulting from recovery activities for state listed species. More information on Fully Protected species and the take provisions can be found in the Fish and Game Code (birds at §3511, mammals at §4700, reptiles and amphibians at §5050, and fish at §5515). Additional information on Fully Protected fish can be found in the California Code of Regulations, Title 14, Division 1, Subdivision 1, Chapter 2, Article 4, §5.93. The category of Protected Amphibians and Reptiles in Title 14 has been repeated. The Fish and Game Code is available online at: http://www.leginfo.ca.gov/cgibin/calawquery?codesection=fgc. Title 14 of the California Code of Regulations is available at http://ccr.oal.ca.gov

Species Act (FESA).

5.0 Project Planning

Coordinated removal projects can lead to control of an invasive plant species in the entire watershed. However, before implementing a removal project, it is important to consider the various project elements, which include:

- integrated weed management
- project prioritization
- working with landowners
- public outreach
- surveys and mapping
- methods
- regulatory requirements
- scheduling
- costs
- funding

5.1 Integrated Weed Management

Integrated Weed Management (IWM) is a comprehensive strategy for the control of weeds. It considers each of the various factors influencing a weed removal strategy, such as different removal methods, the timing of the project, the location of the project, and potential impacts to the environment. There are also other factors such as overall project goals, specific agency policies, and local politics. The federal Noxious Weed Act further narrows the concept of Integrated Weed Management. It defines IWM as "a system for the planning and implementation of a program, using an interdisciplinary approach, to select a method for containing or controlling undesirable plant species or groups of species using all available methods, including education, prevention, physical or mechanical methods, and general land management practices."

Integrated Weed Management is vital for the control and potential eradication of invasive plant species. Removal projects often achieve the most success when a variety of strategies are implemented. For example, it may be effective to implement herbivory as a control measure in one section of a removal project area, while other sections undergo eradication measures. Active surveying can assist with controlling outlier populations of invasive plants that have not established yet. Strategies to prevent the spread of invasive species are also part of IWM. This can be approached from a cultural aspect as educating the public about the threat invasive species pose to the environment may help to avoid the use of these species in residential landscaping.

With IWM practices in place, it is also important to minimize the project impacts. Individual projects will utilize Best Management Practices to reduce impacts to the environment, ensure public health and safety, and increase worker safety. These BMPs are listed in Chapter 14. BMPs can be adapted and modified for each individual project depending upon the removal techniques and sensitive habitat and species present.

The Best Available Technologies are used in addition to the BMPs to achieve successful management strategies. The Best Available Technologies will change over time, as research, technologies, and methods are updated. Geographic Information Systems (GIS) and Global Positioning System units (GPS) assist with surveying and mapping while new methods and equipment can increase removal efficiency. The SCARP is a living document and will be revised as necessary to incorporate the Best Available Technologies.

5.2 Prioritization

Individual projects can be conducted anywhere in the upper Santa Clara River watershed. However, since arundo and tamarisk tend to spread downstream, it is best to begin projects at the headwaters of the mainstem of the Santa Clara River and smaller tributary watersheds such as San Francisquito Canyon to ensure effective invasive plant removal. Ideally, the collective effect of the individual projects will eventually be to control invasive plant populations in the watershed.

There are other factors that influence the project site beyond its location in the watershed. These include landowner cooperation, budget, scheduling, regulatory requirements, and many others. Prioritization of projects beyond starting at the highest known establishment should be oriented toward: 1) early detection and control of outlier establishments, 2) control and restoration of limited infestations where sensitive resources are located, and 3) control and restoration of large infesta-

tions.

Early detection and control of outlier establishments

This strategy concentrates on areas where arundo or tamarisk have small, limited infestations and do not have any upstream source populations. This strategy may be more time and labor intensive due to potentially difficult logistical issues such as hard to reach locations and/or careful hand-removal techniques of arundo or tamarisk to avoid impacts to wildlife. However, this strategy prevents dense establishment of invasive plant species where there is moderate to good habitat.

Control and restoration of limited infestations where sensitive resources are located

This strategy concentrates on areas where arundo or tamarisk have limited infestations and where sensitive resources are located. This strategy may be more time and labor intensive due to careful implementation of hand-removal techniques of arundo or tamarisk to avoid impacts to wildlife. However, this strategy also prevents dense establishment of invasive plant species where there is moderate to good habitat.

Control and restoration of large infestations

This strategy concentrates on areas where arundo or tamarisk are dense monocultures in order to completely eradicate their presence and to restore habitat. It may be easier and/or more cost-efficient to use mechanical removal techniques or broadcast foliar spraying in areas with thick infestations. This strategy allows the restoration of large areas, which previously had no habitat value.

6.0 Surveying and Mapping

Project applicants should develop detailed maps for their specific project areas. Maps are integral to effective eradication of establishments of invasive plant colonies. They are important for documenting the current vegetation status, detecting and tracking pioneer colonies of invasive plant clusters, and monitoring the level of success after invasive plant removal.

Effective mapping is a result of organized and consistent data collection. In planning an invasive species removal project, applicants should follow an established protocol for their data collection efforts. Data collection can be accomplished using field forms, aerial maps, photo documentation, and/or GPS units. Utilization of established protocols for data collection also facilitates the sharing of weed information with other agencies that have a stake in controlling and eradicating invasive plant species.

There are numerous mapping techniques with different protocols and different nomenclature (naming) systems. Maps can be prepared manually via the annotation of aerial photographs, or via various GIS software packages in tandem with GPS hand-held units for data capture. Maps may simply reflect the extent of infestations, or may also contain additional attribute information that further characterizes the infestation. Resources for current mapping protocols include the CDFA weed mapping handbook and The Nature Conservancy's Weed Inventory and Mapping System (WIMS), which is currently being adapted by Cal-IPC for California's wildland weeds. CDFG promotes vegetation mapping according to A Manual of California Vegetation (Sawyer and Keeler-Wolf 1995).

AMEC Earth and Environmental performed mainstem vegetation surveys and a preliminary tributary overview in Winter 2004-2005, which are both discussed within the text of this document. Condor Environmental performed tributary vegetation surverys in Fall 2005. Detailed maps are provided as individual files in the Appendices.

The vegetation mapping surveys undertaken by the VCRCD for the Upper Santa Clara River identified 43 vegetation series located within the 500-year floodplain of the mainstem. Vegetation falling outside of the 500-year floodplain was not mapped. Most of the mapped vegetation series were delineated on maps created from aerial photographs following the vegetation series listed in A Manual of California Vegetation (Sawyer and Keeler-Wolf 1995). However, several of the vegetation series incorporated in the SCARP were not derived from the preceding document, but were rather based on the dominant and associated plant species present (e.g., Pepper Tree).

The VCRCD has a long-term interest in the removal of invasive species from the Upper Santa Clara River watershed. As such, the VCRCD recommends that applicants follow an established protocol of data collection so that consistency of data can be achieved, and for ease of future monitoring efforts. Project applicants are encouraged to use the existing VCRCD maps not only for refer-

ence, but also as models for their own map products.

7.0 Working With Landowners

The majority of the mainstem of the upper Santa Clara River as well as the lower middle reaches of the tributaries are privately owned. A cooperative working relationship with private landowners is critical in order to address the areas of heavy infestations. Several large landowners such as Lennar-LNR and various sand and gravel mining companies own substantial portions of the Santa Clara River. Hundreds of small- and mid-sized parcels are also located throughout the Santa Clara River's middle and upper reaches as well as the lower tributaries. These parcels include private campgrounds, mobile home parks, small ranches, and residential estates. The cooperation of both large and small landowners is essential for successful eradication. Landowners may not be aware of the impacts caused by invasive plants to public safety, property, and the environment. Education and outreach will increase knowledge of these impacts.

Landowners can work with Non-Governmental Organizations (NGOs), Resource Conservation Districts (RCDs), or other groups to perform removal work on their property. Agencies such as RCDs can assist with the regulatory process as well. Project applicants that do not own the property they wish to work on should request a cooperative landowner agreement prior to starting a project.

8.0 Public Outreach

Members of the public are often not aware of the negative impacts that invasive species bring to an ecosystem. The public typically assumes that the presence of any variety of greenery in the environment is beneficial and associates scenic value to it. Therefore, increasing public awareness of the impacts from these invasive species and support for their eradication is a critical component of project success. Public outreach activities should focus on a particular audience and have a specific goal, and individual projects should focus on outreach efforts prior to initiating removal. For example, local residents who live adjacent to removal sites should be notified of project activities, removal techniques, and potential impacts such as noise or visual changes before the commencement of the project.

Various organizations and municipalities are already engaged in outreach activities supporting the removal of invasive plants as well as the preventative measures that help reduce the spread of these plants. CAL-IPC is a non-profit organization that works with the California Department of Food and Agriculture's (CDFA) Weed Management Areas (WMA) and other local agencies to educate the public and municipalities on invasive plants and their eradication. Additionally, the Los Angeles Weed Management Area has created a Best Management Practices for Vegetation Removal as well as a children's booklet on invasive plants. There are numerous brochures from the various agencies on how to prevent the spread removal invasive plants. See Chapter 19.0 for resource information.

Where arundo is targeted for removal from private parcels, personal contact with parcel owners must be made to in order to gain access to removal sites. Landowners are often concerned about the impacts the removal activities will cause, and care should be taken to acknowledge and address their concerns. While one-on-one meetings may be time consuming, they are a beneficial investment towards a successful removal program. Typical landowner concerns include issues relating to privacy, liability, property damage, impacts to natural resources, erosion, and regulatory problems.

When removal projects are planned for sites that

are adjacent to developed areas, especially residential zones, it is important to notify or otherwise communicate with residents about the removal activities. Tolerance and support of residents for removal projects is enhanced via outreach and education efforts. This can be achieved via an informational postcard mailing, or by distributing brochures or handouts on a door-to-door basis.

The success of outreach efforts can be enhanced by incorporating the following points:

- Understand Your Audience: Do not assume individuals are versed in issues pertaining to invasive plant species. Present the information in a manner that is informative and engaging. Photographs and other visual cues are often very helpful in illustrating important points.
- Keep It Basic: Focus on primary issues. Over whelming your audience with information may not necessarily inspire them to join your cause. However, casting illumination on the most important issues will initiate a constructive increase in awareness of the problem.
- Be Context Aware: If members of the public initiate casual dialogue about a removal project with you, a casual response will be more appropriate than a technical monologue.
- Signage: Post signs where removal work is already underway. Incorporate photos that illustrate "before" and "after" scenarios to reinforce the benefits of the project.

For its own arundo removal efforts, the VCRCD has initiated several public outreach activities; selected examples are listed below:

- Prepared and distributed brochures containing information about arundo and tamarisk and the problems they cause, as well as the benefits of removal.
- Held public workshops such as those associated with the EIR/EA scoping in January 2005, as well as more recent workshops in Santa Clarita and Acton about the infestation problem in general.
- Created the SCARP Working Group to facilitate community and agency coordination on this issue.
- Contacted local schools to educate students about invasive plants and Weed Awareness Week.
- Sent out postcards to local residents around the Santa Clarita project site to inform them about the various aspects of the individual project.
- Held two public hearings inviting comments regarding the EIR/EA.
- Participated in the Santa Clara River Rally, a river clean-up event organized by the City of Santa Clarita.

Another important aspect of public outreach is the utilization of local resources. Various organizations and municipalities already support the removal of invasive plant species, and many have implemented preventative measures to reduce the spread of these species. The events they organize help raise public awareness about specific environmental hazards and the measures being taken to remove them. The VCRCD has participated in many such events in an effort to bring additional attention to the Upper Santa Clara River project . The various agencies and/or events that address invasive species are listed below:

- City of Santa Clarita sponsored events such the Santa Clara River Rally, Arbor Day, and Earth Day
- Los Angeles County sponsored events such as the County Fair and Earth Day
- Los Angeles County Weed Management Area Meeting
- Southern California Wetlands Recovery Project (SCWRP) Task Force Meetings
- Santa Clarita Organization Planning for the Environment (SCOPE)
- Friends of the Santa Clara River
- The Nature Conservancy
- Sierra Club
- California Native Plant Society
- Audubon Society
- Santa Clarita Well Owners Society
- Local Schools

9.0 REGULATORY SETTING

A primary goal of the SCARP is to facilitate the permitting of arundo and tamarisk removal projects by state and federal regulatory agencies, consistent with protection of sensitive resources. VCRCD is coordinating with regulatory agencies to develop a programmatic regulatory framework for future removal projects. As this process may take several years, individual permits may be necessary for removal projects. The following discussion provides an overview of the primary existing regulatory structure covering removal projects. Table 5 provides guidance for individual project applicants for regulatory compliance on their projects.

9.1 U.S. Army Corps of Engineers

Under Section 404 of the Clean Water Act (CWA), a permit is required by USACE for any activity that results in discharge of dredged or fill material into "waters of the United States (U.S.)" and associated wetlands. Waters of the U.S. refers to water in drainages that occurs below the plane of the ordinary high water mark. Examples of dredged or fill material for the SCARP projects that would be subject to USACE regulation would include earthmoving associated with temporary water diversions, temporary access roads, and below-ground biomass removal. Different permitting options are available through the USACE. For example, Regional General Permit (RGP) 41 is an existing permit for no or minimal impact invasive plant removal projects for infestations greater than 50 percent cover. Project sites with infestations lower than 50 percent or which have more than minimal impacts require another type of 404 permit such as a nationwide or individual permit.

9.2 U.S. Fish and Wildlife Service

Species listed as endangered or threatened by the USFWS are protected under the Federal Endangered Species Act (FESA). If listed species could be affected by removal activities, consultation with the USFWS is required. Consultations result in a set of formalized protection measures that become a part of the project.

9.3 California Department of Fish and Game

Streambed Alteration Agreement

Pursuant to Section 1602 2 of the Fish and Game Code, the CDFG has jurisdiction over activities that affect the "bed, channel, or bank of any river, stream, or lake that has or benefits fish or wildlife". CDFG jurisdiction includes streamside (riparian) habitat on top of banks as well as the drainage itself.

California Endangered Species Act

The California Endangered Species Act (CESA) provides protection to endangered and threatened species in California. If a project may affect state-listed species, coordination with CDFG is required. In some cases, an incidental take permit may be required.

9.4 Regional Water Quality Control Board

A project that requires a Section 404 permit from the USACE will also require a Water Quality Certification (401 certification) from the RWQCB. A 401 permit certifies that the proposed activity will not violate state or federal water quality standards.

9.5 Southern California Air Quality Management District

Projects that propose controlled burning or incineration of biomass require consultation of the Southern California Air Quality Management District.

9.6 California Department of Transportation Encroachment Permit

The use of California State highways for other than normal transportation purposes may require written authorization from the Department of Transportation. As the responsible Department for protecting the public's investment in the State highway system, CalTrans reviews all requests from utility companies, developers, volunteers, nonprofit organizations, etc., desiring to conduct various activities within the right of way.

9.7 Los Angeles Department of Public Works Encroachment Permit

Project sites that utilize areas owned by or having easements by the Los Angeles Department of Public Works will require an encroachment permit. Road Construction permits are necessary for the construction of driveways, curb drains, sidewalks, curbs and gutters and other types of surface construction. Road Excavation permits are necessary when digging within the road right-of-way, which often includes the portion of land beyond the curb and all the way to the sidewalk. Road Encroachment permits are necessary when you wish to place anything in the road right-of-way temporarily or long term.

9.8 Los Angeles County Grading Permit

The Los Angeles County Building Code requires a grading permit to perform any grading except for the following work:

An excavation that: 1) is less than 2 feet (61 cm) in depth or; 2) does not create a cut slope greater than 5 feet (1.5 m) in height and steeper than 1 unit vertical in 2 units horizontal (50% slope) and does not exceed 50 cubic yards (38.3 m^3).

A fill not intended to support structures and which does not obstruct a drainage course if such fill (a) is placed on natural grade that has a slope not steeper than five horizontal to one vertical and is less than 1 foot (30.5 cm) deep, or (b) is less than 3 feet (91.4 cm) in depth at its deepest point, measured vertically upward from natural grade to the surface of the fill, and does not exceed 50 cubic yards (38.2 m^3), or (c) does not exceed 20 cubic yards (15.3 m^3) on any one lot.

9.9 California Environment Quality Act

The California Environmental Quality Act (CEQA) is intended to provide information to public agencies, decision-makers, and the public regarding the environmental impacts from implementation of a proposed project. CEQA compliance is required for all local and state public agencies, municipalities, and private entities that undertake an activity, which requires a permit, or discretionary approval from a government agency, or that may cause either a direct physical change in the environment or a reasonably foreseeable indirect change in the environment.

The environmental review process was established to enable public agencies to evaluate a project in terms of its environmental consequences, to examine and implement methods of eliminating or reducing any potentially adverse impacts, and to consider alternatives to the project. While CEQA requires major consideration be given to avoid environmental impacts, the lead agency and other responsible public agencies must balance adverse environmental effects against other public objectives, including social and economic goals, in determining whether and in what manner a project should be approved.

Projects using the methods in this long-term plan may utilize the SCARP programmatic EIR once the programmatic permit structure has been developed. Other projects may require a CEQA exemption, negative declaration, mitigated negative declaration, or environmental impact report.

9.10 National Environmental Protection Act

The National Environmental Protection Act (NEPA) requires federal agencies to consider potential environmental consequence of proposed actions in their decision-making process. The law's intent is to protect, restore, or enhance the environment through well-informed federal decisions. Projects which require a permit or discretionary approval from a federal agency will also require NEPA compliance.

The regulatory process may involve a significant investment of time. Table 5 is provided as a planning aid and offers an example illustration of the amount of time applicants can expect to use for this phase of their projects.

Table 5: Guide to Regulatory Compliance

Timeline	Task
1-2 months	Use SCARP to develop project and choose removal or control method.
1-6 months depending on scope and scale of project, engineered design, and other project elements.	Develop project description, including analysis of impacts, avoidance, and minimization measures.
1- 2 months	Complete and submit application materials for: 404 permit (USACE); 401 certification (RWQCB); 1602 Streambed Alteration Agreement (CDFG)
1-3 months depending on agency availability	Agencies require additional information or modification to application or project description. Coordinate with agencies to modify application or project description as necessary.
1-2 months	Agencies accept revised application or project description.
After receipt of complete application	USACE begins consultation with USFWS
3 months to over a year depending on type of consultation	USFWS issues Letter of Concurrence or Biological Opinion.
Usually within 3 months of completed applications and completed consultation with USFWS	Agencies issue permits.
Upon receipt of all permits	Implement project

10.0 Removal Methodology

A wide range of techniques is currently used in the control and removal of arundo and tamarisk. These include hand removal, mechanical removal, herbicide application, tarping, controlled burning, and biological control, as well as various combinations of these techniques. Based upon a review of available literature and contact with different agencies and specialists, it has been determined no single method has been proven most effective for every situation. Different agencies and organizations involved in control of arundo and tamarisk tend to favor differing approaches to control and removal based on their experience, resources, and local environmental and policy circumstances. This is also reflected in the literature, where different researchers have noted variable findings for the effectiveness of different techniques.

For example, the Santa Margarita and San Luis Rey Watersheds Weed Management Area (SMSLRWMA) rely primarily on a fall-period foliar spray application, followed by spring biomass removal for arundo removal. The SMSLRWMA reports this method as having the highest success rate for their arundo infestation problem (Giessow 2005). In contrast, in its initial focused projects, the VCRCD has used various methods, including foliar spray application or the cut and daub technique accompanied by biomass removal, with chipping and reuse of the arundo mulch outside the stream channel. Other groups, such as Circuit Rider Productions, prefer tarping as a non-herbicidal approach, and have found it highly effective on smaller stands of arundo.

Ultimately, the selection of the appropriate removal method for each project will depend upon:

- the time of year
- severity of infestation
- the presence of native plants and wildlife
- the degree of intermixing of invasive species with sensitive native habitats
- the presence of sensitive native species
- access
- proximity to surface water
- budget
- permitting standards

Regardless of the method chosen, all projects will require follow-up treatments and monitoring, and have the potential to impact sensitive species in certain habitat areas. Due to the range of variables that influence the control and removal of these invasive species, and the differences among opinion on which techniques are the most effective and environmentally appropriate for a given circumstance, the SCARP presents a menu of options for different removal techniques. Each technique is described in terms of typical procedures involved and the general circumstances where it is usually employed including a discussion of the general pros and cons of each approach, which is summarized in Table 6.

The general analysis of the pros and cons of available control options is further refined in terms of their potential utility for application to various reaches of the Santa Clara River and its associated tributaries. For planning purposes, the Santa Clara River has been subdivided into six reaches (Chapter 3) based on similar traits such as channel morphology, water availability, vegetation types, and surrounding uses and access. Each major tributary is treated individually with the major tributaries broken into upper, middle, and lower reaches where appropriate based on differing physical characteristics.

The Santa Clara River's reaches and its tributaries vary considerably not only in terms of physical and ecological characteristics, but also in degree of infestation, intermixing of invasive species with native habitats, environmental sensitivity, and access. These factors in turn guide, but not entirely limit, the choice of removal options preferable for a certain reach. For example, the environmental sensitivity of a certain reach may warrant use of more labor intensive but environmentally sensitive techniques (e.g., cut and daub) and limit the widespread use of more intrusive techniques (e.g., mechanical clearing), particularly during the bird breeding season. However, sub-sections of this reach may be less sensitive and warrant consideration of mechanical clearing or other more invasive approaches. For this reason, the methods section is generally inclusive in terms of available techniques. However, regardless of the technique selected, all potential options are accompanied by an extensive list of BMPs in Chapter 14.

Table 6: Summary of Removal Method Options

Method	Appropriate Use	Timing	Tools	Instructions	Advantages	Disadvantages
Hand Removal (Above-Ground only)	Small infestations where there is concern regarding herbicide use.	Removal can be performed anytime, but most effective time to cut arundo and tamarisk is during the growing season (spring through fall). Rain and high water can limit wet season access.	Loppers, machete, chainsaw, bladed weed whipper, or similar equipment.	Stems, canes, and trunks are cut as close to the ground as possible. Cut biomass is generally removed from the project site and chipped, burned, or disposed of at a landfill to prevent reestablishment of cuttings. Roots and rhizomes are left in the ground.	Specific, minimizes damage to native plants/ animals. Minimizes soil disturbance.	Labor and time intensive. Very low mortality rates require repeated re-treatment (>5 years) to be effective which increases the project cost and frequency of disturbance to sensitive areas. Extensive debris removal.
Hand Removal (Above and Below-Ground)	Young plants and small stands, or when there is concern about herbicide use.	Removal can be performed anytime. Rain and high water can limit wet season access.	Pick-axe, mattock, shovel, loppers, machete, chainsaw, picks, or similar equipment.	Above-ground trunks, stems, or canes are first cut near the base. After clearing the material, roots and rhizomes are dug up using hand tools.	Specific, minimizes damage to native plants/animals. Effective if rhizomes and root masses are thoroughly cleared from site.	Labor and time intensive. Requires careful cleaning of roots/ rhizomes and debris removal. Soil disturbance and erosion potential.
Mechanical Removal (Above-Ground only)	Areas with easy access for heavy equipment and on stands not intermixed with native plants.	Removal can be performed anytime, but most effective time to cut arundo and tamarisk is during the growing season (spring through fall). Rain and high water can limit wet season access.	Tractor-mounted mower, towed disc, plow, flail mower, or similar equipment.	The stalks, stems, and canes are cut using the mower, disc or plow as close to the ground as possible. Cut biomass is removed from the project site immediately following cutting to prevent reestablishment of the cut material. Roots and rhizomes will remain in the ground.	Effective biomass removal for extensive stands.	Very low mortality rate requires repeated re-treatments. Extensive manual debris removal necessary when biomass is large enough to resprout. Requires site access by equipment.
Mechanical Removal (Above and Below-Ground)	Areas with easy access for heavy equipment and on stands not intermixed with native plants.	Removal can be performed anytime. Rain and high water can limit wet season access.	Backhoe, excavators or other heavy machinery.	A backhoe or tractor is to be used to simultaneously remove the plants and their root system. If roots/rhizomes remain, the equipment can be used to excavate these larger segments. Hand crews using shovels can dig out smaller fragments.	Effective if rhizomes and root masses are thoroughly cleared from site. Effective for removing very large establishments in open and accessible terrain.	Extensive debris removal. Major soil disturbance and erosion potential. Possible impacts to native wildlife and plant species. Requires site access by equipment.
Tarping	Small stands (<0.25 acres) not intermixed with native plants.	Tarps applied in late spring/ early summer and remain for up to 5 months, usually from June to November.	Chainsaws, machetes, loppers, or similar equipment to cut plants. Opaque thick tarps or pond liners, stakes or weights to hold tarps down.	Stalks and branches should be cut within inches of the ground. Chipped biomass should be placed over cut stalks. The opaque tarp or pond liner is laid over the cut material and secured with stakes or weights. The tarp remains on the target area for a period of five months and is then removed. Dead biomass is removed from the project area and roots and rhizomes are left in the ground.	High success rate when properly applied. Available for active channel areas. Minimizes soil disturbance. Effective on small stands.	Application of method is limited by size of stand. May damage soil microorganisms. Not appropriate for areas that may flood (i.e. channel).
Foliar Spray or Basal Bark Treatment	Any size stand not intermixed with native plants or where herbicide applicators can avoid native plants.	Apply herbicide anytime, but most efficient in early fall through winter when plant energy is transferred to roots. Herbicide should be applied on dry days and during low winds.	Herbicide, applicators such as backpack sprayer, ATV-mounted boom sprayer, spray rig, helicopter, or similar equipment.	Crews apply herbicide using sprayers or wicking on leaves and stems of arundo and foliage or basal bark of tamarisk. Follow herbicide label instructions. Personnel must be trained in the use and handling of herbicides. Timing of application is dependent upon type of herbicide used.	Short duration of labor. Low concentrations of herbicide. Effective on any size of stand. Minimizes soil disturbance.	Risk of drift to non-target plants and wildlife or adjacent sensitive receptors. Herbicide application should not be used in areas where there is great concern regarding herbicide use. Weather conditions must be suitable for herbicide application.

Method	Appropriate Use	Timing	Tools	Instructions	Advantages	Disadvantages
Cut and Paint/Daub	Any size stand. Allows– allows controlled application of herbicide on stands heavily intermixed with native plant species.	Apply herbicide anytime, but most efficient in early fall through winter when plant energy is transferred to roots. Herbicide should be applied on dry days and during low winds.	Chainsaws, loppers, or similar equipment can be used for cutting. Herbicide. Paintbrushes, sponge daubers, or similar equipment for herbicide application.	Trunks, stems, and canes of arundo and/or tamarisk are cut within one foot of the ground and removed. Herbicides is applied to the cut stem surface using brushes or daubers. Timing of application is dependent upon herbicide used. Follow herbicide label instructions. Personnel must be trained in the use and handling of herbicides.	Very high mortality rate. Efficient use of herbicide. Highly selective with little risk of drift of herbicide onto non-target plants or sensitive wildlife species. Little soil disturbance.	Very labor intensive. High concentrations (90-100%) of herbicide. Extensive debris removal is often required. Higher initial labor and herbicide costs than other methods, although less retreatment is required. Weather conditions must be suitable for herbicide application.
Cut, Resprout, and Spray or Paint/Daub	Any size stand not intermixed with native plants or where herbicide applicators can avoid native plants.	Cut one to two months prior to spraying. Apply herbicide when resprouts are 2-4 feet tall, but most efficient in early fall through winter when plant energy is transferred to roots. Herbicide should be applied on dry days and during low winds.	Loppers, chainsaws, flail mower, or similar equipment for cutting. Herbicide. Paintbrushes, sponge daubers,, applicators such as backpack sprayers, ATV-mounted boom sprayers, spray rigs, helicopter, or similar equipment for herbicide application.	Trunks, stems, and canes of arundo and/or tamarisk are cut within one foot of the ground and removed. Herbicide is applie Apply herbicide after a sufficient period has elapsed (approximately one to two months) to allow for re-sprouting. Follow herbicide label instructions. Personnel must be trained in the use and handling of herbicides.	Low soil disturbance associated with this method if hand tools are used. Less risk of herbicide drift than when spraying full-grown canes.	Waiting for resprouts after cutting can be impractical when working in remote areas. Large equipment (such as flail mowers) can substantially disrupt the soil and damage native, non-target species and habitat. Weather conditions must be suitable for herbicide application.
Cut and Spray	Any size stand not intermixed with native plants or where herbicide applicators can avoid native plants.	Apply herbicide anytime, but most efficient in early fall through winter when plant energy is transferred to roots. Herbicide should be applied on dry days and during low winds.	Loppers, chainsaws, flail mower, or similar equipment for cutting. Herbicide. Backpack sprayers, applicators such as backpack sprayer, ATV-mounted boom sprayers, spray rigs, or similar equipment for herbicide application. .	Crews will cut plant to four or five feet and then apply herbicide using hand held sprayers on leaves and stems of arundo and foliage or basal bark of tamarisk. Personnel must be trained in the use and handling of herbicides.	Moderate mortality rate. Minimizes soil disturbance. Minimizes risk of drift onto non-target species.	Biomass removal is labor intensive. Stalks intended for spraying may be trampled. Weather conditions must be suitable for herbicide application.
Controlled Burning	Large stands of pure arundo and tamarisk or for girdling of individual tamarisk trees.	Removal can be performed anytime.Anytime. Burning is most effective during growing season.	Flamethrowers weed burners, or similar equipment. Fuel.	Crews to either broadcast burn large stands or employ flamethrowers or weed-burners to spot treat small clusters, or heat-girdle stems at the base of individual plants. For larger controlled burns, fire crews would likely be required to monitor fires to prevent unintentional spread. . Fires applied during the rain season may help prevent spread of wildfires.	Highly effective in removing biomass.	Requires permits to perform burns and repeated burning to control biomass. Low mortality rates make it ineffective as sole or primary tool. Large potential for regrowth. Potential for associated collateral impacts to native habitat and wildlife. Risk of fire spread to non-intended targets. Arundo and tamarisk readily recover from fire which allows them to out-compete native riparian vegetation in post-fire circumstances.

Method	Appropriate Use	Timing	Tools	Instructions	Advantages	Disadvantages
Controlled Burning with Herbicide Treatment	Large stands of pure tamarisk.	Removal can be performed anytime.Anytime. Burning is most effective during growing season. Herbicide application most effective in the fall through winter.	Flame throwers or weed burners, or similar equipment. Fuel. Herbicide, sponge daubers, paintbrushes, and backpack sprayers.	Crews Controlled burning involves using crews to either broadcast burn large stands or employ flamethrowers or weed-burners to spot treat small clusters, or heat-girdle stems at the base of individual plants. For larger controlled burns, fire crews would likely be required to monitor fires to prevent unintentional spread. Fires applied during the rain season may help prevent spread of wildfires. Herbicide is then may be applied to cut canes or stumps, or applied to resprouts after a sufficient period has elapsed (approximately one to two months). Personnel must be trained in the use and handling of herbicides.	Highly effective in removing biomass.	Requires permits to perform burns. Potential for associated collateral impacts to native habitat and wildlife. Risk of fire spread to non-intended targets. Weather conditions must be suitable for herbicide application.
Grazing	Large stands of pure arundo or tamarisk where herbicide use is a concern.	Anytime. Most effective during growing season.	Grazing animals such as goats, temporary fencing.	Although grazing can be used to reduce or eliminate tamarisk sprouts and reduce arundo growth, this technique requires focusing the grazers on areas with high densities of the target vegetation. This may require fencing, herding, or other techniques to ensure that the method is effective and that grazers do not target native vegetation.	If grazing animals are readily available, then may be effective temporary control of new growth. Provides animal forage.	Labor and time intensive. Very low mortality rates require repeated re-treatment (>5 years) to be effective which increases the project cost and frequency of disturbance to sensitive areas. May be difficult to focus grazing on target species. Concentrated areas of animal waste may cause negative impacts to treatment areas.
Biological Control	Control of large infestations.	Dependent upon pathogen or species released.	Dependent upon pathogen or species released.	Biological control would involve the controlled release of a pathogen, or insect species from these plants' native range to feed upon, create disease in, or otherwise impair the growth, spread, and/or reproduction of arundo and tamarisk. All such biological controls are monitored and regulated by the USDA and it would be necessary to coordinate with that agency.	When implemented, biological control is expected to be effective in controlling the spread of infestations, but may not be extremely effective in the eradication of the target species populations.	No biological control agent is approved for use in the upper Santa Clara River for either arundo or tamarisk as of this writing.

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11.0 Herbicides

The range of herbicides available for use on arundo and tamarisk infestations is limited due to the label restrictions of application to wildlands. However, application of herbicides can be one of the most effective tools for control and eradication of these invasive plants. Most herbicides work by disrupting amino acid production in plants. As humans and wildlife do not share these same metabolic pathways, herbicide function is not directly relevant to health risk assessment. Herbicides are effective when used alone to control infestations, but are often used in conjunction with other techniques such as cutting or mowing. The use of herbicides can substantially increase mortality rates of persistent invasive plants, reducing the need for invasive hand or mechanical excavation of roots and rhizomes and associated soil disturbances. However, the utility of herbicide application in control of arundo and tamarisk can be affected by its relatively high initial cost, restrictions on use in proximity to water, the degree of intermixing of invasive plants with natives, and the presence of sensitive species. These factors can all restrict the type of herbicide allowed, the location and timing of use, and the method of application.

The success of herbicide application primarily depends upon selecting the appropriate herbicide for the task and closely adhering to label directions. Many herbicides are prohibited for use around open water and all may exhibit seasonal variations in effectiveness. The most effective method of application can vary between brands and types of herbicides. Most herbicides require the use of a surfactant, which may be included in the product or added prior to application to increase effectiveness. Colorants are also often added to herbicide solutions to enable spray crews to see where they have sprayed after initial evaporation of the solution. The USEPA and the California Department of Pesticide Regulation (CDPR) must register the herbicides prior to their use in California. Further, the large-scale application of herbicides must be overseen by a licensed professional. Appendices 9 and 10 contain detailed descriptions of herbicides, issues surrounding application, and appropriate techniques for application.

The three herbicides most commonly used in the eradication of arundo and tamarisk in riparian areas of Southern California are glyphosate, triclopyr, and imazapyr. While these herbicides are available under a variety of brand names, the focus of our discussion pertains specifically to these respective active ingredients. Formations of glyphosate and triclopyr for use near aquatic habitats are available, and a formulation of imazapyr is pending for use near water. Different mixtures of these herbicides are effective under different circumstances as discussed in more detail in Appendix 9.

11.1 Glyphosate

Glyphosate can be used to treat arundo and tamarisk is the active ingredient in the retail products such as Aquamaster®, Rodeo®, Glypro®, and Roundup®. The USEPA has approved Rodeo® and Aquamaster® for use in aquatic environments, making glyphosate one of the primary herbicides currently available for use when surface water is present. Roundup®, conversely, is only approved for use in areas where water is not present.

Glyphosate is most effective when used on perennial plants, such as arundo and tamarisk, when applied in the late summer and fall when the plant is entering dormancy, as this permits transmission of the herbicide to the plant's root system (Sonoma Ecology Center 1999).

11.2 Imazapyr

Imazapyr can also be used to treat arundo and tamarisk and is the active ingredient in Stalker® and the new aquatic habitat formulation, Habitat®. Imazapyr is a non-selective herbicide used for the control of a broad range of weeds including terrestrial annual and perennial grasses and broadleaved herbs, wood species, and riparian and emergent aquatic species (Tu, et al. 2001). a low potential for leaching into groundwater. It has low toxicity to invertebrates and is non-toxic to fish, mammals, and birds (USFS 1995). Unlike glyphosate, it can damage adjacent non-target plants, with the exception of conifers, by transfer between root networks.

11.3 Triclopyr

Triclopyr can be used to treat tamarisk and is a selective systemic herbicide. It has little or no impact on

grasses (e.g. arundo). Triclopyr is the active ingredient in Garlon® and Pathfinder® formulations, and is known as Access® in other states. Garlon® 4 and Pathfinder® II are approved for terrestrial habitats. Garlon® 3A is approved for use in closed aquatic habitats such as wetlands and lakes. It is not allowed for use on streams and rivers. It is recommended for use within 300 feet of water by the USFWS.

11.4 Adjuvants

Herbicides generally need to be applied with an adjuvant. There are several types of adjuvants including surfactants, non-foaming agents, and colorants. A surfactant is any compound that is added to an herbicide formulation or tank mix to facilitate the emulsifying, dispersing, spreading, wetting, or other properties of a liquid by modifying its surface characteristics (Vencill 2002). Surfactants, also known as stickers/spreaders, are similar to detergents in their action, reducing water surface tension to allow wetting and penetration of the plant tissues. The surfactant helps to achieve optimum herbicide adsorption into and adherence from the herbicide onto the plant. Surfactants may also improve an herbicide's efficacy so that the concentration or total amount of herbicide required to achieve a given effect is reduced, sometimes as much as five- or ten-fold (Tu et al. 2001). In this way, adding an appropriate surfactant can decrease the amount of herbicide applied and lower total costs for weed control (Tu et al. 2001). All herbicide labels recommend surfactants and other additives to improve herbicide effectiveness. In some cases, the herbicide will already have the surfactant included, but in other cases, it will be necessary to buy one. Herbicide applicators should check the label prior to adding surfactant. USEPA regulated adjuvants should be approved by the regulatory agencies. Non-ionic surfactants, such as Agridex®, are recommended by the USFWS.

12.0 Access and Staging Areas

Staging areas are often utilized during larger removal projects. Staging areas are used for the storage of and servicing of equipment, the chipping and temporary storage of biomass, and the subsequent loading of chipped material onto trucks for removal from the project area. Staging areas are typically 0.25 to 0.5 acres in size.

Staging area selection is based on available space, ease of access from surrounding roads, ease of access to the eradication site, and the least potential to conflict with adjacent land uses. Permission for use of each staging area may need to be coordinated with the appropriate landowner. Staging areas are typically enclosed with orange construction fencing, or by a six-foot-tall chain link fence to prevent unauthorized access and to ensure public safety.

Staging areas should be located outside of the 25-year floodplain on the upper terrace, levee, or bank of the river or tributary where removal is occurring. In staging areas where chipping is not compatible with surrounding land uses (i.e., near residences, schools, and parks), chipping should occur at the nearest staging area that is appropriate for chipping. Each staging area may be used to accommodate equipment storage and maintenance, portable sanitation facilities, emergency decontamination kits, and handheld equipment when not in use. Unsecured herbicides should be removed from the staging areas each night. All handheld equipment, including chainsaws and backpack sprayers, should be removed from the staging area at the end of each work day and not left at the project site. If large equipment, including ladders, tractors, chippers, and booms, are to be left at the work site overnight, they should be stored in the staging area. Large equipment should also be kept in the staging area when not in use. All maintenance and refueling activities should be performed within the staging areas to minimize risk of leakage/spills.

13.0 Disposal Options

Arundo and tamarisk biomass may be disposed of in a variety of ways.

13.1 Drying

Treated biomass is stacked at staging areas and completely dried, so it is no longer viable and able to resprout. The dried biomass can be left at the site, burned, chipped, or taken to a landfill for permanent disposal. Biomass may be left in piles in upland areas outside the 25-year floodplain to enhance wildlife habitat for small mammals only if cut prior to seed production. If left on site, biomass should be monitored for re-growth. Drying may not be appropriate for rhizomes due to their ability to resprout when exposed to moisture, even after long periods of drying,

13.2 Chipping

A chipper is used at the staging area, or on the banks of the river or tributary, or within the river channel itself (often directly into the back of trucks) to shred the arundo canes or smaller tamarisk branches. The chipper should be placed at an appropriate distance from potentially sensitive groups and all noise reduction accessories should be employed. The biomass may either be stacked and dried before being fed into the chipper, or may be fed into the chipper while still green. It is recommended that a large chipper be used as arundo can break the blades of smaller chippers. Chipped arundo biomass is suitable for beneficial reuse as mulch if chips are less than four inches, as longer segments often still remain viable Chipped tamarisk biomass may be contaminated with seed or salt (from foliage). It is recommended that tamarisk mulch be allowed to dry for two weeks to ensure seeds are no longer viable. Chipped biomass of arundo or tamarisk may also be disposed of off-site in a landfill for permanent disposal.

13.3 Incineration

Disposal of biomass occurs by burning cut material (that has not been chemically treated) at the staging area after the biomass has dried. Incineration requires obtaining a permit from the Los Angeles County Fire Department and the Los Angeles Air Quality Management District and would only be appropriate outside of fire season. Incineration should only be used under low wind conditions. Necessary fire control equipment (e.g., extinguishers, water hoses, etc.) should be on hand to prevent any unintended spread of the fire.

13.4 Landfill Disposal

The cut biomass is transported off-site to a landfill for permanent disposal. Chiquita Canyon Landfill is the closest landfill to the project area available for use. Landfills typically charge per load or by ton, which can add to the overall project cost.

13.5 Beneficial Re-use

13.5.1 Commercial and Cottage Industries

Removed arundo stalks may occasionally be sold for commercial purposes. Manufacturers of reeds for woodwind instruments, as well as those producing pressed board and paper products often have an interest in aquiring cut arundo canes. Arundo biomass may also be used to handcraft flutes, walking canes, and other such items as part of a cottage industry. However, as the overall goal of any removal project is to eradicate arundo, the sale of cut arundo for profit, and the development of commercial distribution channels is not encouraged. Project applicants who are approached by commercial entities who either wish to acquire the cut biomass, or who offer cutting/harvesting services, should only undertake such arrangements after entering into contract negotiations with the commercial entity. Appendix 12 lists guidelines that should be included in such a contract.

13.5.2 Cogeneration

Dried arundo and tamarisk biomass may be used as an environmentally friendly fuel in cogeneration power plants. However, and as mentioned above, the establishment of arundo for commercial applications is not encouraged as the overall goal is to eradicate arundo.

14.0 Best Management Practices and Mitigation Measures

Although the primary goal of arundo and tamarisk eradication programs is to improve habitat quality, some eradication techniques have the potential to negatively impact native habitat surrounding, and within, the project footprint. BMPs are intended to reduce the ecological cost of eradication projects and minimize deleterious impacts, while allowing the most appropriate eradication techniques to be used. Regulatory permits require implementation of BMPs. Most BMPs are implemented at the time work is conducted in the field, however some can be implemented prior to commencement of work.

The BMP project checklist provided below (Table 7) is designed to facilitate the application of BMPs for all possible projects. The list is based on three elements that will need to be considered for each project before it is implemented:

(1) how invasive species are to be removed from the project site;
(2) how the biomass of dead invasive plants will be disposed of and removed from the project site after treatment; and
(3) what types of sensitive species are either present or have the potential to be present on the site.

Note that all general BMPs shall be applied to all projects, no matter how small, in order to ensure that removal of invasive species does not adversely affect the remaining habitat quality. To use the checklist, answer the questions in gray bars, and see the text sections of the SCARP referred to next to the answer.

14.1 General BMPs

The following general BMPs are applicable to all removal scenarios and must be implemented for all related projects.

14.1.1 Limits to Site Disturbance

- All projects will coordinate with the regulatory agencies to obtain appropriate permits.
- Work area will be limited to smallest area possible.
- Vehicle use will be limited to the maximum extent possible. If vehicles are to be used, rubber-tired vehicles are preferred over tracked equipment.
- Soil disturbance will be limited to the maximum extent possible.
- Native vegetation and tree damage or removal will be limited to the maximum extent possible.
- No project activities will occur in flowing or ponded water.
  - If water must be crossed, an appropriate spanning method such as a temporary bridge consisting of planks or a steel grate/plate is to be used.
  - If work must occur in areas of flowing or ponded water, approved techniques for water diversion are to be used prior to beginning project activities.
- Staging areas will be located outside the active channel on the upper terrace, levee, or bank of the river or tributary.
- Staging areas will be located in compacted and de graded areas, preferably near access points when site conditions allow.
- Movement of personnel and equipment will be limited to designated work zones, staging areas, and access roads.
- Access points will be located at pre-existing ramps/roads, in areas infested with non-native or invasive plant species, or in areas that are already degraded. Areas with compacted soil will be used preferentially over areas with loose soils. Soil from access points infested with noxious species will be compacted, and biomass from such access points will be mulched to avoid distribution of seeds.

14.1.2 Site and Personnel Management

- All OSHA (Occupational Safety and Health Administration) regulations will be followed by project personnel.
- Chemical toilets for personnel shall be kept in staging areas during removal activities.
- Project activities will be limited to normal business hours.
- Extraneous noise will be limited to the maximum

extent possible (e.g., radios for entertainment).

- Equipment and machinery use will comply with all applicable local noise ordinances and policies.
- Smoking will not be allowed on site.
- Pets of project personnel will not be allowed on site.
- Prior to removal activities, treatment areas will be marked, and signs will be clearly posted along access points to the project site.
- Signs will be posted on affected trails for a sufficient time to warn trail users of heavy-duty equipment crossings. The signs will be posted on either side of the active access and shall be maintained for the entire period of project-related trail use.
- Signs and flaggers shall be used in areas where equipment use would access high speed roads (e.g. blind corners).
- All neighbors within 100 feet of proposed areas will receive notice of proposed projects one month before start of work.

14.1.3 Personnel Education

- All project personnel will be briefed on environmental concerns regarding the project, including the use of herbicides, appropriate work practices (including spill prevention and response mesures), and other measures needed to minimize project impacts. Personnel will be informed of the

Table 7: BMP Checklist

*	All general BMPs (Section 14.1 and all sub sections) must be adhered to at all times.	
1	How will invasive species be removed from the project site?	
	Biomass Removal	14.2.1
	Herbicides	14.2.2
	Foliar Application	14.2.3
	Cut and Paint	14.2.4
	Cut and Spray Resprouts	14.2.5
	Tarping	14.2.6
	Controlled Burning	14.2.7
	Biological Control	14.2.8
	Grazing and Herbivory	14.2.9
2	What method of biomass disposal will be used?	
	Drying	14.3.1
	Chipping	14.3.2
	Incineration	14.3.3
	Landfill Disposal	14.3.4
3	If sensitive species are present on site, what type? (For a description of sensitive species see Section 4.0, Biological Resources.)	
	Birds	14.4.1
	Amphibians/Reptiles	14.4.2
	Fish	14.4.3
	Plants	14.4.4

locations of foot and vehicle access paths, areas that are sensitive, and areas that are closed to access. The construction contractor shall monitor all construction-related activities to ensure that all of the environmental protection measures are followed throughout initial project activities and subsequent activities.

- All project personnel will participate in an educational program to identify the target plant species (arundo or tamarisk), incidental noxious plant species on the site, and native plant species on the site prior to proposed activities.
  This training will include how the target and incidental plant species are distributed in order to prevent spread of viable biomass.
- If special status plant or wildlife species (or species of concern) occur on site, a qualified biologist will conduct an educational program on how to avoid impacts to these species for all project personnel prior to proposed activities. This training will cover a description of all listed species (or species of concern), which occur within the project boundary and their habitats. This training shall also include a description of the applicable regulations such as the ESA and the State Fish and Game regulations, the need to adhere to these regulations, penalties associated with violations, and measures being implemented to conserve the species within the project area.

14.1.4 Air and Water Quality And Site Contaminant Prevention and Control

- All vehicles will observe a maximum speed limit of 15 miles per hour or lower at the project site and staging areas to avoid generation of dust.
- Appropriate dust suppression methods will be used during on-site removal activities. Recommended methods include application of water, use of wind break enclosures, covers on soil piles and dump truck loads, use of silt fences, and suspension of earth-movement activities during high wind conditions.
- Emissions from construction equipment will be controlled by adherence to the recommended maintenance schedules for each individual equipment type. Repairs to malfunctioning equipment will be made as soon as possible.
- All trash items will be enclosed in sealed containers and regularly removed from the site.
- Disposal of project waste materials such as trash, used equipment, oil, grease, and chemicals will be done in accordance with federal, state, and local regulations.
- Erosion control measures (e.g., silt fencing, mulch, matting, soil binder, seeding) will be implemented as appropriate to inhibit sediment transport into the waterways.
- If work is to occur during the rainy season, no work will occur unless there is a three-day clear weather forecast. No work will occur during rain events.
- No unchipped biomass greater than four inches in length will be left overnight within the stream channel.
- Stockpiled biomass, loose soil, or other debris will not be left overnight within the stream channel or on its banks. If stockpiled biomass must be left overnight, it will be moved to staging areas.
- All equipment and clothing will be inspected and cleaned at the end of each work day to prevent the further spread of invasive species.
- Herbicide storage during application, and the fueling and lubrication of mechanical equipment will be confined to staging areas.
- All vehicles and equipment shall be moved to a staging area or removed from the site overnight.
- Immediate control, containment, and cleanup of fluids and herbicides due to spills or equipment failure (broken hoses, punctured tanks, etc.) will be implemented. All contaminated materials will be disposed of promptly and properly to prevent contamination of the site. To reduce the potential for spills, the refueling of portable equipment shall occur within a contained area. Where that is not possible, barriers shall be placed around the site where the fuel nozzle enters the fuel tank. The barriers shall be such that spills shall be contained and easily cleaned up. Refueling activities shall ensure that the potential for spillage from overfilling, nozzle removal, or other action is minimized to the extent feasible.

14.1.5 Biological Resources (If Listed Species or Species of Concern Have Potential to Occur)

- If listed species or species of concern have potential to occur in the area, the project manager shall coordinate with the appropriate resource agencies and a qualified biologist to conduct surveys and implement measures to avoid impacts.
- If listed species or species of concern are known to occur in the area, a qualified biologist will be retained to recommend measures to protect these species such as the project scheduling, delineation of the work area, staging area, and access points.
- If listed species are present, a qualified biologist will monitor project activities as directed by regulatory agencies.
- Impacts to nesting birds per Migratory Bird Treaty Act (MBTA) will be avoided by:
- the cessation of work during bird breeding season (March 15 – September 15);
- the performance of surveys by a qualified biologist to determine presence/absence of nesting birds prior to undertaking work;
- the establishment of appropriate exclusionary buffers around nests, if present.

14.2 Technique-Specific BMPs

14.2.1 Biomass Removal

- Target species' canes/trunks will be cut to less than twelve inches in height and straight across to prevent sharp points from injuring project personnel or the public.

14.2.2 Herbicides

- A DPR licensed Pest Control Advisor (PCA) will prepare a written recommendation for the use of all materials/herbicides on agricultural areas (as defined by CDPR); the recommendation will be submitted to the Los Angeles County Agricultural Commissioner's Office.
- All material/herbicide usage on agricultural areas (as defined by CDPR) will occur only as directed by the written recommendation from a licensed PCA.
- Only herbicides registered for use in California by the EPA and the DPR will be used.
- Only herbicides approved for aquatic use may be used within the banks of rivers and tributaries. Roundup® may not be used within the active channel of rivers and tributaries.
- All adjuvants will be registered by the EPA and approved for use by the resource agencies.
- Herbicide application will be conducted only by personnel with an operator identification number from the Agricultural Commissioner's Office or supervised by a DPR certified or licensed Qualified Applicator (QAC or QAL).
- Herbicide usage will be limited to the minimum amount required to be effective.
- Herbicides shall be applied according to the manufacturer's label specifications.
- Herbicides will be colored with a biodegradable dye to facilitate visual control of application.
- Avoidance measures such as pulling back or temporarily tarping desired vegetation will be used to the extent feasible to prevent unintended herbicide impacts.
- Herbicides will be secured or removed from staging areas at night.

14.2.3 Foliar Application (Full Stands, Cut Stands, Resprouts)

- Herbicide will not be applied when conditions are windless or greater than ten miles per hour (mph).
- Herbicide will not be applied if air temperature exceeds volatization limits of herbicide, unless adjacent native species are protected (e.g., tarped).
- Tarps shall be used to cover desired vegetation (to the extent feasible) to prevent unintended herbicide impacts.
- Booms or ladders will not be employed for foliar spraying within 200 feet of residences, parks, schools or similar sensitive receptors. Foliar spray applications shall be limited to the cut and spray technique within this setback.

14.2.4 Cut-and-Paint

- See BMPs for biomass removal and herbicides.

14.2.5 Cut and Spray Resprouts

- See BMPs for biomass removal and herbicides.

14.2.6 Tarping

- Target species' canes/trunks will be cut to less than twelve inches in height and straight across to prevent sharp points from injuring project personnel or the public.
- Mechanical equipment will not be driven over tarped areas.
- Tarps shall be manually transported into seasonally and perennially wet areas.
- Tarping material will be removed and disposed of properly after completion of the project.

14.2.7 Controlled Burning

- This method will be used in compliance with all local laws and regulations and will be conducted in conjunction with the local fire department and AQMD.
- Adjacent land uses and land ownership will be considered prior to implementing controlled burns.
- All controlled burns will be conducted during the rainy season.
- All controlled burns will be supervised by qualified fire personnel.
- All controlled burns will be conducted during low-wind conditions.
- Adjacent landowners will be notified prior to implementing controlled burns.

14.2.8 Biological Control

- Biological control vectors will not be released without USDA approval.

14.2.9 Grazing and Herbivory

- The use of grazing animals shall be restricted to areas outside of flowing water with a minimum setback of 50 feet for grazing from any flowing water.
- Grazing will be controlled by erection of temporary fencing to restrict grazing animal to the target area.

14.3 Storage and Disposal Methods

14.3.1 Drying

- Drying of biomass will occur outside of the active channel at designated staging areas.

14.3.2 Chipping

- All chipped biomass will be disposed of off site in a landfill or will be used as mulch.
- All measures shall be taken to reduce the noise of chipper and to prevent noise disturbance to potentially sensitive receptors.
- Necessary measures shall be taken to reduce and control dust generated by chipping.
- Chipping shall occur on staging areas only with prior approval of the appropriate landowner and/or agency.

14.3.3 Incineration

- All federal, state, and local laws and provisions regarding incineration of biomass shall be followed, including those of the local fire department and AQMD.
- All incineration will take place at appropriate designated locations.

14.3.4 Landfill Disposal

- Cut biomass is transported off-site to a landfill for permanent disposal. Chiquita Canyon Land fill is the closest landfill to the project area avail able for use. Landfills typically charge per load or by ton, which can add to the overall project cost.

14.4 Threatened and Endangered Species-Specific BMPs

14.4.1 Birds (Western Yellow-Billed Cuckoo, Southwestern Willow Flycatcher, California Condor, Least Bell's Vireo, Coastal California Gnatcatcher)

- Project activities (e.g., application of herbicide, mechanical trimming, and/or removal, etc.) shall be conducted between 15 September and 15 March to avoid impacts to listed bird species such as least Bell's vireo and southwestern willow

flycatcher during the breeding season, or shall provide a 500 foot radius buffer around each nest, if either species is present.

- Noise levels will not exceed 60 dBA (A-weighted decibel scale) within 500 feet of nests.

14.4.2 Amphibians (Arroyo Toad, California Red-legged Frog)

- No work will be conducted within areas of known or potential arroyo toad habitat during the breeding season (February to August).
- Vehicles and equipment shall be removed from the habitat before sunset in sensitive amphibian areas.
- Stockpiles of biomass will not be kept in habitat areas, but will be moved to upland areas outside the 25-year floodplain immediately to minimize amphibian and reptile usage.

14.4.3 Fish (Unarmored Threespine Stickleback, Santa Ana Sucker)

- No work will occur in flowing or ponded water.
- Grading and excavation will be set back a minimum of 50 feet from the edge of the active channel. Grazing areas will be fenced to prevent animals from entering water. The boundaries of excavated projects will be demarcated by temporary construction fencing or flagged stakes.

14.4.4 Plants (e.g., Nevin's Barberry, Slender-Horned Spineflower, Spreading Navarretia)

- All listed plant locations will be fenced to avoid disturbance and accidental damage/mortality.
- Herbicides will not be used near known or probable locations of sensitive plant species.

Areas identified as potential special status plant habitat will be surveyed by a qualified botanist prior to commencing work.

15.0 Maintenance and Monitoring

Arundo and tamarisk are aggressive invasive plants with an extraordinary ability to spread, reproduce, and thrive under a wide range of conditions. As such, any removal program for substantial infestations requires a long-term commitment of resources, repeated treatments, and ongoing monitoring in order to be successful (Table 8). This adds to the overall cost of removal efforts, but without such repeated treatments and monitoring, successful removal projects can quickly experience reinvasion, with the potential for a treated area to return to a pre-removal condition, sometimes within a few years.

The issue is exacerbated within the upper Santa Clara River watershed because extensive infestation increases the chance of re-infestation from offsite sources. Therefore, all removal methods will require at least three years of continuous monitoring and follow-up treatments. Even approaches with high initial mortality rates such as cut and daub/paint will require this extent of monitoring, and likely follow-up treatments in spots. For methods with lower mortality rates, monitoring times and the number of required re-treatments may increase to five years. Monitoring site visits are recommended quarterly for the first year and biannually for years two to five.

Table 8: Comparison of Re-Treatment Requirements of Removal Methods

Method	Average 1st Year Mortality Rate	Level of Re-Treatment Effort Required	Average Number of Re-Treatments Required
Hand Above-Ground Removal	<50%	Same as initial treatment.	>5
Hand and Mechanical Above-Ground Removal	5-50%	Varies depending on success of initial treatment. Potentially the same as initial treatment.	>5
Mechanical Above-Ground Removal	<50%	Same as initial treatment.	>5
Mechanical Above- and Below-Ground Removal	5-50%	Varies depending on success of initial treatment. Potentially the same as initial treatment.	>5
Tarping	50-95%	Few resprouts – little effort.	At least 3
Foliar Spray	50-95%	Few resprouts – little effort.	3-5
Cut and Spray or Paint/Daub	50-90%	Few resprouts – little effort.	3-5
Cut, Resprout, and Spray	~50%	Some resprouts – close to the same amount of effort as initial treatment.	3-5

The level of intensity, duration, and frequency of required re-treatment depends on many factors such as the skill of the crews involved, initial budget, etc. As such, this table is provided for general reference only.
Source: Sonoma Ecology Center 1999.

16.0 Habitat Restoration and Revegetation

There are two types of revegetation: passive and active. Passive revegetation means there will be natural recruitment from native species while active revegetation means introducing native species by planting seeds, cuttings, or container stock.

Passive revegetation means replanting by natural processes. Surrounding native plant habitats provide seed sources for propagation. Once the competition of arundo or tamarisk is removed, native species will continue to propagate and grow there. This method requires the least effort and expertise to restore native riparian vegetation. It also doesn't require repeated disturbance for maintenance and ensures the revegetation of local genetic stock. However, passive revegetation may take several years or more to become established. If invasive plants are established upstream of the project area or in surrounding areas, the site is at risk of being repopulated by invasive plants.

Passive revegetation is most appropriate when:

- There are native plant and seed sources, either on-site or upstream.
- The site does not contain extensive disturbed, unvegetated, exposed ground that would attract non-native pest plants.
- The soils are stable and at low risk of erosion.
- The site tends to flood each year, allowing nearby native plant material to settle and become established.

If these conditions exist, passive revegetation may be a more appropriate use of time and resources than active revegetation.

Active revegetation means collecting and planting seeds, cuttings, or container stock. Active revegetation is recommended for sites are located on upper banks where natural recruitment is unlikely to occur or on areas which have erosion problems. Project sites should be monitored during removal activities for natural recruitment of native species. Supplemental water or irrigation may be required. Active revegetation is often planned after removal activities have been completed to avoid impacts to newly planted vegetation. Active revegetation may take from three to five years.

Active revegetation is most appropriate when:

- The site is located downstream from, or near invasive plant species. In such cases, prompt revegetation with natives may be necessary to prevent reinvasion of the treated site.
- The soil or stream bank is unstable and at high risk of erosion.
- A landowner strongly desires a privacy screen.
- There are special status species utilizing the project area.
- Natural recruitment is not providing species diversity.

There are several different revegetation techniques. Depending upon the project site conditions and desired habitat diversity, a combination of revegetation techniques may be used. Active revegetation alone may not provide sufficient soil or bank stabilization. Soil retention materials and stabilizing structures may be needed to adequately prevent erosion and bank failure. In such cases, materials such as erosion control fabrics and engineered structures should be considered before engaging in invasive plant removal. For structural changes, consult with a professional engineer or landscape architect, or a government agency such as Resource Conservation Districts.

Depending upon the level of habitat restoration desired and various individual project factors, the project costs will vary. A successful revegetation project will provide habitat, include a diverse set of plant types and species, reduce erosion, and require minimal annual management (CDFG 2003). If revegetation of a project site is intended, it is advisable to plan ahead to obtain local native plant material, grow container stock if necessary or prepare seeds for planting, and create a schedule for planting and maintenance. Planting cuttings or container stock usually works well for species that do not germinate well from seed or need intensive seed preparation. Seeding can be applied to species that germinate well from seed. It is important to consider the species diversity and local genetics when planning the plant palette. Native plant material such as seeds and cuttings should be obtained from the project site or as close as possible. Site preparation may include reducing the weed seed bank in the soil by herbicide application or disking prior to seed set. If there is a large

weed seed bank, this process may be performed several times. Planting or seeding is usually performed in the fall season to take advantage of rains for germination and encourage root growth. If rains are late, revegetation may occur in the winter or early spring. If planting or seeding is performed at another time of year, supplemental water or irrigation should be considered (Sonoma Ecology Center 1999).

Revegetation techniques include:

- Hand broadcasting of native grass, forb, and/or shrub seed mixes
- Hydroseeding of native grass, forb, and/or shrub seed mixes, may also contain binders for erosion control
- Drill, imprint, or pit seeding
- Direct planting of tree or shrub seeds
- Planting of tree and/or shrub cuttings
- Planting of tree, shrub, forb, and/or grass container plants

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16.1 Planting Methods

16.1.1 Broadcast Seeding

Broadcast seeding can be performed by hand, with hand-held or rolling broadcast seeders, or larger broadcasters towed by all-terrain vehicles or tractors. The soil bed should be prepared prior to seeding. If there is compaction, the soil should be disked or tilled. Also, the soil should be raked before and after seeding to incorporate the seeds into the soil. If available, large equipment such as a harrow and a ring roller can assist with working the seeds into the soil and enhance soil compaction after seeding. The seeding rate for broadcast seeding is usually 25 to 30 pounds per acre.

Drill or Imprint Seeding

Dry seeding can also be performed with large equipment such as drills, imprinters, or pitters. A tractor-drawn drill makes small furrows, deposits seeds in the furrows, and covers the seed with soil. Drills come in different sizes and types with attachments to improve seeding different species. Imprinters have a hydraulic wheel system with different seed boxes and a roller with teeth. These allow for diverse seed mixes and fertilizer or mycorrhizal inoculum to be applied at the same time. Both of these seeding applications can be faster and more uniform than broadcast seeding. The seeding rate for drilling or imprinting is usually 12 to 18 pounds per acre.

16.1.2 Hydroseeding

Hydroseeding uses hydraulic equipment to spread a wet mixture of seeds, fertilizer, mycorrhizae, erosion control binder, and green daya dye. This method can seed a large area quickly. The hydroseed mixture can be applied from a turret on top of a truck while driving or with a hose. Hydroseeding is most effective during the fall or early spring when rains will encourage germination. However, if supplemental water is available, it can be applied at other times of the year. It is important for the components of the hydroseed mixture to be correctly combined in appropriate proportions and the soil

bed is prepared prior to application. The California Native Grass Association recommends a two step process: 1) applying seed, a small amount of virgin wood fiber mulch, mycorrhizal inoculum, compost , and an organic time-released fertilizer first and; 2) applying a second layer of wood fiber and compost to cover. If erosion control is necessary on steep slopes, apply a third layer of rice or native straw with a tackifier.

16.1.3 Transplanting Emergent Plants

Rushes, sedges, and tulles are often called "emergent" plants since they usually emerge from water. These plants may grow from seeds or spread by rhizomes, which makes them good candidates for transplanting. Plants with intact rhizomes should be harvested in the winter or early spring. Several small clumps from a variety of larger clumps should be taken to ensure the parent population will survive and to include genetic diversity in the new planting area. Collected plant material should be stored in moist soil and transplanted within a reasonable time. Collected specimens should be planted in a large enough hole to accommodate the entire rhizome, soil should be packed around the rhizome, and thoroughly watered. Above ground portions of plant should be trimmed to stimulate growth.

16.1.4 Planting Cuttings

Willows, cottonwoods, Mexican elderberry, and many other riparian species can be planted from cuttings. These plants have the ability to grow roots from stems. Cuttings should be made when plants are dormant during winter months. Cuttings should be sliced so that the inner side of the branch is at an angle to indicate the end that will be planted in the ground. The cuttings may be a variety of sizes with different diameters and lengths depending upon the plant species and the location of the planting. Cuttings should have several viable buds along the stem in order to ensure new growth. Cuttings may be stored in water until ready to use, grown in water until roots appear, or planted as container stock. Cuttings should be planted in soil with angled, cut side down (buds should be pointing up) with three-quarters of the cutting in the ground and one-quarter exposed. If holes are augured, fertilizer or mycorrhizal innoculum may be added to the hole or mixed with the backfill soil before planting. Cuttings can also be driven into the ground with a mallet if soil is soft. Damage to the top of cuttings may be, sliced off.

16.1.5 Planting Container Plants

Container plants may be ordered in a wide variety of species from a native plant nursery. Ideally, container stock with be grown from locally collected plant material. Container plants will require supplemental water – from either winter rains or irrigation. Holes should be dug twice as wide and twice as deep as the container plant. In addition, fertilizer or mycorrhizal innoculum may be added to the hole or mixed with the backfill soil before planting. The hole should be firmly backfilled to depth of the rootball, and then the container plant placed inside.

17.0 Developing a Budget and Schedule

17.1 Cost of Removal

Removal costs vary greatly and are influenced by many factors including the extent and degree of infestation, labor rates, the ease of site access, the removal method employed, the frequency, duration, and level of effort required for follow-up treatments, biomass transport distances, and disposal techniques. Typical costs associated with various arundo and tamarisk removal methods are not well documented and can vary greatly from project to project. Removal of minor or isolated stands of arundo or tamarisk can often be accomplished relatively inexpensively (less than $2,000 per acre). However, current available methods which are suitable for successful removal of major infestations are all relatively expensive, ranging in price from approximately $2,500 to $9,500 per acre, depending on many variables. Techniques with the highest initial mortality rates and the lowest resultant follow-up monitoring and re-treatment costs tend to be the most expensive in terms of up-front costs, but the least expensive over longer periods. A project checklist is provided in Table 9.

Because such a wide range of factors affect removal project cost, it is not possible to provide precise estimates. Similar removal methods employed under generally similar circumstances can even exhibit variations in cost if just one key factor, such as difficulty of access or material transport, increases substantially due to factors such as distance or variable landfill tipping fees.

17.2 Cost Effectiveness

The SCARP proposes several methods for removal. Each method has advantages and disadvantages in different respects. Public agencies need to balance needs across the entire geographic area under their jurisdiction, as issues of social justice and environmental justice are important considerations in public and private policy and planning. (LAWMA 2005).

Although there may be certain concerns over the use of herbicides in the environment, this method may be more cost-effective in terms of funds and time. However, local communities or organizations may choose non-chemical methods of control, which may not be as cost-efficient. These groups have options to obtain additional funding for alternative methods of control such as volunteer programs and grants.

Development of a project schedule is an integral component to any removal project. Table 9 is provided as a planning aid and offers examples of the steps applicants can expect to incorporate in their projects.

18.0 Funding

There are several ways to fund invasive plant removal projects. Local agencies and non-profit organizations may apply for funding through grants, restoration loans, cost-share programs, in-lieu fees, mitigation banking, or through alternative sources. Individual landowners should contact their local agencies or NGOs for grant or cost-share opportunities.

18.1 Grants

Grants are provided by governmental agencies or NGOs. There is usually a lengthy process for the application of grants. The process may take up to two years before funding is obtained. Each source will have different applications and contract requirements. There may be a two-part application, which consists of a pre-proposal or conceptual proposal and a final proposal if the pre-proposal is accepted. Grants often need to have matching funds provided by donated cash, labor, or equipment.

Some agencies and organizations that provide grants are listed below:

- State Water Resources Control Board
- National Fish and Wildlife Foundation
- State Resources Agency
- California Department of Parks
- Recreation Land and Water Conservation Fund
- Habitat Conservation Fund
- Natural Resource Conservation Service

Websites, which provide information regarding available grants, are listed below:

- http://www.epa.gov/watershedfunding
- www.calwatershedfunds.org
- http://www.invasivespecies.gov/toolkit/grants-info.shtml

Table 9: Project Checklist

PREPARATION	
	Choose site - from headwaters down
	Obtain Landowner Cooperative Agreement
	Perform site assessment - level of infestation, potential for wildlife, staging areas, access
	Prepare project description - site plan, maps, choose removal/disposal methods, BMPs
	Survey project boundary
	Determine level of CEQA and which permits are necessary
	Complete vegetation/habitat surveys
	Complete wildlife surveys
	Complete sensitive species surveys
	Prepare CEQA - Initial Study, Negative Declaration, Mitigated Negative Declaration, Environmental Impact Report
	Contact resource agencies and prepare permits, including fees - CDFG, USACE, RWQCB, USFWS, AQMD, LADPW
	Prepare SWPPP
	Prepare specifications - safety, access to water, ingress/egress, removal methods, transport, disposal
	Prepare maintenance and monitoring plan
	Prepare bid package
	Contact youth groups such as CCC or City Corps for labor
	Notify and educate any surrounding residents via postcards, brochures, or handouts.
CONSTRUCTION	
	Mobilization - move in equipment, portable restrooms, signage, security fencing
	Clear & grub - staging areas, access roads, debris removal
	Construct access roads - equipment, dust/weed issues, watering truck for dust control
	Dewatering, if necessary
	Remove invasive species - labor, equipment, & herbicides
	Biological monitoring
	Transportation - to staging area (equipment & labor)
	Disposal - landfill, chipping/landfill, chipping - onsite/offsite mulch, incineration (equipment, landfill fees, transportation costs)
	Clean up, deconstruct access roads
	Demobilization - move out equipment, portable restrooms, signage, security fencing
MAINTENANCE & MONITORING (3- 5 years)	
	Remove invasive species - labor, equipment, & herbicides
	Biological monitoring
	Transportation - to staging area (equipment & labor)
	Disposal - landfill, chipping/landfill, chipping - onsite/offsite mulch, incineration (equipment, landfill fees, transportation costs)
	Annual reports to resource agencies
	Management

- http://www.wcb.ca.gov
- http://www.cdfa.ca.gov/phpps/ipc/weedmg-mtareas/Funding/funding_hp.htm

Further information regarding available public and private grants can be obtained from the Foundation Center Libraries (http://fdncenter.org). Locations of these libraries include:

Ventura County Community Foundation
Funding and Information Resource Center
1355 Del Norte Road
Camarillo, CA 93010
(805) 988-0196

California Community Foundation
Funding Information Center
606 S. Olive St. Suite 2400
Los Angeles, CA 90014-1526
(213) 413-4042

Los Angeles Public Library
West Valley Regional Branch Library
19036 Vanowen Street
Reseda, CA 91335
(818) 345-4393

Santa Monica Public Library
1343 Sixth Street
Santa Monica, CA 90401-1603
(213) 458-8859

18.2 Resource Loans

The State Water Resource Control Board has low interest loans for restoration and conservation projects. The Federal Water Pollution Control Act (Clean Water Act or CWA), as amended in 1987, provides for establishment of a State Revolving Fund (SRF) loan program. The program is funded by federal grants and State bond funds. The purpose of the SRF loan program is to implement the CWA and various State laws by providing financial assistance for the construction of facilities or implementation of measures necessary to address water quality problems and to prevent pollution of the waters of the State. The SRF Loan Program provides low-interest loan funding for construction of publicly-owned wastewater treatment facilities, local sewers, sewer interceptors, water reclamation facilities, as well as, expanded use projects such as implementation of non-point source (NPS) projects or programs, development and implementation of estuary Comprehensive Conservation and Management Plans, and storm water treatment. There is more information available on the website: http://www.swrcb.ca.gov/funding/srf.html.

18.3 Cost-Share Programs

The NRCS has two cost-share programs to assist private landowners perform restoration and conservation projects.

18.3.1 Environmental Quality Incentives Program – EQIP

The Environmental Quality Incentives Program (EQIP) provides a voluntary conservation program for farmers and ranchers that promote agricultural production and environmental quality as compatible national goals. EQIP offers financial and technical help to assist eligible participants install or implement structural and management practices on eligible agricultural land.

EQIP offers contracts with a minimum term that ends one year after the implementation of the last scheduled practices and a maximum term of ten years. These contracts provide incentive payments and cost-shares to implement conservation practices. Persons who are engaged in livestock or agricultural production on eligible land may participate in the EQIP program. EQIP activities are carried out according to an environmental quality incentives program plan of operations developed in conjunction with the producer that identifies the appropriate conservation practice or practices to address the resource concerns. The practices are subject to NRCS technical standards adapted for local conditions. The local conservation district approves the plan.

EQIP may cost-share up to 75 percent of the costs of certain conservation practices Incentive payments may be provided for up to three years to encourage producers to carry out management practices they may not otherwise use without the incentive. However, limited resource producers and beginning farmers and ranchers may be eligible for cost-shares up to 90 percent. Farmers and ranchers may elect to use a certified third-party provider for technical assistance. An individual or entity

may not receive, directly or indirectly, cost-share or incentive payments that, taken together, exceed $450,000 for all EQIP contracts entered during the term of the Farm Bill.

18.3.2 Wildlife Habitat Incentives Program - WHIP

This program is available for all landowners with less than $2 million income. The Wildlife Habitat Incentives Program (WHIP) is a voluntary program for people who want to develop and improve wildlife habitat primarily on private land. Through WHIP, USDA's Natural Resources Conservation Service provides both technical assistance and up to 75 percent cost-share assistance to establish and improve fish and wildlife habitat. WHIP agreements between NRCS and the participant generally last from five to 10 years from the date the agreement is signed.

WHIP has proven to be a highly effective and widely accepted program across the country. By targeting wildlife habitat projects on all lands and aquatic areas, WHIP provides assistance to conservation minded landowners who are unable to meet the specific eligibility requirements of other USDA conservation programs.

18.4 In-Lieu Fee Program

The in-lieu-fee program is a program run by the USACE to offset impacts to Waters of the United States, which are permitted under Section 404 of the CWA. In-lieu-fee mitigation occurs in circumstances where a permittee provides funds to an in-lieu-fee sponsor instead of either completing project-specific mitigation or purchasing credits from a mitigation bank approved under the Banking Guidance. Funds collected from the permittees under in-lieu-fee arrangements are used for replacing wetland and riparian functions and values and are not used to finance non-mitigation programs and priorities such as education projects or research. Currently no in-lieu-fee program agreements exist within the SCARP project area. To further research the in-lieu-fee program option or to develop an in-lieu-fee program, contact the USACE Los Angeles District office.

18.5 Mitigation Bank

Invasive weed removal can serve as compensatory mitigation for certain projects affecting aquatic resources and can be incorporated into the BMPs of many projects. The USACE, RWQCB, and CDFG can require permittees whose activities involve temporary or construction-related disturbance of aquatic areas to ensure that the disturbed areas are not invaded by arundo, tamarisk, or other weeds. This can help reduce proliferation of infestation, as often happens in recently disturbed areas. When on-site mitigation is not appropriate, the Corps can direct permittees to mitigate the impacts of their activities by removing invasive weeds in strategic areas of the watershed; thereby contributing to the overall control program. Wetland mitigation banks strive to establish large, contiguous wetland areas, which can be used to mitigate for a number of independent impacts. This allows eligible permittees to purchase compensatory mitigation credits from another entity that has already produced and banked them, thereby eliminating the need to produce compensatory mitigation areas on-site (ELI and IWR 1994). Mitigation banks advance effective regional habitat conservation by encouraging the bundling of mitigation "credits" at sites recognized to be high priorities for habitat protection and restoration in watersheds and ecosystems and provide a mechanism that assigns a monetary value to habitat, which in turn allows a landowner to obtain a financial return for conserving land rather than developing it. The USACE has been an active participant in the establishment a mitigation bank in the Santa Ana River, which is focused on invasive weed removal. The goal of the Santa Ana River Mitigation Bank (SARMB) is to reestablish native riparian ecological diversity and other riparian functions through the removal of invasive weeds. Currently, a mitigation bank has not been established for the Santa Clara River, although the SARMB may serve as a template for the development of one in the future.

19.0 Resources

The following list of resources provides further information and guidance to project applicants.

19.1 Local Agency and NGO Contacts

Large amounts of material already exist on the problems posed by arundo and tamarisk including the benefits of removal, and general approaches and techniques to successful removal. When combined with the detailed information contained in the SCARP document, ample information is available both to the public and to future project applicants. The primary points of contact for the public would be:

Ventura County Resource Conservation District
P.O. Box 147 (Mailing address)
3380 Somis Road (Street Address)
Somis, Ca 93066
(805) 386-4685

Antelope Valley Resource Conservation District
44811 N. Date Ave., Suite G
Lancaster, CA 93534
(661) 945-2604

Other agencies and organizations that can provide assistance are provided in Table 10.

Table 10: Agencies and Organizations Assistance

Agency or Group Name	Assistance Available	How to Contact
Los Angeles County Agricultural Commissioner	Regulates herbicide use. Provides information to obtain certification or licenses. Also provides Operator Identification Number and safety training for application of non-restricted materials.	(626)575-5471 12300 Lower Azusa Road Arcadia, CA 91006-5872 http://acwm.co.la.ca.us/
Southern California Air Quality Management District	May require permit for controlled burning or incineration of biomass. Advises days when burning can occur.	(909)396-2000 21865 Copley Dr Diamond Bar, CA 91765 http://www.aqmd.gov/
County or Local Water Districts	May require a permit to access properties.	(661)259-3610
California Conservation Corps (CCC) (Camarillo/Los Angeles/ Norwalk)	Eradication of invasive plants and restoration of native plants	(805)484-4345 1878 South Lewis Rd. Unit 60 Camarillo, CA 93010 http://www.ccc.ca.gov/
Los Angeles Conservation Corps	Eradication of invasive plants and restoration of native plants	(213)747-1872 P.O. Box 15868 Los Angeles, CA 90015 http://www.lacorps.org/
Concerned Resource Environmental Workers (CREW)	Eradication of invasive plants and restoration of native plants	(805)646-5085 P.O. Box 1532 Ojai, CA 93024 (No Website)
California Department of Fish and Game (San Diego)	Issues Streambed Alteration Agreements and consults for impacts to state listed species.	(916)445-0411 1416 Ninth Street Sacramento, California 95814 http://www.dfg.ca.gov/
California Invasive Plant Council	Provides information on non-native invasive plants in California.	(510)843-3902 1442-A Walnut St., #462 Berkeley, CA 94709 http://www.cal-ipc.org/

Agency or Group Name	Assistance Available	How to Contact
Los Angeles County or local Fire Department	Provides information for fire safety. May issue a burn permit.	(818)890-5783 12605 Osbourne St Pacoima, CA 91311 http://www.lacofd.org/
Natural Resource Conservation Service (Lancaster)	Provides information for erosion control, non-native plant removal, habitat restoration, and funding	(661)945-2604 44811 N. Date Avenue, Suite G, Lancaster, CA 93534 http://www.ca.nrcs.usda.gov
Antelope Valley and Ventura County Resource Conservation District	Provides information for non-native plant removal, habitat restoration, permitting, and funding	(805)386-4685 P.O. Box 147 Somis, CA 93066 http://www.vcrcd.org
Los Angeles County Public Works	Issues encroachment permits	(626)458-4300 900 South Fremont Avenue Alhambra, CA 91803 http://ladpw.org/wmd/
Team Arundo del Norte (Sonoma Ecology Center)	Provides information on eradication techniques, biology, grant information, regional eradication coordination	(707)996-0712 P.O. Box 1486 Eldridge CA 95431 http://www.sonomaecologycenter.org/
Arundo Task Force	Provides information on eradication techniques, biology, and grant information.	(805)386-4685 P.O. Box 147 Somis CA 93066 http://www.arundotaskforce.org
US Army Corps of Engineers (Los Angeles Region)	Issues Section 404 permit (for earthmoving or fill in stream)	213) 452-3908 P.O. Box 532711 Los Angeles CA 90053-2325 http://www.spl.usace.army.mil/
US Fish and Wildlife Service (San Diego)	Provides consultations for potential impacts to federal listed species and may have potential funding through Partners for Wildlife or Santa Clara River Trustee Council	1-800-344-WILD 2493 Portala Road, Suite B Ventura, CA 93003 http://www.fws.gov/
Regional Water Quality Control Board (Los Angeles)	Provides information on water quality issues and issues 401 Water Quality Certification (for earthmoving or fill in stream)	(213) 576-1364 P.O. Box 2815 Sacramento, CA 95812-2815 http://www.calepa.ca.gov/
US Bureau of Land Management	Potential funding through War on Weeds	(202) 452-5125 1849 C Street, Room 406-LS Washington, DC 20240 http://www.blm.gov/nhp/index.htm
City of Santa Clarita, Environmental Services Division	Provides information on City activities	(661)222-7222 23920 Valencia Boulevard, Ste. 300 Santa Clarita, California 91355 http://www.santa-clarita.com/
Los Angeles Weed Management Area	Provides information on weed management	(626)575-5471 12300 Lower Azusa Road Arcadia, CA 91006-5872 http://acwm.co.la.ca.us/

Agency or Group Name	Assistance Available	How to Contact
The Nature Conservancy	Provides information on eradication methods	(805)642-0345 3639 Harbor Boulevard, Suite 201 Ventura, CA 93001 http://www.tnccalifornia.org
California Native Plant Society (Ventura)	Provides information on California native plants	(916) 447-2677 2707 K Street, Suite 1 Sacramento, CA 95816-5113 http://www.cnps.org/
Society for Ecological Restoration (SER Cal)	Provides information on California native habitat restoration	2701 20th Street Bakersfield, CA 93301-3334 Tel. (661) 634-9228 http://www.sercal.org/
Chiquita Canyon Landfill	Closest landfill to the project area	3 miles west of Interstate 5 on State Route 126 in Santa Clarita Valley. http://www.chiquitacanyon.com

19.2 Books

The Nature Conservancy Handbook:

Weed Control Methods Handbook: Tools & Techniques for Use in Natural Areas

Cal IPC Handbook:

The Weedworker's Handbook: A Guide to Techniques for Removing Bay Area Invasive Plants

Team Arundo del Norte Handbooks:

Arundo: A Landowner Handbook

Controlling Arundo in Your Watershed: A Guide For Organizations

19.3 Web Resources

ARUNDO

NPS PCA	http://www.nps.gov/plants/alien/fact/ardo1.htm
SAWPA	http://www.sawpa.org/arundo/
SMSLRWMA - Arundo Biology	http://www.nps.gov/plants/alien/fact/ardo1.htm
Team Arundo del Norte	http://teamarundo.org/
TAdN Arundo Reference Library	http://teamarundo.org/research_reference/index.html#biblio
TNC - Arundo Stewardship Abstract	http://tncweeds.ucdavis.edu/esadocs/documnts/arundon.html
TNC - Arundo Images	http://tncweeds.ucdavis.edu/esadocs/arundona.html
USDA	http://plants.usda.gov/cgi_bin/plant_profile.cgi?symbol=ARDO4
USACE - Arundo Removal	http://www.wes.army.mil/el/pmis/plants/html/arundo_d.html

TAMARISK

CAIN NBII - Tamarisk	http://cain.nbii.gov/crisis/crisiscat/viewResource?resource=http://cain.nbii.gov%2Fcrisis%2Finvasive_terms%23Tamarix
Earlham College	http://www.earlham.edu/~biol/desert/invasive.htm
Invasive Species.gov - Saltcedar profile	http://www.invasivespecies.gov/profiles/saltcedar.shtml
Proceedings Saltcedar Workshop June 12, 1996	http://www.invasivespecies.gov/education/workshopJun96/index.html
NPS	http://www.nps.gov/plants/alien/fact/tama1.htm
TNC – Tamarisk Stewardship Abstract	http://tncweeds.ucdavis.edu/esadocs/tamaramo.html
USFS	http://www.fs.fed.us/database/feis/plants/tree/tamspp/all.html
WA NWCB	http://www.nwcb.wa.gov/weed_info/saltcedar.html
USACE	http://www.wes.army.mil/el/pmis/plants/html/tamarix_.html

INVASIVE PLANT ORGANIZATIONS

Cal IPC	http://www.cal-ipc.org/
California Weed Management Areas	http://www.cdfa.ca.gov/phpps/ipc/weedmgtareas/
L.A. County Weed Management Area	http://acwm.co.la.ca.us/scripts/wma_2.htm
Santa Barbara County Weed Management Area	http://www.countyofsb.org/agcomm/wma/
Santa Margarita & San Luis Rey Weed Mgmt	http://smslrwma.org/
Invasive Species Information Node (ISIN) of the NBII	http://invasivespecies.nbii.gov/
Noxious Weed Information Project	http://www.cdfa.ca.gov/phpps/ipc/noxweedinfo/noxweedinfo_hp.htm
Center for Invasive Plant Management	http://www.weedcenter.org/
NPS - Monitoring Invasives	http://science.nature.nps.gov/im/monitor/invasives.htm
USACE Aquatic Plant Control	http://www.wes.army.mil/el/aqua/
SFWI NIS Guidebook	http://www.sfei.org/nis/NISguidebook.pdf
TNC Weed Removal Handbook	http://tncweeds.ucdavis.edu/handbook.html
Global Invasive Species Specialists Groups	http://www.issg.org/

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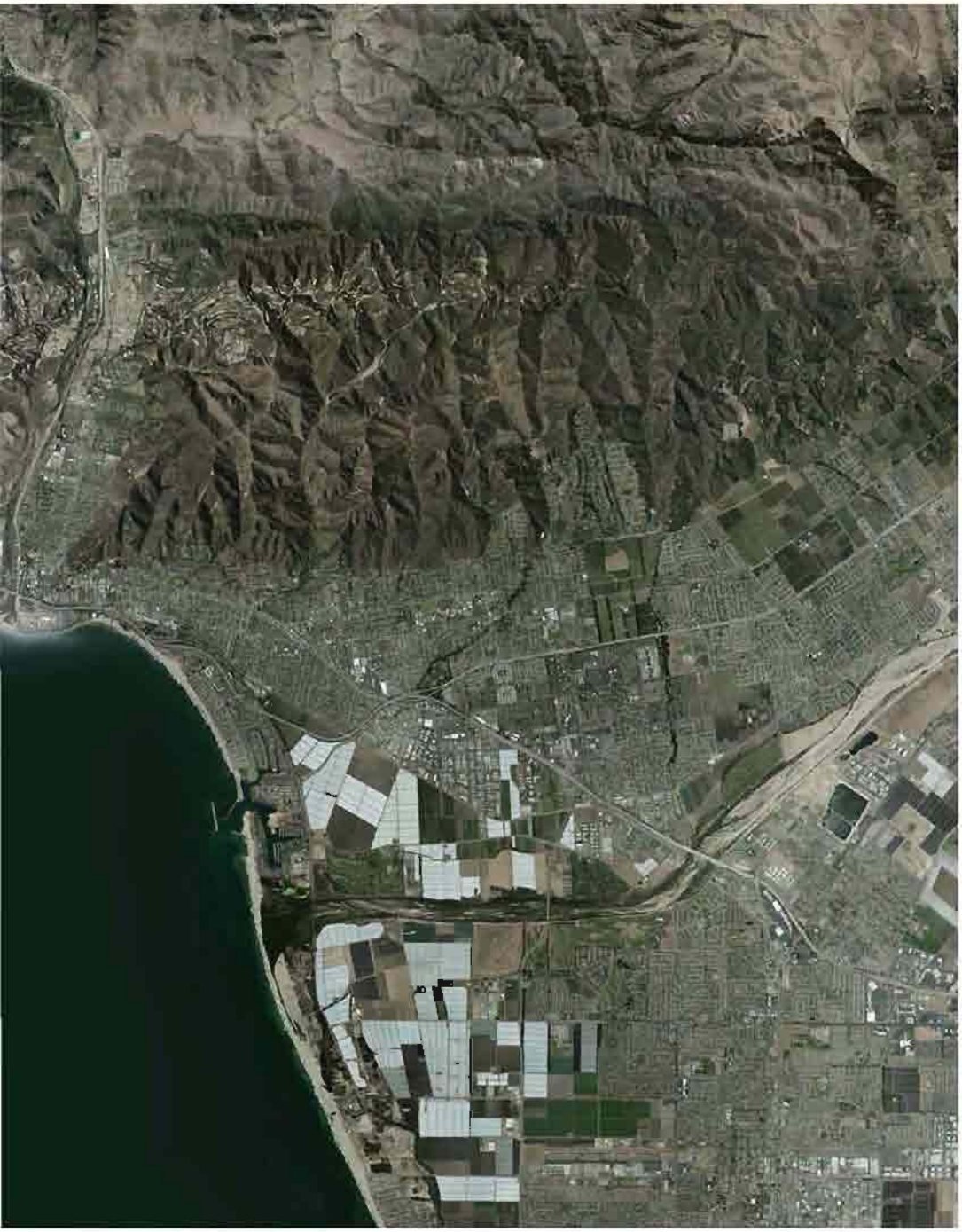
DRAFT
2013 Comprehensive Water Resources Report



Prepared for:

CITY OF VENTURA

Prepared by:

RBF Consulting,
a Company of Michael Baker Corporation

RBF CONSULTING
A Baker Company

2013 COMPREHENSIVE WATER RESOURCES REPORT

DRAFT Report

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February 2013

EXECUTIVE SUMMARY

Introduction

On July 26, 2010 Public Works conducted a workshop with City Council that included information on the City's current water supply issues. It was presented that with continued years of drought, tightening water restrictions and environmental responsibilities, Ventura's water supply was being impacted by several factors. These factors included and continue to include the following:

- The City's historical water rights to the Ventura River may be significantly limited as concern for the health of the endangered Southern California Steelhead and its habitat ecosystem restrict how much and at what time of the year this water source is available. Storm events over the past 15 years have restricted our ability to withdraw historical amounts from this source.
- City allocation from two groundwater basins, Oxnard Plain Basin and Santa Paula Basin, are increasingly regulated and monitored. Studies being conducted by the oversight agencies have indicated that potential overdraft and water quality issues may occur in the near future.
- The Mound Groundwater Basin has experienced water quality degradation and projections for reliable supply may be lower than originally anticipated.

A recommendation from the workshop was to provide a comprehensive evaluation of current and projected water supply needs.

In addition, as a part of this year's City Council Priority Projects, the Community Development (Planning) Department and Ventura Water have focused their time and energy on streamlining and documenting the development review process as it pertains to water and wastewater services. More specifically, we are working to:

- Ensure transparency and consistency to our customers,
- Create equity in assigning costs; and
- Protect the reliability of our water and wastewater infrastructure.

In order to provide a comprehensive evaluation of the City's current and projected water supply needs, Ventura Water has been engaged with the City's Planning Department to provide their input and expertise on what development has taken place since the 2005 General Plan, the pace of proposed development and what water demands those developments may require. This Report will review previously developed water demand projections, anticipated water supplies and planned development projects and compare

them to where the City is today for each of these three categories. City staff is collaboratively looking forward to help plan the City's water resources to accommodate future development in the most responsible manner for its customers.

Purpose

The main purpose of this report is twofold. The report will identify water demand and water supply conflicts in various reports and will evaluate how current and future anticipated water demands match current and future anticipated water supply. Ventura Water and Planning recognize the need to develop a process that tracks proposed development projects, consistently calculates the anticipated increase in water demand associated with each proposed development project, and the evaluates the impact on the current water supply. This Comprehensive Water Resources Report ("Report") is intended to be a tool in the development review process as it pertains to water supply and demand.

Water Supply

The City's potable water supply is derived from local groundwater basins, Lake Casitas and sub-surface water from the Ventura River. The City also has a 10,000 acre-foot per year allocation from the California State Water Project. To date the City has not received any of this water because there are no facilities to get the water to the City. There are presently five local water sources that provide water to the City water system:

- Casitas Municipal Water District (Casitas)
- Ventura River Foster Park Area (Foster Park)
    - Surface Water Intake
    - Upper Ventura River Groundwater Basin/Subsurface Intake and Wells
- Mound Groundwater Basin (Mound Basin)
- Oxnard Plain Groundwater Basin (Fox Canyon Aquifer)
- Santa Paula Groundwater Basin (Santa Paula Basin)

The City also provides recycled water from the Ventura Water Reclamation Facility (VWRF).

Estimated Water Demand

Based on the known supply conditions and the calculated water demand for the present condition, it appears that the current water demand exceeds the available supply. However, it is apparent that the "calculated" water demand for the current condition (22,754 AFY) is overly conservative. The current water demand figures calculated within this Report utilize a baseline water demand from 2005 of 20,808

AFY. Based on the FY 2011-2012 water consumption data, it is likely that the City's current water demands are closer to 17,300 AFY, below the current available supply of 19,600 AFY.

Utilizing development projections developed as a part of the 2005 General Plan, the anticipated growth in water demand through 2025 is 4,020 AFY, which results in a total projected water demand of 26,774 AFY, well above the predicted 24,200 AFY of supply (which is on the high end of the range). The future water demand projections utilize the water demand factors published in the 2005 General Plan FEIR. The demand factors are "planning-level" numbers, and therefore are on the conservative side. It is likely that the actual water demand factors are much lower than those used to project the future demands.

Figure ES-1 provides a graphical representation of the current water consumption, water demand projections and water supply range.

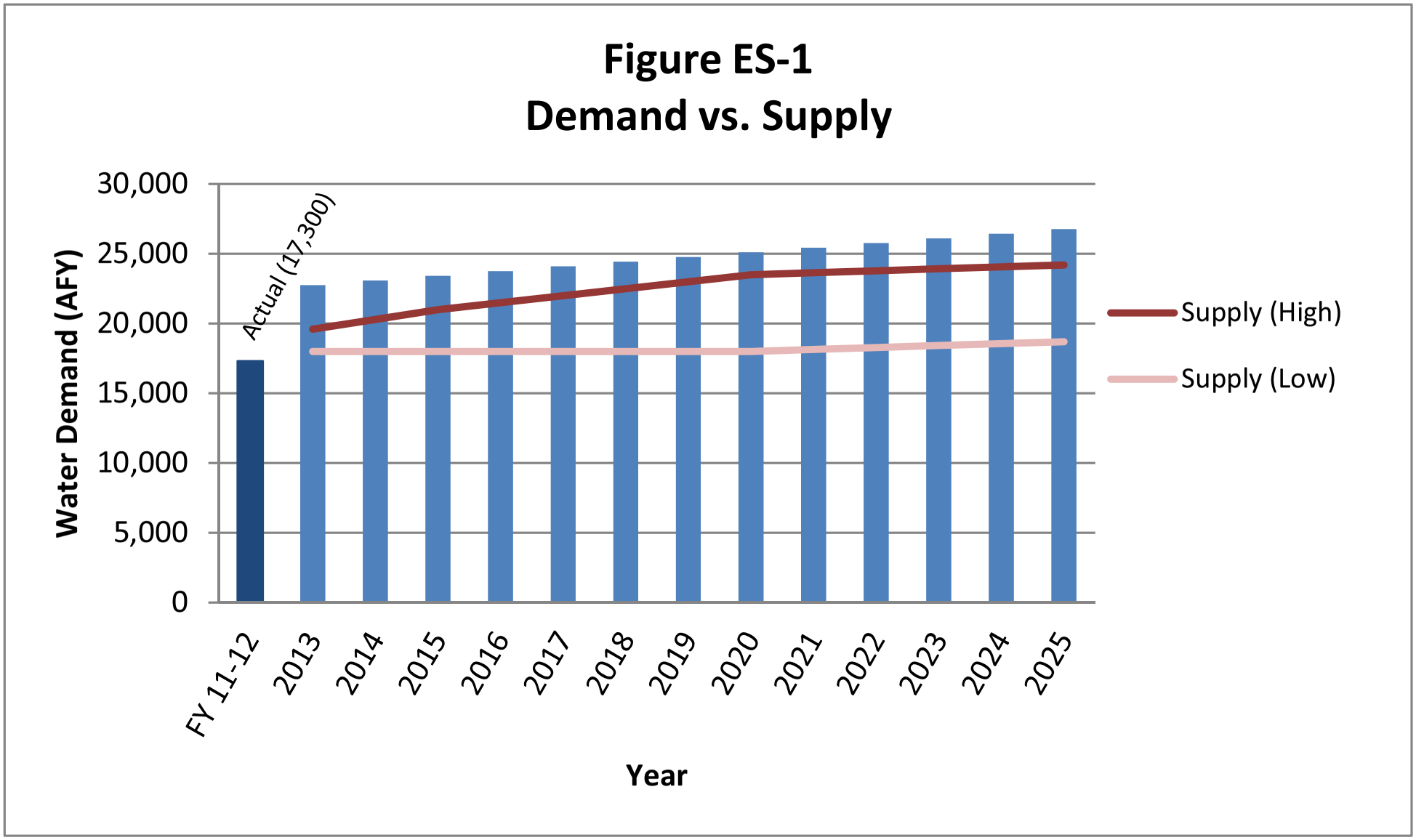
Figure ES-1
Demand vs. Supply
30,000
25,000
20,000
15,000
10,000
5,000
0
Water Demand (AFY)
Actual (17,300)
FY 11-12
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Year
Supply (High)
Supply (Low)

Recommendations

Moving forward, it is recommended that the City utilizes current consumption data to develop both the existing demand condition, and also develop more realistic demand factors for the various land uses within the City. In order to develop more realistic demand factors, the City will need to accurately define the existing land use conditions for the various land use categories within the City. In addition, the water consumption data will need to be attributed to the correct land use categories. This can be accomplished by mapping the water billing classifications with the General Plan land use categories, and perhaps developing a new set of water demand factor classifications. By utilizing current water consumption data, and current land use data, a more accurate set of water demand factors can be determined. The more accurate demand factors will allow for a more realistic projection of future water demands where the development plan has been identified.

Due to the wide range of demand and supply estimates in this initial analysis, it is clear that a thoughtful and multi-faceted approach to managing and planning for Ventura's water supply will be absolutely critical in the coming years to support economic growth and quality of life.

1. INTRODUCTION

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A recommendation from the workshop was to provide a comprehensive evaluation of current and projected water supply needs.

In addition, as a part of this year's City Council Priority Projects, the Community Development (Planning) Department and Ventura Water have focused their time and energy on streamlining and documenting the development review process as it pertains to water and wastewater services. More specifically, we are working to:

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input and expertise on what development has taken place since the 2005 General Plan, the pace of proposed development and what water demands those developments may require. This Report will review previously developed water demand projections, anticipated water supplies and planned development projects and compare them to where the City is today for each of these three categories. City staff is collaboratively looking forward to help plan the City's water resources to accommodate future development in the most responsible manner for its residents.

B. PURPOSE OF REPORT

The main purpose of this report is twofold. The report will identify water demand and water supply conflicts in various reports and will evaluate how current and future anticipated water demands match current and future anticipated water supply. Ventura Water and Planning recognize the need to develop a process that tracks proposed development projects, consistently calculates the anticipated increase in water demand associated with each proposed development project, and then evaluates the impact on the current water supply. This Comprehensive Water Resources Report ("Report") is intended to be a tool in the development review process as it pertains to water supply and demand.

Over the past several years, the City has prepared various documents that address water demand and water supply. More specifically, there are three documents that have been used as a reference document for both historical figures and future projections. The three documents are:

- 2005 General Plan, 2005 General Plan FEIR and 2007 Supplement
- 2010 Urban Water Management Plan (amended in 2011)
- 2011 Water Master Plan

The following section provides the background on each report and includes a summary table to compare the reports information. Each report was completed at a different time and for a specific purpose therefore, the following section includes the following information on each report: the purpose of the report; the resources utilized for the report; the water demand factors utilized and the estimated water demands based on those factors in each report and the anticipated current and future water supply in each report.

C. STUDY AREA

The City of San Buenaventura is located 62 miles north of Los Angeles and 30 miles south of Santa Barbara along the California coastline. The City is located within the County of Ventura, and bound by the City of Oxnard to the south, by unincorporated Ventura County to the east and north, and by the Pacific Ocean to the west. The northwest portion of the City is bound by the Ventura River, while the southern portion is bound by the Santa Clara River. The Ventura Freeway (101) bisects the City in the north-south direction, while the Santa Paula Freeway (126) runs east to west through the center of the City. The Ojai Freeway (33) runs along the northwestern edge of the City. The City currently occupies an estimated 21 square miles and has an estimated population of 109,000 persons. Exhibit 1-1 identifies the City of San Buenaventura boundary, the Sphere of Influence and General Plan boundary.

Ventura Water provides potable water service to a population of approximately 113,500 persons and has approximately 32,000 service connections. The City's existing water service area includes all portions within the City limits, as well as portions of unincorporated Ventura County that meet the City's policy for water connections outside City limits (Municipal Code Section 22.110.055).

Ventura Water also operates the Saticoy Country Club (SCC) water system, which consists of residences and country club facilities that are located east of the City. They have their own stand-alone system, which includes two groundwater wells, a booster pump station and two storage tanks. The ownership responsibility for the system is shared between the City and SCC (1/3 and 2/3, respectively). The SCC system has a separate Domestic Water Supply Permit from the California Department of Public Health.

On January 16, 2013, the Ventura County Local Agency Formation Commission (LAFCo) adopted resolution LAFCo 13-01S, which updated the City of Ventura Sphere of Influence (see Appendix). The Sphere of Influence (SOI) included in this Report depicts the updated SOI.

CITY OF VENTURA

City Overview

Legend

- Location Sites
- Ventura City Limit
- General Plan Boundary
- City Sphere of Influence

0 0.5 1
Miles

Source: Eagle Aerial, 2010

RBF CONSULTING

Exhibit 1-1

M:\Mdata\10104392\January_2013\EXI_1_CityOverview_L11x17.mxd 2/19/2013-- DJ

D. DOCUMENT COMPARISON

1. 2005 General Plan, General Plan FEIR and 2007 Supplement

State law requires each California city to adopt a comprehensive, long-term General Plan for the physical development of the community that guides local decision-making by expressing community goals about the future distribution and character of land uses and activities. The General Plan serves as a long-term guide, establishing policies for day-to-day land use decisions over a 20-year planning horizon. The General Plan is a policy document that sets over-arching goals for the future development of the City and specifies policies and actions to achieve these over-arching goals.

The 2005 General Plan Final Environmental Impact Report (FEIR) provides an analysis of the potential environmental impacts associated with the potential development identified in the General Plan.

The City prepared a supplement to the FEIR in 2007 to address the impact of an additional 329,000 square feet of non-residential development in the Ventura Harbor area.

<u>Land Use</u>

Chapter 3 of the City's 2005 General Plan defines the City's plan for growth over the 20-year planning horizon (through 2025). Specifically, Table 3-2 of the General Plan provides the estimated amount of development that could reasonably be expected to occur within the City and the Sphere of Influence by 2025, and together with Figure 3-1 provides a picture of where such change might occur. The 2007 FEIR Supplement included an additional potential of 329,000 square feet of non-residential development in the 20-year planning horizon.

<u>Water Supply</u>

Chapter 4.13 of the 2005 General Plan FEIR addresses the impacts of the General Plan on the public utilities, which includes the water system. Table 4.13-7 summarizes the City's historic and projected water supply. The source used in preparation of Table 4.13-7 is the City's 2004 Biennial Water Supply Report, which provides projections for the

City's future water supply and demand based on current information at the time (thru 2003).

Water Consumption (Demands)

Table 4.13-8 summarizes the City's historical and projected water consumption. The source used in preparation of Table 4.13-8 is the City's 2004 Biennial Water Supply Report. Projected demands are based on the post-mandatory water conservation demand factor of 0.179 AFY/capita, the 2000 U.S. Census and the City growth rate of 0.9%. However, the table only projects out to Year 2020. In order to identify the water demand projections for Year 2025, you must utilize the projected water demands developed in Table 4.13-15 (5,806 AFY) in conjunction with the calculated demand increase (115 AFY) identified in the 2007 FEIR Supplement. The demand projections in Table 4.13-15 are based on a set of water demand factors to be discussed later in this Section.

2. 2010 Urban Water Management Plan

An Urban Water Management Plan (UWMP) is a long-term planning tool that provides water purveyors and their customers a broad perspective on water supply issues. The UWMP is a management tool, providing the framework for action, but not functioning as a detailed project development plan. Preparation of the UWMP is a requirement of the California Urban Water Management Planning Act. UWMP's must be prepared every five years. The primary goals of the UWMP are to: 1) plan the water supply over a 20-year period, 2) identify and quantify water supply for future demands in normal, single-dry and multiple-dry year conditions, and 3) implement conservation and efficient water use practices in urban settings.

Land Use

The UWMP does not evaluate land use. The UWMP projects water demands based on population projections. The population projections are based on historical data provided by the California Department of Finance (2000 Benchmark). Future projections are based on the 0.88 percent annual growth rate as identified in the City's 2005 General Plan, and are shown in Table 2-1 of the 2010 UWMP.

Water Supply

Table 3-1 in the 2010 UWMP provides a summary of the existing and projected water supply. The water supply data are based on historical production data and estimates of current water supply sources available and operational constraints.

Water Consumption (Demands)

Table 2-5 in the 2010 UWMP provides a summary of the past, current and projected water demands. The 2005 and 2010 water demand data are the actual metered demands based on billing records. The water demand projections are based on the per capita water demand factor of 168 gallons per capita day, multiplied by the population growth projections identified in Table 2-1 of the UWMP.

3. 2011 Water Master Plan

A Water Master Plan (WMP) is a document that is typically prepared every 5-10 years. They are not mandated by state law, but most water purveyors prepare a WMP to document the plan for improvement or expansion of the existing water distribution system. The master plan provides a comprehensive evaluation of the water system infrastructure to determine the systems' capacity to meet the current and future water demand, and evaluates the operational efficiency of the system. The primary focus of a master plan is to evaluate the capacity of the system facilities (pipelines, pump stations, reservoirs, wells, etc.) to provide a safe and reliable water supply to the customers at minimum specified criteria. The criteria will include system pressure, pipe velocity, fire flow availability, reservoir storage, pump capacity, etc., which are based on guidelines provided by the American Water Works Association (AWWA), Environmental Protection Agency (EPA), and California Department of Public Health (DPH). The primary goal of a WMP is to develop a capital improvement program that identifies specific projects, costs and priorities for system improvements.

Land Use

The 2011 Water Master Plan utilized the land use data provided in Table 3-1 of the 2005 General Plan to establish the existing land use condition. The future "near-term" land use conditions were based on the City's 2006 Pending Project list. The ultimate land use condition was based on the remaining vacant land as identified in the 2005 General Plan,

less the proposed projects listed on the 2006 Pending Project list. The figures are summarized in Tables II-1 thru II-4 in the 2011 Water Master Plan.

Water Supply

The summary of the current (2010) water supplies are identified in Table V-14. The current water supply is shown as a historical supply projection range from 18,760 – 25,800 AFY.

Water Consumption (Demands)

The existing water demands identified in the 2011 Water Master Plan are based on actual billing records taken from a two-year period from January 2004 through December 2005. The actual billing records, coupled with the existing land use identified in the 2005 General Plan were used to develop "actual" water demand factors. The actual demand factors were increased by approximately 10% to account for water loss. The demand factors were applied to the 2006 Pending Project list and then to the remaining vacant land to calculate the future water demands.

The water supply and water demand figures provided within each document are summarized on Table 1-1. The table includes the source of the data used to develop the figures presented within each document, and the various factors and methods used to come up with the projections. As you will note, the water supply projections in the 2005 General Plan documents are the most optimistic and the water demand projections in the 2005 General Plan documents are the most conservative. This is likely due to the fact that these projections were made based on actual data available through Year 2003, and obviously could not factor in the economic conditions of later in the decade, nor the drought and water supply limitations of the same time frame.

It is prudent to point out that comparing the demand and supply projections within each of these three documents is not an "apples to apples" comparison, as each document was prepared at a different time using actual data from different time periods, incorporating current information regarding water supply sources at that specific time, using different methodologies (land use based vs. population based) to calculate future projections, using different demand factors and making different assumptions.

E. DEMAND FACTOR COMPARISON (from previous documents)

Demand factors are used to calculate the future water demand projections. Demand factors are either land use based (per area (acre/ksf) or per dwelling unit) or population based (per capita). Demand factors are typically derived from actual water consumption data, and a safety factor is applied for planning purposes. Demand factors were used in each of the three documents described above to arrive at the future demand projections presented within each report. As briefly described above and shown in Table 1-1, the demand factors and methodologies used within each document vary. Since each document uses different methodologies and demand factors, an “apples to apples” comparison is difficult. Table 1-2 lists the demand factors used within each report. In an attempt to show an “apples to apples” comparison, the residential demand factors have been converted to similar units and are shown on Table 1-3.

The Appendix includes water usage factors from other local agencies with similar characteristics – population, climate and water supply sources. These include Simi Valley, Thousand Oaks, Irvine Ranch Water District and Santa Margarita Water District.

Table 1-1
Summary of Previous Documents

Total Water Supply (AFY)							
Document	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**Data Source & Factors**
2005 General Plan, GP FEIR and 2007 Supplement	*21,566* [1]	26,300	28,262	28,262	28,262	28,262	Table 1 of the 2004 Biennial Water Supply Report - Based on actual water production data thru 2003 - Future projections based on assumptions and limitations for each supply source known at the time (2004) - [1] Figure includes 1,129 AFY for raw water and oil operation use - Figures do not include recycled water
2010 Urban Water Management Plan	n/a	n/a	20,600	22,000	24,600	24,700	Table 3-2 of the 2010 UWMP - Water production data for 2010 is based on annual average data from 2000 - 2009 as presented in Table V-14 of the 2011 WMP - Future projections based on assumptions and limitations for each supply source known at the time (2011) - Figures do not include raw water and oil operation use - Figures include 700 AFY of recycled water annually
2011 Water Master Plan	n/a	n/a	n/a	n/a	n/a	25,800	Tables V-1, V-2, V-7, V-10, V-13 and V-14 of 2011 WMP - Based on actual water production data thru 2009 - Future projections based on assumptions and limitations for each supply source known at the time (2011) - Figures do not include raw water and oil operation use - Figures do not include recycled water

Total Water Demand / Consumption (AFY)							
Document	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**Data Source & Factors**
2005 General Plan, GP FEIR and 2007 Supplement	*20,437*	20,594	21,724	22,918	24,181	27,421 [2]	Tables 2, 3 and 4 of the 2004 Biennial Water Supply Report - Based on actual water consumption data thru 2003 - Historical population based on 2000 U.S. Census - Growth rate in City = 0.9%, outside City = 0.6% - Water Use Factor = 0.179 AFY/capita - [2] Year 2025 projections based on demand factors provided for FEIR
2010 Urban Water Management Plan	n/a	*20,808*	*17,351*	22,286	23,256	24,270	Table 2-5 of the 2010 UWMP - Based on actual water consumtion data through 2010 - Historical population based on California Department of Finance Table E-4 Population Estimates for Cities, Counties and the State (2000 Benchmark) - Growth rate in City = 0.88%, outside City = 0.1258% in connections - Water Use Factor = 168 gpcd = 0.188 AFY/capita
2011 Water Master Plan	n/a	*16,190*	17,896	n/a	n/a	22,708	Table IV-5 and Figure IV-2 of the 2011 WMP - Based on actual billing records from 2004-2005. - Near-term projections (allocated to 2010) based on actual billing data from 2004-2005, calculated demand factors from the same period applied to the 2006 Pending Projects list. - Long-term projections (allocated to Year 2025) based on applying the calculated demand factors to the remaining developable land as identified in the 2005 GP, excluding the land accounted for in the 2006 Pending Projects list.

Table 1-2
Summary of Water Demand Factors in Previous Documents

General Plan FEIR, August 2005

Land Use Description	Density (DU/Acre)	Demand Factor [1]	Unit
Residential	n/a	450	gpd/du
Retail	-	250	gpd/ksf
Office	-	250	gpd/ksf
Industrial	-	315	gpd/ksf
Hotel	-	500	gpd/ksf

[1] Provided in email corrspondence from Chandra Chandrashaker, City CD, (January 8, 2013). Only used to calculate the year 2025 projections.

Note: Future projections through year 2020 based on population data and 0.179 AFY/capita factor

2010 Urban Water Management Plan

Land Use Description	Density (DU/Acre)	Demand Factor [1]	Unit
Single-Family	n/a	0.33	AFY/Acct
Multi-Family	n/a	1.71	AFY/Acct
Commercial	-	1.69	AFY/Acct
Industrial	-	10.87	AFY/Acct
Institutional/Governmental	-	2.80	AFY/Acct
Landscape	-	4.86	AFY/Acct
Petroleum Recovery	-	465	AFY/Acct
Other	-	0.83	AFY/Acct

[1] Adapted from 2005 data in Tables 2-5 and 2-6 of the 2010 UWMP.

Note: Future projections based on population data and 168 gpcd factor = 0.188 AFY/capita

Water Master Plan, March 2011

Land Use Description [1]	Density (DU/Acre) [1]	Demand Factor [2]	Unit
Neighborhood Low (NL)	0-8	1.20	gpm/acre
Neighborhood Medium (NM)	9-20	2.00	gpm/acre
Neighborhood High (NH)	21-54	5.00	gpm/acre
Commerce (C)	-	1.60	gpm/acre
Industry (I)	-	1.60	gpm/acre
Public and Institutional (PI)	-	0.75	gpm/acre
Parks and Open Space (POS)	-	0.10	gpm/acre
Downtown Specific Plan	21-54	2.55	gpm/acre

[1] Source: 2005 General Plan

[2] Per Table III-1 of WMP. Factors are calculted based on 2004-2005 billing data, and 2005 General Plan land use data.

Table 1-3
Comparison of Residential Water Demand Factors in Previous Documents

Comparison of Residential Demand Factors					
2005 General Plan FEIR		**2010 UWMP [2]**		**2011 Water Master Plan [1]**	
Residential	450 gpd/du	Single-Family	293 gpd/du	Low (NL)	432 gpd/du
				Medium (NM)	199 gpd/du
		Multi-Family	1530 gpd/du	High (NH)	192 gpd/du

[1] Assumes the average density (du/acre)
[2] Assumes 1 account = 1 du

F. CURRENT PLANNING DATA

The Community Development Department maintains a database of all projects that are in the planning, design or construction phase. These projects are known as the "Pending Projects." The pending projects database is updated constantly as new projects are proposed or existing projects are modified.

Table 3-2 in the 2005 General Plan predicted the anticipated development intensity and pattern throughout the City through 2025. The Community Development Department provided actual development data for the period from 2005 – 2012. This Report will take into account the actual development data provided by the City for years 2005-2012 to determine the current land use condition. This Report will utilize the date provided in Table 3-2 of the 2005 General Plan, less the actual development data from 2005-2012 to determine the remaining developable land through year 2025.

G. 2012 LAFCo Municipal Service Review

It should be noted that in 2012, the Ventura Local Agency Formation Commission (LAFCo) completed the Municipal Service Review for nine Ventura County cities, including the City of San Buenaventura. LAFCos exist for each county in California. LAFCos are responsible for achieving three primary objectives: encouraging the orderly formation and expansion of local government agencies; preserving agricultural land and open space resources; and discouraging urban sprawl. To accomplish these objectives, LAFCos are responsible for coordinating logical and timely changes in local government boundaries, conducting special studies that review ways to reorganize and streamline government structure and preparing a sphere of influence for each city and special district over which they have authority.

LAFCos are required to review, and as necessary, update the sphere of influence for each city or special district every five years. Prior to updating a sphere of influence, LAFCo is required to conduct a Municipal Service Review (MSR). MSRs consist of written determinations relating to seven different factors, one of which is the "present and planned capacity of public facilities, adequacy of public services, and infrastructure needs or deficiencies related to … municipal and industrial water… within or contiguous to the sphere of influence."

The MSR for the City of San Buenaventura (City) was accepted by the LAFCo Board on November 14, 2012. LAFCos findings regarding the potable water system concluded the City's current potable water demand is 88 percent of the supply, with approved development projects it increases to 94 percent of the supply, with proposed development projects it increases to 96 percent of the supply, and in drought conditions the normal water demand exceeds supply.

A copy of the MSR for the City is included as an Appendix.

H. REFERENCE DOCUMENTS

The following documents were used as reference for the preparation of this Comprehensive Water Resources Report. Specific excerpts and data sources from these documents used in the preparation of this Report are included in the Appendix.

2004 Biennial Water Supply Report

2005 Ventura General Plan (August 2005), City of San Buenaventura.

2005 Ventura General Plan Final EIR, Volumes I and II (August 2005), City of San Buenaventura.

2007 General Plan FEIR Supplement

2010 Urban Water Management Plan (June 2011), Kennedy/Jenks Consultants.

Water Master Plan (March 2011), RBF Consulting.

Municipal Service Reviews for Nine Ventura County Cities (November 14, 2012), Ventura Local Agency Formation Commission (LAFCo).

2. LAND USE

A. EXISTING LAND USE

In order to determine the existing land use make-up within the City's water service area as of year-end 2012, existing land use data from the 2005 General Plan was used in conjunction with the "Development Entitlement Report 2005-2012" as provided by the City Planning Department (see Appendix). It should be noted that the "Development Entitlement Report 2005-2012" includes a listing of all development areas that have been constructed, are currently under construction, or are approved for construction. Since a breakdown of the construction status for the development areas listed in the table are not available at this time, then all of the development area listed is assumed to be "existing" as of the end of year 2012 for the purposes of this Report.

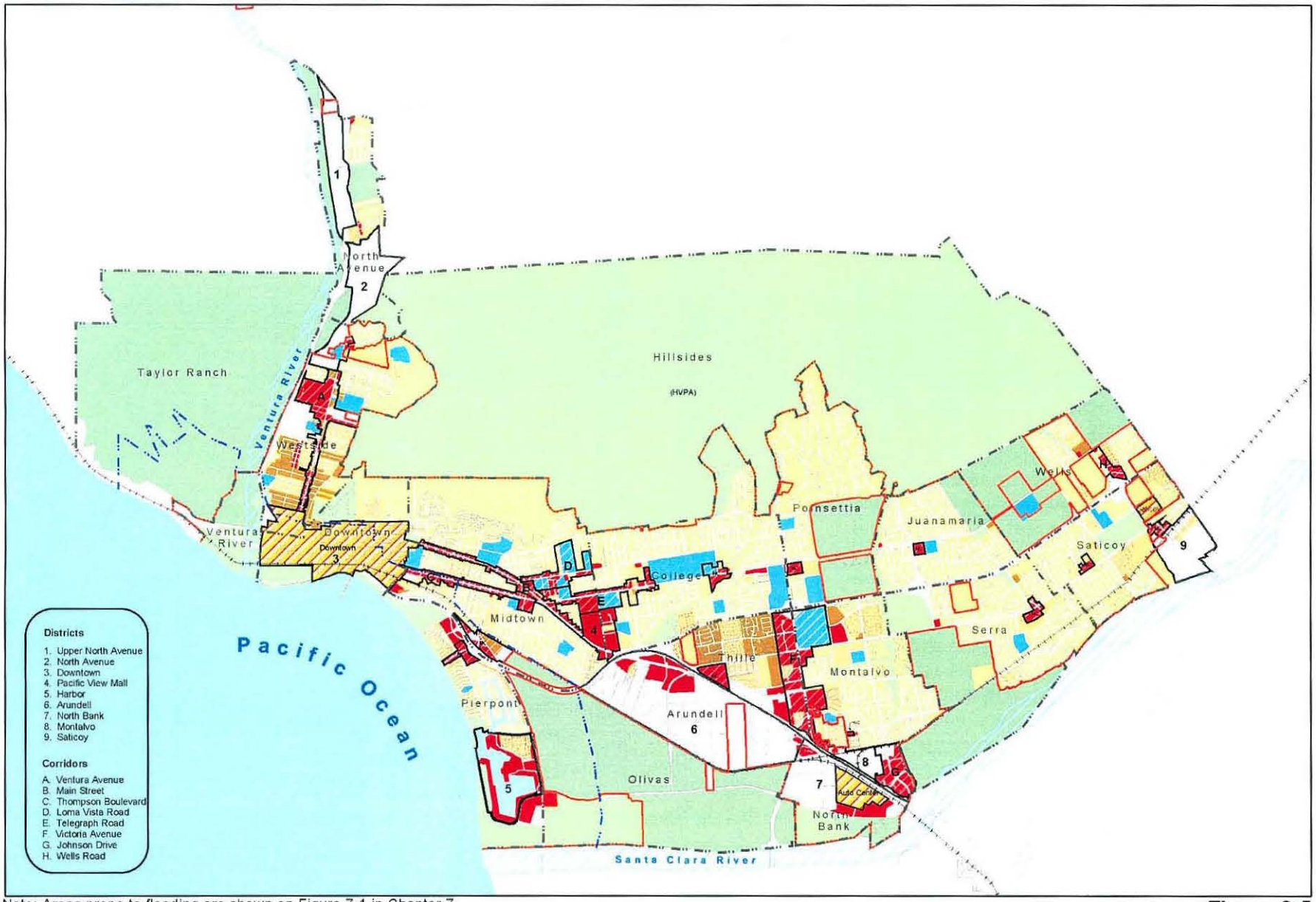
Table 3-1 of the 2005 General Plan (see Appendix) identifies the existing land uses (as of year-end 2004) in dwelling-unit count and square-footage, and the additional potential development area within the General Plan boundary. Table 2-1 herein provides a summary of the existing development as of year-end 2004 and the potential future development within the General Plan land use categories. Exhibit 2-1 (a copy of Figure 3-5 from the General Plan) depicts the land use designations throughout the City as identified in the 2005 General Plan.

Table 2-2 summarizes the existing development identified in the 2005 General Plan into Residential and Non-residential categories. The development information for years 2005-2012 provided by the City was added to the existing land use information from the 2005 General Plan to determine a snap-shot of the current land use condition for year-end 2012.

Table 2-1
Existing Land Uses per 2005 General Plan [1]

Planning Designation	Allowed Density (du/acre)	Existing Development as of 2004		
		Single Family (units)	Multi Family (units)	Comm/Ind (sf)
Neighborhood Low	0-8	19,425	3,335	49,386
Neighborhood Medium	9-20	1,163	8,965	149,513
Neighborhood High	21-54	814	2,468	194,143
Commerce		257	490	4,995,248
Industry		29	31	8,299,840
Public and Institutional		4	0	54,422
Park and Open Space		6	0	15,491
Agriculture		4	0	19,550
Downtown Specific Plan	21-54	332	1,543	1,795,401
Harbor District		0	310	350,160
Total		**22,034**	**17,142**	**15,923,154**

[1] Source: Table 3-1 of 2005 Ventura General Plan



Note: Areas prone to flooding are shown on Figure 7-1 in Chapter 7.

Figure 3-5

GENERAL PLAN DIAGRAM

Neighborhood
- Low (up to 8 du/ac)
- Medium (9-20 du/ac)
- High (21-54 du/ac)

- Commerce
- Industry
- Public and Institutional

- Agriculture
- Parks and Open Space
- Specific Plan Area

- Corridors, Neighborhood Centers (NC)
- Districts

- City Limits
- Planning Communities
- California Coastal Zone Boundary

This map is a product of the City of San Buenaventura, California. Although reasonable efforts have been made to ensure the accuracy of this map, the City of San Buenaventura cannot guarantee its accuracy.

Exhibit 2-1

Table 2-2
Summary of Existing Land Use

	Residential Development (units)	Non-Residential (sf)
Existing (as of 2005 General Plan) [1]	39,176	15,923,154
Constructed (2005 thru 2012) [2]	3,035	1,280,823
Total Existing Land Use (through 2012)	**42,211**	**17,203,977**

[1] Source: Table 3-1 of 2005 General Plan.
[2] Source: Attachment D: Development Entitlement Report (2005-2012) (Approved, Under Construction and Built Projects), provided by City 02/26/2013.

B. FUTURE LAND USE

Table 3-2 of the 2005 General Plan (see Appendix) identifies the predicted development intensity and pattern that was anticipated to occur within the General Plan boundary through the planning horizon of year 2025. As mentioned previously, the City provided information as to the development areas that have been constructed, are currently under construction, or are approved for construction since the 2005 General Plan through the end of year 2012. Table 2-3 provides a summary of the 2005 General Plan predicted development, a summary of the 2005-2012 development report, and calculates the remaining developable land through the 2025 planning horizon. It should be noted that in each of the referenced tables, the residential unit count is not divided up by the density.

Table 2-3
Summary of Predicted Development, Actual Development and Remaining Development

	Residential Development (units)	Non-Residential				
		Retail (sf)	Office (sf)	Industrial (sf)	Hotel (sf)	Total (sf)
2005 General Plan Prediction [1]	8,318	1,241,377	1,213,214	2,235,133	530,000	5,219,724
Actual Development (through 2012) [2]	3,035	258,974	485,733	449,116	87,000	1,280,823
Remaining Developable Land (through 2025)	**5,283**	**982,403**	**727,481**	**1,786,017**	**443,000**	**3,938,901**

[1] Source: Table 3-2 of 2005 General Plan.

[2] Source: Attachment D: Development Entitlement Report (2005-2012) (Approved, Under Construction and Built Projects), provided by City 02/26/2013.

3. WATER DEMANDS

A. Existing Demand Condition

Typically, the existing demand condition can be determined by evaluating the most recent historical water consumption records maintained by the City. Water consumption data is available through FY 2011-2012, however, as discussed in Section 2, the land use data is not currently available to directly correlate the FY 2011-2012 water demand data with the occupied land use at that time. For that reason, it makes it more difficult to project the future demands. Therefore, in order to determine the existing water demand condition, and also to project the future demand conditions, this Report will utilize water consumption data from water demands with data for the year 2005, which can be directly correlated to the land use data at that time. The "existing" water demand will be projected based on the 2005 consumption and land use data, the current land use condition as described in Section 2, and water demand factors identified in the 2005 General Plan FEIR (see Appendix).

The City's water production to meet the annual metered consumption of its customers in 2005 was approximately 20,808 AFY, per the 2010 UWMP. In comparison, the FY 2011-2012 water consumption was approximately 17,300 AFY. Utilizing the development data provided by the City for 2005-2012, and applying the water demand factor for each land use as identified in the 2005 General Plan FEIR, the estimated current water demand in the City water service area is 22,754 AFY (see Table 3-1).

B. Future Demand Projection (through 2025)

The 2005 General Plan FEIR water demand factors were then applied to the remaining developable area, per Table 2-3, to calculate the anticipated water demand increase. Per Table 3-2, the water demand is projected to increase by 4,020 AFY, resulting in an estimated future water demand in the City water service area of 26,774 AFY in 2025.

Table 3-1
Current Water Demand Projection

	Usage Factor [1]	Quantity [2]	Estimated Average Annual Water Demand	
2005 Water Demand [3]				20,808 AFY
Water Demand Projections (2005-2012)				
Residential	450 gpd/du	3,035 du	1,365,750 gpd	1,530 AFY
Retail	250 gpd/ksf	259 ksf	64,744 gpd	73 AFY
Office	250 gpd/ksf	486 ksf	121,433 gpd	136 AFY
Industrial	315 gpd/ksf	449 ksf	141,472 gpd	158 AFY
Hotel	500 gpd/ksf	87 ksf	43,500 gpd	49 AFY
Total Current Water Demand				***22,754 AFY***

[1] Per Table 1-2 "General Plan FEIR" water demand factors.

[2] Per Table 2-3.

[3] Per Table 2-5 of 2010 UWMP.

Table 3-2
Future Water Demand Projection (through 2025)

	Usage Factor [1]	Quantity [2]	Estimated Average Annual Water Demand	
Current Water Demand [3]				22,754 AFY
Future Water Demand Projections (thru 2025)				
Residential	450 gpd/du	5,283 du	2,377,350 gpd	2,663 AFY
Retail	250 gpd/ksf	982 ksf	245,601 gpd	275 AFY
Office	250 gpd/ksf	727 ksf	181,870 gpd	204 AFY
Industrial	315 gpd/ksf	1,786 ksf	562,595 gpd	630 AFY
Hotel	500 gpd/ksf	443 ksf	221,500 gpd	248 AFY
Total Future Demand Projection				***26,774 AFY***

[1] Per Table 1-2 "General Plan FEIR" water demand factors.

[2] Per Table 2-3.

[3] Per Table 3-1.

4. WATER SUPPLY

A. INTRODUCTION

The City's potable water supply is derived from local groundwater basins, Lake Casitas and sub-surface water from the Ventura River. The City also has a 10,000 acre-foot per year allocation from the California State Water Project. To date the City has not received any of this water because there are no facilities to get the water to the City. There are presently five local water sources that provide water to the City water system:

- Casitas Municipal Water District (Casitas)
- Ventura River Foster Park Area (Foster Park)
    - Surface Water Intake
    - Upper Ventura River Groundwater Basin/Subsurface Intake and Wells
- Mound Groundwater Basin (Mound Basin)
- Oxnard Plain Groundwater Basin (Fox Canyon Aquifer)
- Santa Paula Groundwater Basin (Santa Paula Basin)

The City also provides recycled water from the Ventura Water Reclamation Facility (VWRF). The six current water supply sources are presented in the following section. Please refer to Exhibit 4-1 for the locations and boundaries of the City's current supply sources.

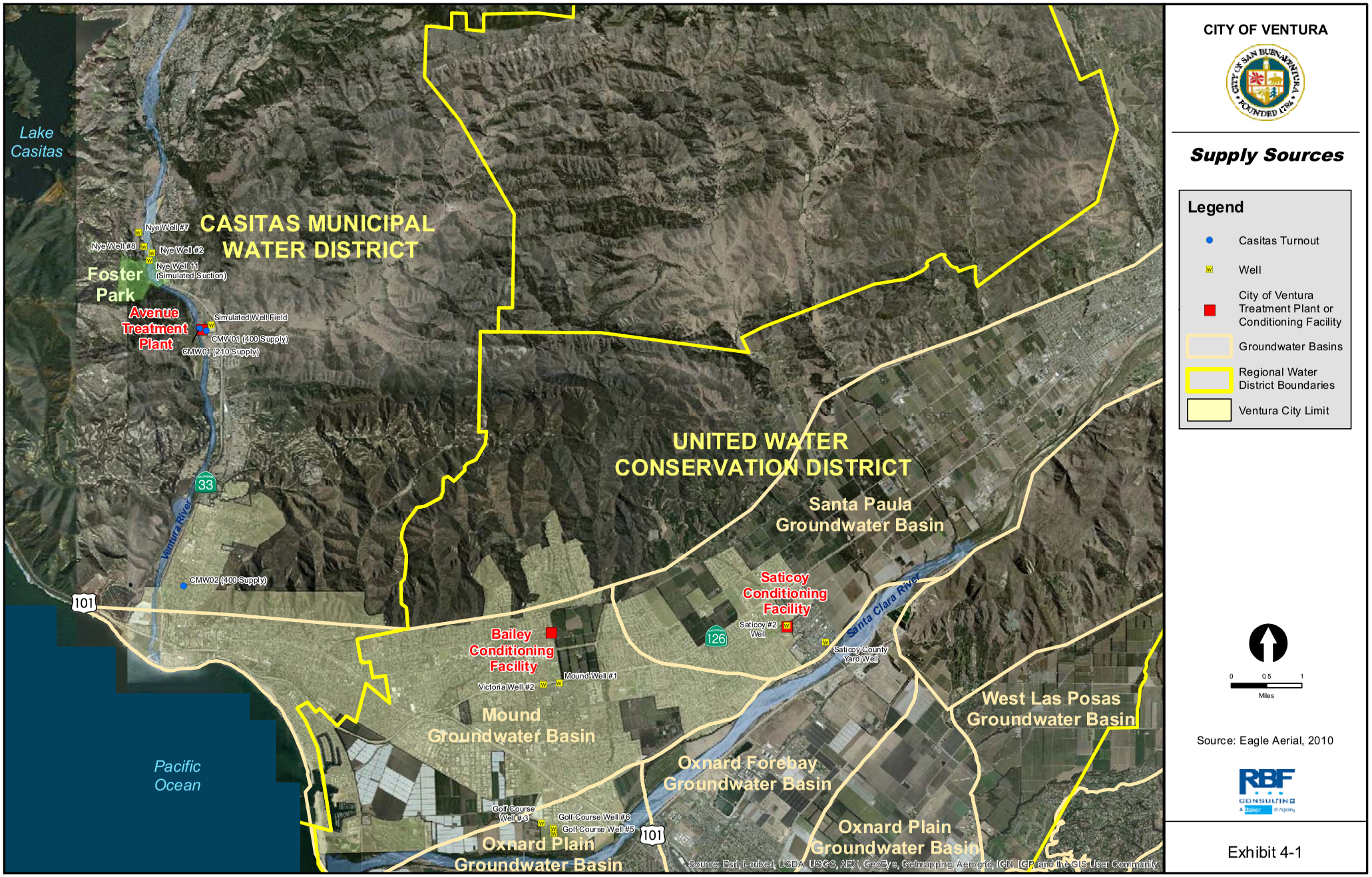


Exhibit 4-1

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B. CURRENT WATER SUPPLY SOURCES

1. Casitas Municipal Water District (Casitas)

The City purchases treated water from Casitas Municipal Water District to provide water supply to a portion of the City. In the western portion of the City approximately 30 percent of the City's water accounts are located within the Casitas service area. Storm water runoff from local watersheds is stored in Lake Casitas, located approximately 10 miles northwest of the City, then treated and delivered to customers by Casitas. Casitas supplies potable water to agricultural, domestic, municipal, and industrial users within its service area. The Casitas service area includes the Ojai Valley, the western part of the City, and the coastal area between the City and Santa Barbara County. Use of Casitas water is restricted to areas within its boundaries.

The "'safe yield" of Lake Casitas is defined to be the amount of water that can be removed from the lake each year without excessive risk that the lake will become dry. The safe yield of Lake Casitas is currently estimated to be 21,920 acre-feet per year (AFY), based on the critical historical dry period from 1944 to 1965. Studies by Casitas' engineering department have shown that this period represents the most critical dry spell for the lake's watershed of all the years which historical data is available.

To maintain the future operation of Lake Casitas at safe yield, Casitas established an allocation program for its customers in 1992. The City's allocation can be as high as the in-District demand for Stage I (wet or average year or 8,000 AFY), or reduced to 7,090 AFY for Stage 2 (dry conditions). This amount is incrementally reduced during Stages 3 and 4 dry weather conditions and results in 4,960 AFY for Stage 5 (extremely dry conditions). Stage 2 is initiated when Lake Casitas storage drops below 95,000 AF and Stage 5 is initiated when levels drop below 65,000 AF. The lower allocation remains in effect until the storage is recovered to 90,000 AF. A possible future impact to the multistage allocation system may be the operation of the fish ladder at the Robles Diversion. Casitas is currently reviewing its allocation program and this may limit the amount of water available to the City.

In July 1995, the City signed the present operating agreement with Casitas establishing the City's minimum annual purchase at 6,000 AFY, which is subject to the allocation program described above during drought periods. However, due to recent demand reductions within the Casitas boundary City customers are currently using approximately 5,000 AFY. The City is presently renegotiating the water supply agreement with Casitas. While additional supply (up to 8,000

AFY) may be available to the City in future years, the present annual supply used within the Casitas district boundary of the City service system is approximately 5,000 AFY. Therefore the City's current reliable water supply from Casitas is 5,000 AFY.

2. Ventura River Surface Water Intake and Upper Ventura River Groundwater Basin/Subsurface Intake and Wells (Foster Park)

Surface water from the Ventura River is collected via surface diversion, subsurface collector, and shallow wells and delivered to the Avenue Treatment Plant through the City's Foster Park facilities. Production from this source is a function of several factors including diversion capacity, local hydrology, environmental impacts, and the storage capacity of the Ventura River alluvium and upstream diversions.

The Ventura River water source is dependent upon local hydrology. Currently, the surface intake structure at Foster Park is unused due to the natural channeling of the active river channel bypassing the structure. Each year the flows can change the position of the active river channel in relation to the intake structure. According to a model of the Ventura River developed in 1984 and modified in 1992, the Upper Ventura River Basin fills after one or more years of above average rainfall. Once full, it takes three successive years of drought, with below average rainfall to deplete the river basin subsurface storage and cause river water production to drop until the drought ends. More recent ongoing studies are looking at the interaction between groundwater diversion and surface water flow in the Foster Park reach.

The Foster Park facilities produce groundwater throughout the year. However, due to storm flows, the wells are subject to inundation and erosion. The early 2005 winter storms destroyed Nye Well 1A and damaged Nye Wells 2, 7 and 8. The pipeline between Nye Wells 7 and 8 along the west bank of the river and the pipeline that crosses the river from Nye Well 8 to the intake pipeline for the Avenue Treatment Plant were also damaged during the storms. Nye Wells 7 and 8 were repaired in late 2006, the pipeline across the river was repaired in late 2007 and the pipeline repair between Nye Wells 7 & 8 was completed in early 2009. To date, Nye Well 2 has not been repaired.

With input from resource agencies and consultants in 2008, the City began conducting studies of the Ventura River flow conditions and is presently operating the Foster Park facilities in an environmentally responsible manner. Presently the City operations staff has voluntarily adopted a

well production schedule that limits its pumping based on annual rainfall conditions. The City intends to work with experts to ascertain a pumping regime that will balance production demands with environmental concerns and is presently studying the relationship between groundwater production and surface flows.

Estimations of approximately 6,000 AFY on average is available based on this operational scenario and is comparable to the 50-year average historical City production records between 1960 and 2009. However, current operational constraints allow a diversion efficiency of up to 70 percent (average 4,200 AFY) to be obtained under the City's operations schedule, which can be considered reliable for planning purposes and is roughly equal to the annual average for the last 10 years. Therefore the City's current reliable water supply from the Ventura River / Foster Park is 4,200 AFY. This supply number may further be drastically reduced by proposed regulatory and environmental constraints.

3. Mound Groundwater Basin (Mound Basin)

The Mound Groundwater Basin has historically provided water for overlying beneficial uses and satisfies agricultural, municipal, and industrial demands. Historical use has been documented to temporarily exceed the yield of the basin and result in water levels that have fallen below sea level and created a threat of seawater intrusion. To abate this threat the City abandoned its historical coastal well facilities and located groundwater extraction near the center of the Mound Basin. A report (Fugro, 1997) compiled as part of a 1996 study of the basin indicated that historical data supports a basin yield of at least 8,000 AFY during drought conditions as long as pumpage is reduced during wet years to allow water levels to recover.

The 1983 to 1996 average annual production from the Mound Basin was approximately 5,000 AFY (Fugro, 1997). While the resulting water levels in the basin over that time period reportedly ranged from significantly below sea level to a sufficient elevation about sea level to control seawater intrusion, the basin water level trend did not indicate an average production significantly above 5,000 AFY could be sustained without creating adverse conditions.

Currently, two wells withdraw water from the Mound Groundwater Basin; Victoria Well No. 2, which was installed in 1995, and Mound Well No. 1, which began production in April 2003. Victoria Well No. 1, which was installed in 1982, is considered an inactive well at this time due to maintenance and water quality issues and is scheduled for destruction.

Historical agricultural and private well uses have typically extracted about 2,000 AFY while the City's average annual extraction for the last ten years has been approximately 4,000 AFY. Therefore the City's current reliable water supply from the Mound Basin is 4,000 AFY.

4. Oxnard Plain Groundwater Basin (Fox Canyon Aquifer)

Wells near the Buenaventura Golf Course have drawn from the Oxnard Plain Groundwater Basin since 1961. Currently, two wells, Golf Course Wells No. 5 and 6, produce potable water for the City's system and a third well (Golf Course Well No. 3) is out of service for major rehabilitation. This third well could be used as an emergency source and will only return to service during a drought, following the replacement of wellhead, pump, electrical and raw water connection. These wells pump from the Fox Canyon Aquifer of the Oxnard Plain Groundwater Basin.

The Fox Canyon Groundwater Management Agency (GMA) was created by state legislation in 1982 to manage local groundwater resources in a manner to reduce overdraft of the Oxnard Plain and stop seawater intrusion. A major goal of the GMA is to regulate and reduce future extractions of groundwater from the Oxnard Plain aquifers, in order to operate and restore the basin to a safe yield. In August 1990, the GMA passed Ordinance No. 5, which required existing groundwater users to reduce their extractions by five percent every five years until a 25 percent reduction was reached by the year 2010.

The City's historical allocation was set by the GMA at 5,472 AFY, which was the average extraction from the Golf Course Wells for the base period 1985 to 1989. Beginning in 1992, historical extractions set by the GMA were reduced by five percent (5%) to 5,198 AFY, in 1995 it was reduced to 4,925 AFY, in 2000 it was reduced to 4,651 AFY and further reduced in 2010 to the current allocation of 4,100 AFY. Therefore the City's current reliable water supply from the Oxnard Plain Basin is 4,100 AFY.

5. Santa Paula Groundwater Basin (Santa Paula Basin)

The Saticoy Water Company was acquired by the City in 1968, which included Saticoy Well No. 1 that produced water from the Santa Paula Basin. Due to casing failure, the well was destroyed and replaced in 1991 with a new well designated as Saticoy Well No. 2. Well No. 2 was placed in

the same general location as Well No. 1. In May 2003, Saticoy Well No. 2 was rehabilitated. After rehabilitation, the resulting sustainable well supply was 1,600 AFY.

In March 1996, the City ended a five-year stalemate over the use of the Santa Paula Basin. Under a court stipulated judgment, the United Water Conservation District (United), the Santa Paula Basin Pumpers Association (an association of ranchers and businesses) and the City all have an interest in the Santa Paula Basin. The City can pump on average 3,000 AFY from the Santa Paula Basin. The City is not limited to this allocation in any single year, but may produce seven times its average annual allocation (21,000 AF) over any running seven-year period. In addition, the City may pump an additional 3,000 AFY in case of an emergency resulting from a long-term drought situation.

If the court finds that the safe yield of the basin is less than the total pumping allocations, then the City may have reductions in pumping allocations. Stage 2 reduces the City's pumping to 1,141 AFY, Stage 3 reduces the City's pumping allocations to 641 AFY, Stage 4 reduces the City's pumping allocations to 481 AFY and Stage 5 reduces the City's allocations to zero.

However, due to the existence of only the one well, the City can only reliably count on the production of that well to provide supply at this time. Therefore the City's current reliable water supply from the Santa Paula Basin is 1,600 AFY.

6. Recycled Water

The City collects and treats wastewater at their Ventura Water Reclamation Facility (VWRF). The reclamation facility has a current capacity of 12 MGD. Average annual flows to the reclamation facility total approximately 9 MGD. A portion of the effluent is pumped to recycled water customers and the remaining effluent is discharged to the Santa Clara River Estuary (Estuary). The recycled water produced from the VWRF is used for general irrigation of the two golf courses, a City park and landscape irrigation areas located along the existing distribution alignment. The City's average annual recycled water demand is approximately 700 AFY.

The City's existing water supply portfolio is summarized in Table 4-1.

Table 4-1
Summary of Current Water Supply

Water Supply Source	Current Supply (AFY)
Casitas Municipal Water District	5,000
Ventura River / Foster Park	4,200
Mound Groundwater Basin	4,000
Oxnard Plain Groundwater Basin	4,100
Santa Paula Groundwater Basin	1,600
Recycled Water	700
Total	**19,600**

C. FUTURE WATER SUPPLY

1. Casitas Municipal Water District (Casitas)

While additional supply (up to 8,000 AFY) may be available to the City in future years, the present annual supply used within the Casitas district boundary of the City service system is approximately 5,000 AFY. Since the estimated future water demands within the Casitas district boundary of the City will only nominally increase, the anticipated future water supply from Casitas will remain approximately 5,000 AFY.

2. Ventura River Surface Water Intake and Upper Ventura River Groundwater Basin/Subsurface Intake and Wells (Foster Park)

In conjunction with the Matilija Dam Ecosystem Restoration Project, two additional wells were installed at Foster Park as part of the mitigation measures. The wells, identified as the Foster Park Wellfield Restoration Project (Wells no. 12 and 13), were constructed by and funded through a grant received by the Ventura County Watershed Protection District for the City in order to mitigate for water lost as a result of increases in turbidity due to the removal of Matilija Dam. To date these wells have not been activated and are not to be operated until the project related impacts after removal of Matilija Dam necessitate the activation of these new wells. These two wells will be operated in accordance with the National Marine Fisheries Biological Opinion for the project.

It is anticipated that future construction of the Foster Park Wellfield Production Restoration Project and the expansion of the Avenue Treatment Plant to its maximum capacity will increase the supply from this source in the future. These improvements are anticipated to restore historical production capabilities to produce up to 6,700 AFY.

3. Mound Groundwater Basin (Mound Basin)

The City anticipates conducting a study within the next few years to review the perennial yield of the Mound Basin and determine if the annual average yield of the basin is still believed to be accurate. The anticipated future water supply from the Mound Basin will remain approximately 4,000 AFY.

4. Oxnard Plain Groundwater Basin (Fox Canyon Aquifer)

The anticipated future water supply from the Oxnard Plain Basin will remain as 4,100 AFY per the discussions in the previous section on the basin.

5. Santa Paula Groundwater Basin (Santa Paula Basin)

In March 1996, the City ended a five-year stalemate over the use of the Santa Paula Basin. Under an agreement with the United Water Conservation District (United) and the Santa Paula Basin Pumpers Association (an association of ranchers and businesses), the City can pump on average 3,000 AFY from the Santa Paula Basin. The City is not limited to this allocation in any single year, but may produce seven times its average annual allocation (21,000 AF) over any running seven-year period. In addition, the City may pump an additional 3,000 AFY in case of an emergency resulting from a long-term drought situation.

The City is currently constructing Saticoy Well No. 3, which will improve the water supply from the Santa Paula Basin. It is anticipated that Saticoy Well No. 3 will have an operational capacity of 2,000 gpm, thereby maximizing use of the City's 3,000 AFY allocation from the Santa Paula Basin in the near future.

However, as stated in the previous section on the Santa Paula Basin, there is potential for future reductions in the available supply. Therefore, the anticipated future water supply from the basin has a range from zero to 3,000 AFY.

6. Recycled Water

The City's existing Reclaimed Water Policy continues to encourage the use of recycled water. New development located near existing recycled water mains or within the defined recycled water focus area is required to use recycled water in lieu of potable water for irrigation and other uses as appropriate. In 2007, Kennedy Jenks Consultants completed a study on the potential recycled water market within the City. The total demand within the City limits that could potentially utilize recycled water was estimated at 1.3 MGD. Therefore, the anticipated future water supply from the VWRF at this time is 1,400 AFY.

The City's future water supply portfolio is summarized in Table 4-2.

Table 4-2
Summary of Future Water Supply
From Existing Sources

Water Supply Source [1]	2015 Supply (AFY)	2020 Supply (AFY)	2025 Supply (AFY)
Casitas Municipal Water District	5,000	5,000	5,000
Ventura River / Foster Park	4,200	4,200 - 6,700	4,200 - 6,700
Mound Groundwater Basin	4,000	4,000	4,000
Oxnard Plain Groundwater Basin	4,100	4,100	4,100
Santa Paula Groundwater Basin [2]	0 - 3,000	0 - 3,000	0 - 3,000
Recycled Water	700	700	1,400
Total	**18,000 – 21,000**	**18,000 – 23,500**	**18,700 – 24,200**

[1] None of these numbers preclude the City's water rights.

[2] The Santa Paula Basin Judgment allows the City to utilize on average 3,000 AF annually. There is potential for future reductions, therefore the supply range is shown from zero to 3,000 AFY.

D. POTENTIAL ADDITIONAL FUTURE SUPPLY SOURCES

This section will briefly describe any planned or proposed projects which may affect the water supply sources for the City.

1. State Water Project

The City has a 10,000 acre-foot per year allocation from the California State Water Project (SWP). The base contractual agreements concerning the City's annual entitlement to 10,000 acre-feet of SWP are: (1) the 1963 State Water Supply Contract of 20,000 acre-feet entitlement of SWP water between the Department of Water Resources (DWR) and Ventura County Watershed Protection District (VCWPD) known formerly as Ventura County Flood Control District (VCFCD); (2) the 1970 agreement between VCFCD and Casitas known formerly as the Ventura Municipal Water District that assigned the 20,000 acre-feet entitlement to Casitas; and (3) the 1971

agreements between Casitas and the City providing the City with an annual entitlement of 10,000 acre-feet and Casitas and United providing United with an annual entitlement of 5,000 acre-feet. Ventura's 10,000 acre-foot entitlement offers the City the potential future advantage of using the SWP entitlement to augment the current water supply. At this time the City does not have the facilities required to deliver SWP water into the distribution system. The City's goal has been to protect and provide the additional water supply for our community, while minimizing the financial impact of keeping this entitlement.

The City pays annual SWP Table A water fees to DWR, which cover construction costs for SWP facilities and administration to deliver allotments of water throughout the state. In addition, the citizens of Ventura voted November 3, 1993 in favor of desalinating seawater over importing water through the SWP, as the preferred supplemental water supply option. However, based on the City Attorney's review of the City's SWP Table A water, the City cannot unilaterally end its involvement in the SWP's financial obligations and SWP Table A water without great risk.

The Monterey Amendment to the State Water Contract in 1999 provided the City a formal mechanism to allow the City to place their SWP water into a "turn back" pool to be purchased by other SWP contractors. The City has taken part in the SWP "turn back" pool over the past several years which has provided a small annual revenue offset. The City has also worked recently with United who requested to receive the City's allocation at the "turn back" pool rate which provided water benefits to the County area as a whole.

Recent changes in the regulations and the current potential market for state water has provided a possible opportunity for the City to recover a more significant revenue offset. However, at the same time the annual costs associated with SWP water are anticipated to increase substantially while the available supply from the state has gone down resulting in a reduction of allocation to SWP Contractors in recent years to 40-50%. The higher costs and lower supplies are due to proposed projects in the Sacramento-San Joaquin Delta because of several years of drought and environmental concerns over protecting endangered species. The City is evaluating the existing policy on SWP water and the City's options related to short term and long term leases of its SWP entitlement.

2. Saticoy County Yard Well

In 2004 the County of Ventura proposed relocating their maintenance yard from the existing location to a site within the Saticoy Community contiguous to the City's water system. In exchange for City water service, which required an extraterritorial water service agreement, the County provided the City with a new well and pipeline facilities. The new well was provided to offset the County's anticipated water demand, as well as, provide significant additional water supply. The pipeline facilities provided by the County included approximately 2,320 feet of 14" pipeline from the new well to a location where the City would eventually complete the remainder of the raw water pipeline to the City's existing Saticoy Conditioning Facility for treatment.

A domestic pipeline was also provided that tied into the City's existing pipeline system at two locations. The County's' facilities were completed in 2006. The City's Capital Improvement Program (CIP) Plan included the City's portion of the raw water pipeline that connected the County provided raw water pipeline to the City's Saticoy County Yard Well. The City's' portion was completed in 2009. In November 2009 the City Council was to certify the Final EIR for the Saticoy & Wells Community Plan and Development Code. During the certification process the Fox Canyon Groundwater Management Agency (FCGMA) and United voiced concerns regarding the water supply anticipated from the Saticoy Yard Well for the project area. Consequently, the City approved a *Limitation and Tolling Agreement* whereby the parties agreed to a cooperative Operations Testing Plan to provide testing of the impact of the water drawn from the Saticoy County Yard Well. As a result of the testing under the Operations Plan it was determined that the April 2004 County of Ventura Saticoy Operations Yard EIR was not sufficient for the anticipated operations of the Saticoy County Yard Well and therefore additional environmental clearance is warranted for operation of the well.

Therefore, the anticipated future water supply from the Saticoy County Yard Well is unknown at this time. It should be noted that the City's 2005 Urban Water Management Plan (UWMP) and 2008 Biennial Water Supply Report included the Saticoy County Yard Well as a water supply source of up to 2,400 acre-feet per year.

3. Recycled Water

a. Ventura Water Reclamation Facility (VWRF)

As mentioned previously, currently the City's Water Reclamation Facility (VWRF) discharges most of its tertiary treated effluent to the Santa Clara River Estuary (Estuary) with approximately 700 acre-feet per year (AFY) diverted as recycled water for landscape irrigation by several users.

The City's current and past recycled water planning efforts have centered on issues related to the beneficial uses of the Estuary. These issues have required the City to consider whether or not discharge from the VWRF provided enhancements to the beneficial uses of the Estuary, and consequently affects the amount of recycled water that can supplement domestic water supply. The following describes the history and issues related to recycled water planning within the City's service area.

Historically, the VWRF has been permitted to discharge the majority of its effluent to the Estuary. However, during the 2008 re-issuance process, controversy arose on whether or not the City should be permitted to continue its current volume of discharge into the Estuary. The Discharge Permit issued by the RWQCB allowed continuation of the discharge but required the City to perform three extensive studies.

The studies included the Estuary Subwatershed Study (completed March 2011), Phase 1 Recycled Water Market Study (completed March 2010), and Treatment Wetlands Study (completed March 2010). The Discharge permit also identified a Phase 2 of the Recycled Water Study.

A draft of the Phase 2 Recycled Water Study was recently completed and a Stakeholder Workshop was held at the City on February 21, 2013. The intent of the study was to answer the following question, "What is the best use of the treated water resources from the VWRF to protect the health of the Estuary?" The previous studies mentioned and previous workshops narrowed potential project alternatives down to the most feasible and most beneficial. Some of the alternatives being considered in the Draft Phase 2 Recycled Water Study have the potential of providing the City with some amount of additional water supply in the future. This could be additional recycled water to offset

current potable uses or an additional water supply utilizing indirect or direct potable reuse.

b. Ojai Valley Sanitary District (OVSD)

In 2007, the City in partnership with the Ojai Valley Sanitary District (OVSD), completed a preliminary feasibility analysis for the re-use of effluent currently discharged from OVSD into the Ventura River. The discharge averages approximately 2 million gallons per day, and enters the river approximately 5 miles upstream of the Pacific Ocean. The first part of the analysis focused on environmental issues primarily related to impacts of reduced discharge flow on the receiving environment, and possible impacts to water quality as a function of reduced flows. The second part of the analysis considered engineering and market issues related to different levels of effluent re-use. Ultimately, from an economic perspective, the cost and difficulty of providing the infrastructure necessary to supply recycled water to potential users has to be balanced against the demand for such water, and the willingness of potential users to pay for it.

The engineering and market analysis identified a cost-effective combination of localized users that minimized the additional infrastructure necessary to supply the recycled water. The primary users identified were Aera Energy and local growers, with Aera accounting for the bulk of the demand. These users, which are currently supplied water from the City with a combination of untreated and potable water, could utilize recycled water in the future. The primary users in the 2007 study have reduced their water demands and the combined FY 2011-2012 water consumption of these users is approximately 300 AFY. Collectively, the environment, engineering and market analysis suggested that the re-use of at least a portion of the effluent is sufficiently feasible to justify further consideration, although full CEQA documentation and review will be necessary prior to implementation. The City and OVSD continue to discuss and work together to investigate the potential reuse of OVSD effluent.

4. Water Conservation Measures/Water Efficiency Plan

Water conservation measures may help sustain existing water use and delay the need for new water supplies. In 2011, City Council adopted a five-year Water Efficiency Plan that focuses, amongst other efforts, on educating the youth and reducing outdoor landscape watering. Outdoor

landscaping accounts for 40% to 60% of water use for residential units. The second year of the plan continues to focus efforts on reducing residential landscape watering. The efforts concentrate on appropriate watering for mature landscape as well as the planting of more sustainable gardens. Ocean Friendly Gardens provide potable water use savings as well as environmental sustainability capturing storm runoff. The City currently meets the State mandated 20% reduction target. City efforts now focus on maintaining this savings threshold and possibly providing a buffer in a three year drought period. This will be a continuing challenge for the City.

5. Establish Water Rights Ordinance

In September 2012, Ventura Water took the concept of a water rights ordinance to Council. As new development is proposed, a consistent methodology is important for securing water rights and projecting water demands. To maintain the City's supply levels and support long term sustainability, Ventura Water is drafting language for inclusion in a new water rights ordinance. The draft language includes providing rights, buying rights to offset new development demand, purchasing the City's rights as well as the payment of in-lieu fees. Parcels that are within the Fox Canyon Groundwater Management Agency (FCGMA) boundary that use groundwater for current water use have an opportunity to bring water rights with any proposed development. According to the FCGMA current policies, if a parcel has an "allocation" from a well within the boundary, the "allocation" may be transferred to the City so that the City's current allocation will be increased by that amount. This would generally be the case where the "allocation" is currently a municipal and industrial use (M&I). In the case where the parcel is in agriculture use and is utilizing the FCGMA's agriculture efficiency policy then the "allocation" that may be transferred to the City would be 1.5 acre-feet of groundwater "allocation" per acre of land. Parcels that are within the Santa Paula (SP) Basin boundary may have an allocation from an existing well that is serving that parcel or several parcels. Under the SP Basin Stipulated Judgment, the SP Basin Technical Advisory Committee has transfer procedures where a property owner may transfer water rights associated with the parcel to the City.

5. CONCLUSIONS & RECOMMENDATIONS

A. Conclusions

Based on the known supply conditions and the calculated water demand for the present condition, it appears that the current water demand exceeds the available supply. However, it is apparent that the "calculated" water demand for the current condition (22,754 AFY) is overly conservative. The current water demand figures calculated within this Report utilize a baseline water demand from 2005 of 20,808 AFY. Based on the FY 2011-2012 water consumption data, it is likely that the City's current water demands are closer to 17,300 AFY, below the current available supply of 19,600 AFY.

However, it is also well documented that current water demands are at historically low levels, mainly due to drought, environmental and economic factors. The City's average annual water demand for years 2005-2009 was 19,300 AFY, which is uncomfortably close to the current water supply available.

Utilizing development projections developed as a part of the 2005 General Plan, the anticipated growth in water demand through 2025 is 4,020 AFY, which results in a total projected water demand of 26,774 AFY, well above the predicted 24,200 AFY of supply (which is on the high end of the range). The future water demand projections utilize the water demand factors published in the 2005 General Plan FEIR. The demand factors are "planning-level" numbers, and therefore are on the conservative side. It is likely that the actual water demand factors are much lower than those used to project the future demands.

The City's available water supply is constantly changing, depending upon environmental and legal constraints. At any time, the available water supply for the City could drop to an annual average of 18,000 AFY.

Figure 5-1 provides a graphical representation of the existing and projected water demand

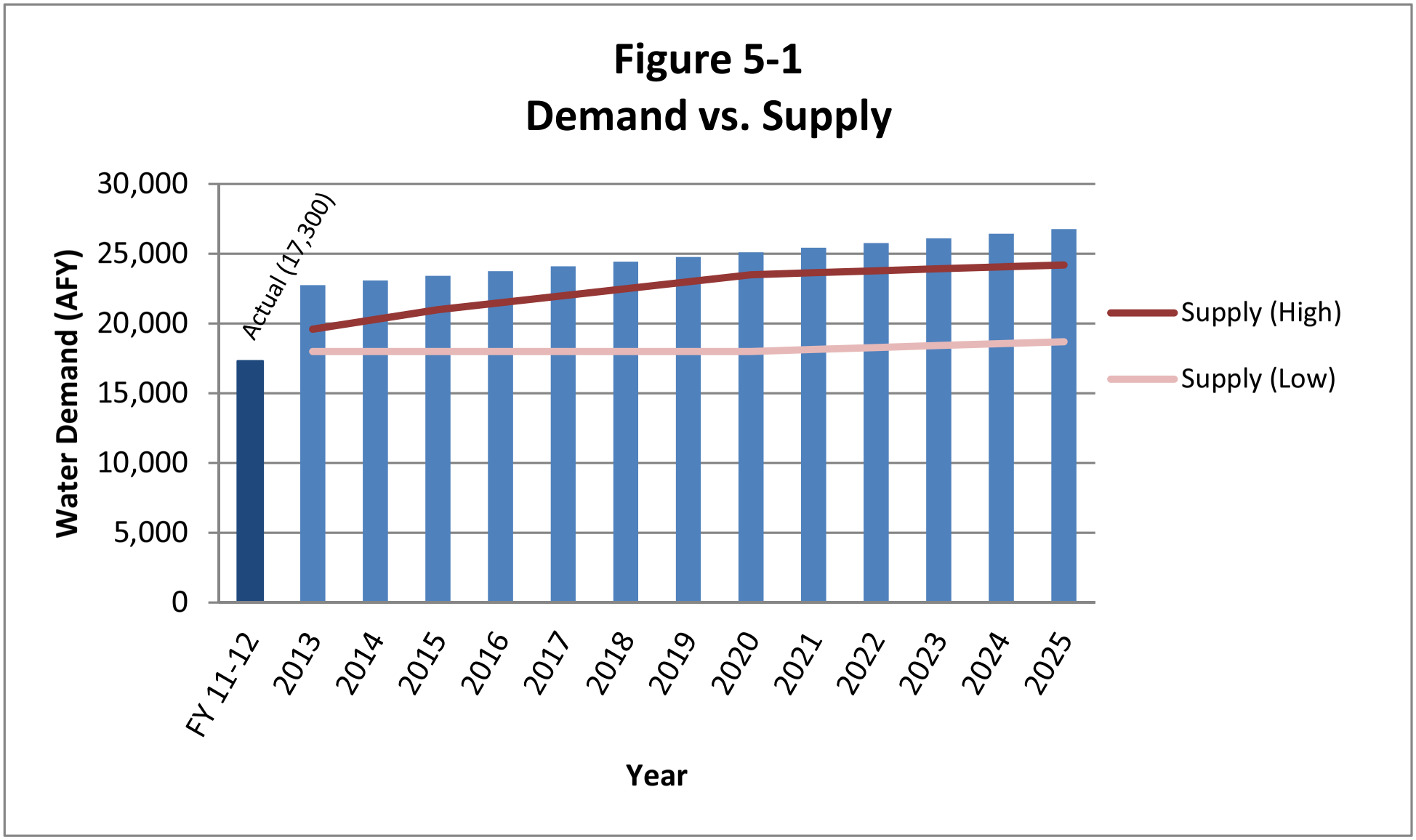


Figure 5-1
Demand vs. Supply
30,000
25,000
20,000
15,000
10,000
5,000
0
Water Demand (AFY)
Actual (17,300)
FY 11-12
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Year
Supply (High)
Supply (Low)

B. Recommendations

Moving forward, it is recommended that the City utilizes current consumption data to develop both the existing demand condition, and also develop more realistic demand factors for the various land uses within the City. In order to develop more realistic demand factors, the City will need to accurately define the existing land use conditions for the various land use categories within the City. In addition, the water consumption data will need to be attributed to the correct land use categories. This can be accomplished by mapping the water billing classifications with the General Plan land use categories, and perhaps developing a new set of water demand factor classifications. By utilizing current water consumption data, and current land use data, a more accurate set of water demand factors can be determined. The more accurate demand factors will allow for a more realistic projection of future water demands where the development plan has been identified.

APPENDICES

Demand Factors from Other Agencies:
- Simi Valley (VCWWD No. 8)
- Thousand Oaks
- Irvine Ranch Water District
- Santa Margarita Water District

LAFCo 13-01S Sphere of Influence Report

2005 General Plan:
- Table 3-1
- Table 3-2
- Figure 3-1
- Figure 3-5

2005 General Plan FEIR:
- Table 4-13.7
- Table 4-13.8
- Table 4-13.15

2010 UWMP:
- Table 2-1
- Table 2-5
- Table 3-1

2011 Water Master Plan:
- Tables II-1 thru II-4
- Table V-14

LAFCo MSR Report

Attachment D: Development Entitlement Report 2005-2012 (Approved, Under Construction and Built Projects)

2005 General Plan FEIR Water Demand Factors (email correspondence)

C. Water Demand and Peaking Factors

The water demand factors for different land use types within the District are as follows:

Table III - 1: Water Demand Factors

Land Use Description	Density (DU/Acre)	Demand Factor*	Unit*
High Density Residential	10.1 – 18.1+	5.70	gpm/acre
Medium Density Residential	3.1 – 10	1.40	gpm/acre
Low Density Residential	0 – 3	1.10	gpm/acre
Detached Residential			
Small, up to 9,999 SF lot	--	420	gal/du/day
Medium, 10,000 to 22,000 SF lot	--	840	gal/du/day
Large, 22,001 to 1 Acre SF lot	--	1680	gal/du/day
Condominium	--	259	gal/du/day
Multi-Family Apartment	--	222	gal/du/day
Retirement Facility (per room)	--	92	gal/du/day
Senior Apartment	--	111	gal/du/day
Commercial – Light	--	1.75	gpm/acre
Commercial – Heavy	--	2.35	gpm/acre
Commercial – Office	--	2.00	gpm/acre
Industrial – Light	--	1.95	gpm/acre
Industrial – Heavy	--	9.20	gpm/acre
Industrial – Business Park	--	2.00	gpm/acre
Parks	--	1.10	gpm/acre
Hospitals	--	1.85	gpm/acre
Schools	--	1.20	gpm/acre
Community Services	--	1.35	gpm/acre

*Factor shall be applied to raw acreage and not building footprint.

Peaking factors are used to estimate maximum month, maximum day and peak hour demands. These factors, wherever possible, are based on actual water usage. When actual water data is not available, peaking factors are based on typical industry standards for water purveyors in Southern California.

Table 3-1 Land Use and Water Use Factors

		Land Use		Local Demands			Irrigation Demands	
Code	Land Use description	Agency	Average Density	Local Interior	Local Exterior	Total	% Irrigated Area	Irrigation Factor
1100	*Residential*		*DU/Ac*		*Gal/DU/Day*			*Gal/Ac/Day*
1111	Res - Rural Density	Orange	0.30	300	750	1,050	5	2,800
1121	Res - Estate Density	Orange	1.20	300	300	600	8	2,900
1131	Res - Low Density	Orange	4.00	300	300	600	15	2,900
1141	Res - Low-Medium Density	Orange	10.50	200	100	300	22	3,300
1161	Res - Medium Density	Orange	19.50	225	185	410	17	3,100
1122	Res - Estate Density	Irvine	0.50	300	600	900	7	2,800
1132	Res - Low Density	Irvine	3.00	225	180	405	16	3,000
1162	Res - Medium Density	Irvine	7.50	200	110	310	20	3,100
1172	Res - Medium-High Density	Irvine	17.50	165	15	180	25	3,600
1182	Res - High Density	Irvine	32.50	180	20	200	20	3,300
1133	Res - Low Density	Newport Beach	1.00	250	190	440	17	3,100
1153	Res - Medium-Low Density	Newport Beach	2.75	250	200	450	10	2,800
1163	Res - Medium Density	Newport Beach	5.00	190	60	250	22	3,300
1183	Res - High Density	Newport Beach	12.25	155	20	175	25	3,600
1134	Res - Low Density PC	Tustin	4.50	225	185	410	17	3,100
1164	Res - Medium Density PC	Tustin	11.80	155	15	170	25	3,600
1184	Res - High Density PC	Tustin	17.40	135	15	150	15	3,700
1115	Res - Rural Density	County	0.26	300	750	1,050	05	2,800
1135	Res - Suburban Density	County	9.25	225	180	405	16	3,000
1175	Res - Urban Density	County	29.00	165	15	180	25	3,600
1200	*Commercial*		*KSF/Ac*		*Gal/KSF/Day*			*Gal/Ac/Day*
1210	Comm - General Office		25.00	56	4	60	30	4,000
1221	Comm - Community		9.09	209	11	220	30	3,500
1222	Comm - Regional		10.53	180.5	9.5	190	20	5,000
1230	Comm - Recreation		8.33	54	6	60	30	4,500
1240	Comm - Institutional		8.88	39.38	5.62	45	50	2,750
1244	Comm - Hospital		8.70	218.50	11.50	230	25	2,850
1260	Comm - School		13.33	14.25	0.75	15	50	2,500
1273	Comm - Military Air Field							
1300	*Industrial*		*KSF/Ac*		*Gal/KSF/Day*			*Gal/Ac/Day*
1310	Industrial - Light		25.00	56	4	60	25	4,000
1320	Industrial - Heavy		25.00	4,500	500	5,000	25	4,000
	Open Space & Other							*Gal/Ac/Day*
1820	Park - Community						90	3,400
1830	Park - Regional						85	2,100
2100	AG - Low-Irrigated						100	1,800
2200	AG - High-Irrigated						100	3,100

Note: The database includes the following land use codes that do not use set factors or do not generate water demands: 0 = area not served by IRWD; 1411 = Airports; 1413 = Freeway and Major Roads; 1850 = Park-Wildlife Preserve; 1880 = Park-Open Space (Rec); 1900 = Vacant; 4100 = Water Body; 9100 = Mixed Use (uses a combination of factors)

Pipe velocities should be a minimum of 1 foot per second (fps) in order to adhere to required water quality regulations and maintain proper circulation throughout the system.

C. WATER DEMAND FACTORS

The City does not currently have published water demand factors for different land use types. For future planning projects, a more detailed list of conservative demand factors is recommended. The following demand factors, listed in Table III-1, are based on industry standards for water purveyors in the Southern California region.

Table III-1
Water Demand Factors

Land Use Description	Density (DU/Acre)	Demand Factor	Unit
High Density Residential	15-30	180	gal/du/day
Medium Density Residential	4.5-15	310	gal/du/day
Low Density Residential	2-4.5	405	gal/du/day
Very Low Density Residential	0-2	440	gal/du/day
Reserve Residential (ultimate need)	0-2	440	gal/du/day
Commercial/Residential (High Density)	15	200	gal/du/day
Commercial	-	130	gal/ksf/day
Industrial	-	60	gal/ksf/day
Institutional	-	45	gal/ksf/day
Elementary School	-	15	gal/ksf/day
Intermediate School	-	15	gal/ksf/day
High School	-	15	gal/ksf/day
Existing Parks, Golf Courses, Open Space	-	3400	gal/ac/day
Proposed Park and Recreation Areas	-	3400	gal/ac/day
Residential Developable Land (ultimate need)	0.2-1.0	440	gal/du/day

Table 3-1 Land Use and Water Use Factors

		Land Use		Local Demands			Irrigation Demands	
Code	Land Use description	Agency	Average Density	Local Interior	Local Exterior	Total	% Irrigated Area	Irrigation Factor
1100	*Residential*		*DU/Ac*		*Gal/DU/Day*			*Gal/Ac/Day*
1111	Res - Rural Density	Orange	0.30	300	750	1,050	5	2,800
1121	Res - Estate Density	Orange	1.20	300	300	600	8	2,900
1131	Res - Low Density	Orange	4.00	300	300	600	15	2,900
1141	Res - Low-Medium Density	Orange	10.50	200	100	300	22	3,300
1161	Res - Medium Density	Orange	19.50	225	185	410	17	3,100
1122	Res - Estate Density	Irvine	0.50	300	600	900	7	2,800
1132	Res - Low Density	Irvine	3.00	225	180	405	16	3,000
1162	Res - Medium Density	Irvine	7.50	200	110	310	20	3,100
1172	Res - Medium-High Density	Irvine	17.50	165	15	180	25	3,600
1182	Res - High Density	Irvine	32.50	180	20	200	20	3,300
1133	Res - Low Density	Newport Beach	1.00	250	190	440	17	3,100
1153	Res - Medium-Low Density	Newport Beach	2.75	250	200	450	10	2,800
1163	Res - Medium Density	Newport Beach	5.00	190	60	250	22	3,300
1183	Res - High Density	Newport Beach	12.25	155	20	175	25	3,600
1134	Res - Low Density PC	Tustin	4.50	225	185	410	17	3,100
1164	Res - Medium Density PC	Tustin	11.80	155	15	170	25	3,600
1184	Res - High Density PC	Tustin	17.40	135	15	150	15	3,700
1115	Res - Rural Density	County	0.26	300	750	1,050	05	2,800
1135	Res - Suburban Density	County	9.25	225	180	405	16	3,000
1175	Res - Urban Density	County	29.00	165	15	180	25	3,600
1200	*Commercial*		*KSF/Ac*		*Gal/KSF/Day*			*Gal/Ac/Day*
1210	Comm - General Office		25.00	56	4	60	30	4,000
1221	Comm - Community		9.09	209	11	220	30	3,500
1222	Comm - Regional		10.53	180.5	9.5	190	20	5,000
1230	Comm - Recreation		8.33	54	6	60	30	4,500
1240	Comm - Institutional		8.88	39.38	5.62	45	50	2,750
1244	Comm - Hospital		8.70	218.50	11.50	230	25	2,850
1260	Comm - School		13.33	14.25	0.75	15	50	2,500
1273	Comm - Military Air Field							
1300	*Industrial*		*KSF/Ac*		*Gal/KSF/Day*			*Gal/Ac/Day*
1310	Industrial - Light		25.00	56	4	60	25	4,000
1320	Industrial - Heavy		25.00	4,500	500	5,000	25	4,000
	Open Space & Other							*Gal/Ac/Day*
1820	Park - Community						90	3,400
1830	Park - Regional						85	2,100
2100	AG - Low-Irrigated						100	1,800
2200	AG - High-Irrigated						100	3,100

Note: The database includes the following land use codes that do not use set factors or do not generate water demands: 0 = area not served by IRWD; 1411 = Airports; 1413 = Freeway and Major Roads; 1850 = Park-Wildlife Preserve; 1880 = Park-Open Space (Rec); 1900 = Vacant; 4100 = Water Body; 9100 = Mixed Use (uses a combination of factors)

Table IV - 1
Santa Margarita Water District
Improvement District Nos. 4C, 4E, 5 & 6 Plan of Works
Domestic Water Use Factors

Land Use	Demands			
	Interior	Exterior	Total	
A. Residential				
Detached Residential	300	150	450	gpd/ DU
Attached Residential	175	0	175	gpd/ DU
Apartments	175	0	175	gpd/ DU
Senior SFR	200	100	300	gpd/ DU
B. Non-Residential Uses				
Commercial/ Industrial			225	gpd/ 1000sf
Community Facilities			225	gpd/ 1000sf
Elementary School			10	gpd/ student
Middle School			10	gpd/ student
High School			15	gpd/ student

VENTURA LOCAL AGENCY FORMATION COMMISSION

STAFF REPORT

Meeting Date: January 16, 2013

Agenda Item 12

TO: LAFCo Commissioners

FROM: Kim Uhlich, Executive Officer KU

SUBJECT: LAFCo 13-01S City of San Buenaventura Sphere of Influence Review and Update

---

RECOMMENDATIONS:

Adopt attached Resolution LAFCo 13-01S making determinations and updating the sphere of influence for the City of San Buenaventura.

BACKGROUND:

For each city and special district LAFCo must determine and adopt a sphere of influence. A sphere of influence is defined as a plan for the probable physical boundaries and service area of a local agency, as determined by the Commission (Government Code §56076). Effective January 1, 2001 each LAFCo is required to review and, as necessary, update the sphere of influence ("sphere" or "SOI") of each city and special district on or before January 1, 2008, and every five years thereafter (Government Code §56425(g)). Prior to updating a SOI, LAFCo is required to conduct a municipal service review ("service review" or "MSR") (Government Code §56430).

On March 21, 2007 the Commission accepted a MSR report and, on June 13, 2007, updated the City of San Buenaventura sphere of influence to conform to assessor parcel boundaries and exclude all territory subject to the Hillside Voter Participation Act. Based on a work plan for the second round of sphere reviews adopted by the Commission in May 2008, a sphere of influence review for the nine cities was scheduled for completion in 2012. On November 14, 2012 LAFCo accepted the MSR report for nine cities in Ventura County, including the City of San Buenaventura.

COMMISSIONERS AND STAFF

COUNTY:	CITY:	DISTRICT:	PUBLIC:
Kathy Long	Carl Morehouse	Bruce Dandy	Linda Ford-McCaffrey
Linda Parks	Janice Parvin, Chair	Gail Pringle, Vice Chair	
Alternate:	*Alternate:*	*Alternate:*	*Alternate:*
Steve Bennett	Carol Smith	Elaine Freeman	Lou Cunningham
Executive Officer:	Dep. Exec. Officer	Office Mgr/Clerk	Legal Counsel
Kim Uhlich	Kai Luoma	Debbie Schubert	Michael Walker

DISCUSSION:

Based on the recently accepted MSR report for the nine cities, no significant changes to the sphere for the City of San Buenaventura appear to be necessary at this time. However, a minor amendment to the sphere of influence is being recommended to remove several agricultural and rail road right of way parcels located between Highway 101 and Channel Drive (Attachment 1). The reason is to correct a recently discovered mapping error. According to County Information Technology Services Department staff, the subject territory was erroneously included in the sphere when the County transitioned to GIS from a CAD (computer aided design) system prior to 2001. Since that time, each subsequent sphere map adopted by the Commission included the territory so any decision to exclude it may only be done through formal Commission action.

The County General Plan land use designation for the territory is "Agricultural-Urban Reserve" and it is zoned "Coastal Agriculture, 40 acre minimum". The City Comprehensive Plan land use designation is "Agriculture" and is therefore subject to the City SOAR ordinance which prohibits any amendment of the agricultural land use designation without an affirmative vote of the people. The area is currently in agricultural production, no City services are being provided and no proposals for development are pending with the City. As the territory has not been designated for non-agricultural use by the City's General Plan and is not likely to be developed within five years, removal of the area from the sphere would be consistent with the Commission's general policies pertaining to agricultural and open space preservation.

Attachment 2 is a December 20, 2012 letter from Jeffrey Lambert, Community Development Director for the City of San Buenaventura, acknowledging the recommended sphere of influence update and commenting that any future decision by the City to convert the affected territory to non-agricultural uses would be largely influenced by provisions of the California Coastal Act and the City's Local Coastal Program relating to the protection of coastal agricultural lands.

For CEQA purposes, the City of San Buenaventura sphere of influence update is exempt from CEQA under Section 15061(b)(3) of the CEQA Guidelines. This is the "general rule" exemption, meaning that it can be seen with certainty that there is no possibility that the activity in question may have a significant effect on the environment because the recommended sphere of influence update reduces the extent of territory planned to be included within the City's physical boundaries and service area.

Pursuant to Government Code Section 56425(e) it is recommended that the Commission consider and adopt written statements of its determinations with respect to each of the following:

(1) *The present and planned land uses in the area, including agricultural and open-space lands.* – The sphere of influence update for the City of San Buenaventura is to provide for all areas currently developed and within the City boundary to be

included in the City's sphere of influence, and to correct a previous mapping error which resulted in the inadvertent inclusion of agricultural and rail road right of way segments within the sphere. The affected territory is currently being used for agriculture and no changes in land use are anticipated at this time.

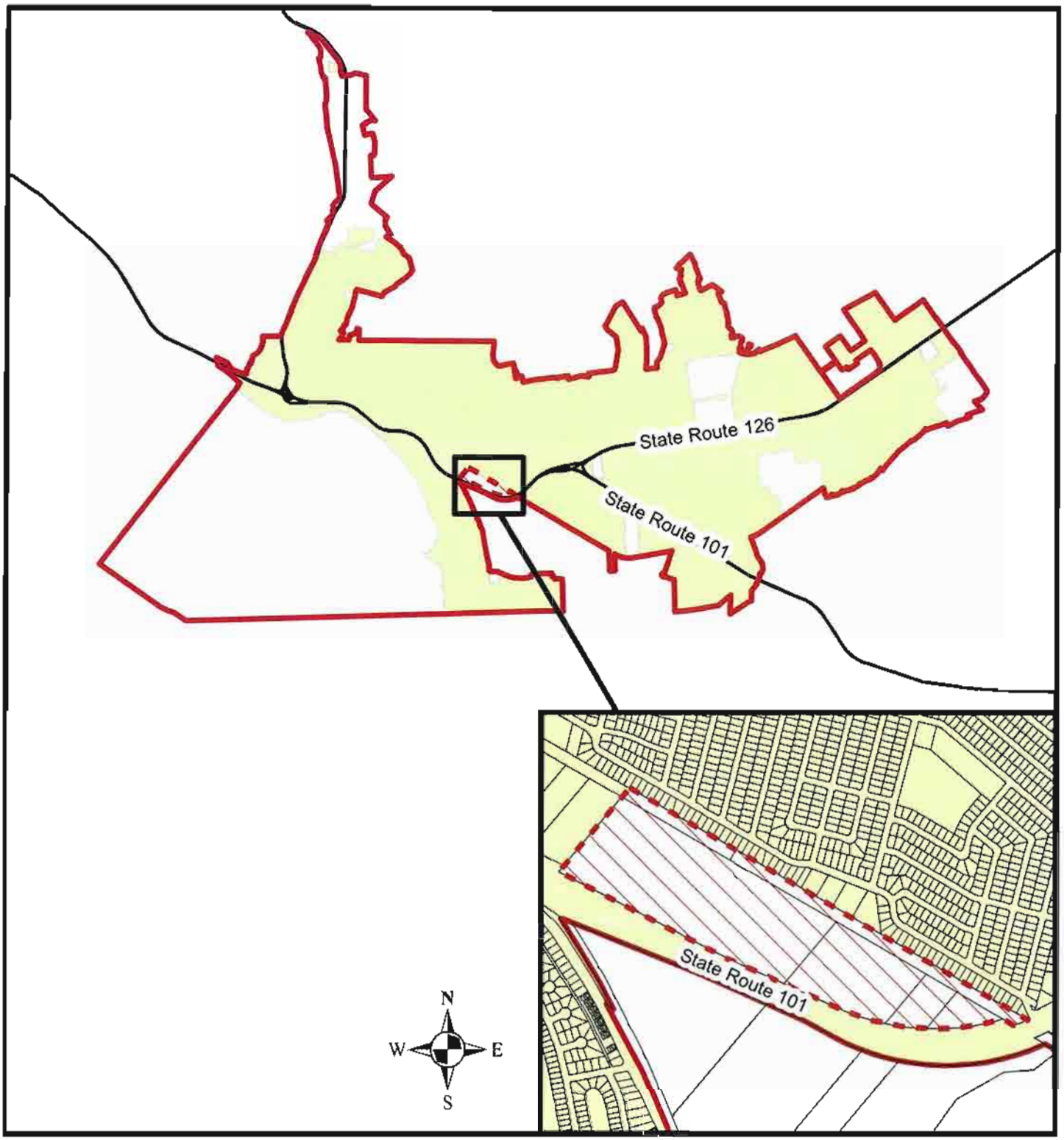
(2) *The present and probable need for public facilities and services in the area.* – No changes in public facilities or services provided by the City will result from this sphere of influence update.

(3) *The present capacity of public facilities and adequacy of public services that the agency provides or is authorized to provide.* – The sphere of influence update will not affect the present capacity of public facilities or the adequacy of the services provided by the City of San Buenaventura.

(4) *The existence of any social or economic communities of interest in the area if the commission determines that they are relevant to the agency.* - The sphere of influence update will not affect any social or economic communities of interest in the area.

(5) *The present and probable need for City sewer, municipal and industrial water, or structural fire protection services for any disadvantaged unincorporated communities within the existing sphere of influence.* – The Commission determined that the community of Saticoy, located within the City sphere of influence, is a disadvantaged unincorporated community (Commissioner's Handbook Section 3.2.5). Saticoy receives wastewater services from the Saticoy Sanitary District, an independent special district which serves only the community of Saticoy. Potable water services are provided by the City and customers are subject to the City's water surcharge for service provided outside of City limits. City policy generally precludes new or expanded water services greater than a ¾-inch meter, thus, limiting the amount of multi-family, commercial, and industrial development/redevelopment that can occur within the community. Law enforcement services are provided by the County Sheriff's Office and fire protection services are provided primarily by the City under a mutual aid agreement.

Attachments:
(1) City of San Buenaventura Sphere of Influence Map
(2) Letter from City of Ventura Community Development Director Jeff Lambert dated December 20, 2012
(3) Resolution LAFCo 13-01S – City of San Buenaventura Sphere of Influence Update



LAFCo 13-01S
City of San Buenaventura
Sphere of Influence Review/Update

Legend

- Current Sphere of Influence
- Area to be Excluded from Sphere
- City of San Buenaventura

CITY OF
VENTURA

December 20, 2012

Ms. Kim Uhlick
Ventura LAFCo Executive Officer
800 South Victoria Avenue
Mail Stop 1850
Ventura CA 93009-1850

Subject: LAFCo Sphere of Influence (SOI) Review and Updates

Dear Kim:

City staff met recently with LAFCo staff to discuss your current effort to review and update the City of San Buenaventura Sphere of Influence (SOI). LAFCo is mandated to initiate and complete this review and your intent to provide the review and update to the Commission at their January 2013 hearing.

During your review process, you found that a mapping error has occurred during the conversion of hard maps to the County GIS system for the City's SOI boundary. The subject properties in question involve several agricultural and rail road right of way parcels located between Highway 101 and Channel Drive (see attached Map and County GIS/IT Services staff memorandum). Based upon the current review effort, LAFCo seeks to correct the SOI boundary by removing the subject properties. You also provided SOI boundary documentation maps from 1981 and 1991, in addition to a 1992 City letter from then Community Development Director Everett Millais, all of which identifies the properties outside of the SOI boundary. You concluded that the SOI map adopted on June 12, 2002 is when the properties were mistakenly included in the SOI.

The City has reviewed your request and researched our historical files regarding the property site and the SOI boundary. If the mapping error is correct, then the erroneous boundary has been tracking across many planning efforts at the City. For example, the City's 1989 Comprehensive Plan includes the subject properties, the 2002 re-adoption of the Ventura-Oxnard Greenbelt excludes the properties because they were identified in the SOI, and lastly the 2005 General Plan and EIR also included the sites within the SOI, are designated under County SOAR, and were studied as part of the City's Potential Expansion Areas. The City cannot make a conclusive determination of the error or not, and therefore the Commission will need to complete their review and decide their action.

Regardless of the SOI boundary line and any future LAFCo action to update it or not, these properties are within the City's coastal zone and as such are subject to the Local

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Coastal Program (LCP) and Coastal Act provisions for agricultural resource protection. Conversion of this land to non-agricultural uses would require significant evidence and justification to overcome the strong agricultural resource protection findings of the LCP. Therefore in the framework of local/state land use regulations processes, the LCP and any necessary amendment is frankly the most important determinant for current and future land uses.

Sincerely,

Jeffrey Lambert, AICP
Community Development Director

c: Dave Ward, Planning Manager

Enclosure: County Memorandum and Map Exhibit, June 9, 2010

MEMORANDUM

DATE: 6-9-2010

TO: Kim Uhlich, Ventura LAFCo Executive Officer

FROM: David Hutchison, Sr. GIS Specialist, IT Services Department, GIS Division

SUBJECT: The Relationship of Assessor Parcels 080-0-020-150, -170, - 210, and - 290 to the City of Ventura Sphere of Influence Boundary as Reflected in the County's Initial GIS mapping records

---

The following is provided in response to your request for information about the subject territory in relation to the City of Ventura sphere of influence boundary at the time the County's Cadds data was first converted into a GIS format. As you are aware, the sphere boundary reflected in the original GIS mapping records included the subject territory and was the basis for the sphere boundary that LAFCo "re-adopted" for the City of Ventura in 2002.

The parcels in question are located between US 101 and Ventura city limits and include APNs 080-0-020-150, -170, - 210, and -290 and the freeway annexation LAFCO Resolution 69-44, Freeway Addition No. 1.

Process description: The dataset was initially developed by interpreting legal descriptions and matching boundaries to the existing parcel layer (property lines). Updates are made by merging or detaching recent city annexation or detachments polygons into the existing city sphere data.

In 1998 County GIS (formally – PWA, Engineering Mapping) started the conversion of Cadds data into a GIS format. Polygon parcels were created in ArcInfo (GIS format) from Cadds line work. City Boundaries and City Sphere boundaries were created using the same process.

In the latter months of 2001 County GIS began the process of converting City Annexations from a Cadds environment into a GIS environment. Cadds line work was imported into the GIS program and polygons were created. The polygons created were assigned attributes fields and those fields were populated. The program at the time did not allow for null polygons (holes or islands) within the boundaries. A field was created called "Island" and a value given. If the polygon was not an annexation or detachment with value fields the island field was populated with the value "y" which meant yes.

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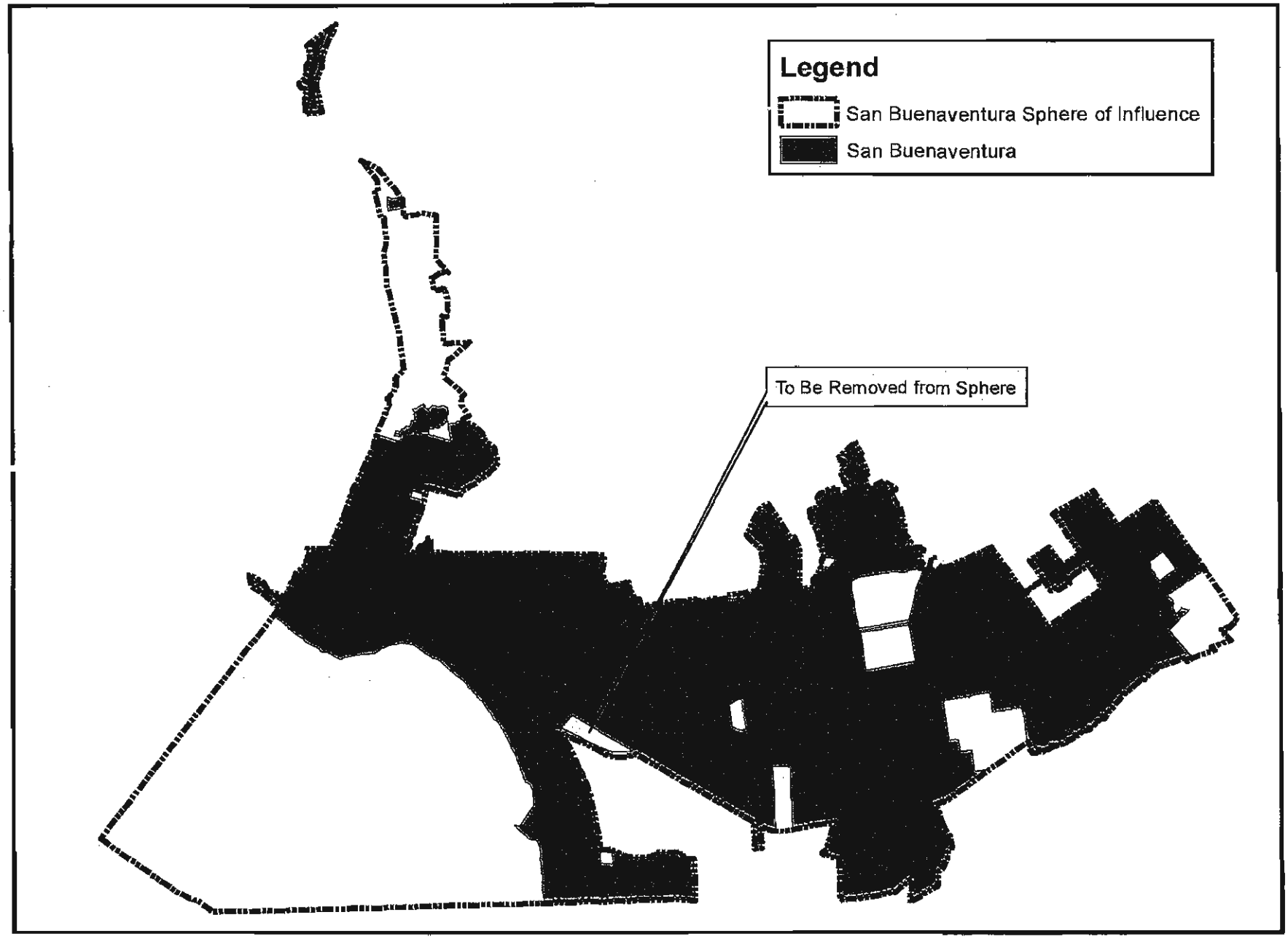
http://www.ventura.lafco.ca.gov

In order to minimize the update process for city boundaries and for the spheres to have coincident geometry for shared boundaries a work flow was developed to maintain the city annexations. The appropriate polygons were exported out to create the city boundaries and merged or detached from the sphere boundary.

The archive computer logs show:
During the creation of the city sphere for the City of Ventura the city annexations were merged to create the sphere boundary (where applicable). An island was missed as being excluded in this process (it is assumed as being missed as no documentation or correspondence can be found to support its' inclusion)* and incorporated into the sphere boundary.

*County GIS works closely with the Public Works Agency, Survey Engineering group and LAFCO to insure the accuracy of its data. After the data was converted into a GIS format the annexations, boundaries and spheres were internally checked by GIS then reviewed by Survey Engineering and LAFCO. There is no documentation or correspondence to support the inclusion of this area and it can only be assumed that at this time this was an overlooked error, as another island in a different area was not included.
It should also be noted that LAFCO Resolution 69-44 Freeway Addition No. 1 Ordinance No. 1592 Recorded on October 22, 1969 does not mention the inclusion of that area into the sphere either.


Legend
San Buenaventura Sphere of Influence
San Buenaventura
To Be Removed from Sphere

LAFCo 13-01S

RESOLUTION OF THE VENTURA LOCAL AGENCY FORMATION COMMISSION MAKING DETERMINATIONS AND APPROVING THE UPDATE OF THE SPHERE OF INFLUENCE FOR THE CITY OF SAN BUENAVENTURA

WHEREAS, Government Code Section 56425 et seq. requires the Local Agency Formation Commission (LAFCo or Commission) to develop and determine the sphere of influence of each local governmental agency within the County; and

WHEREAS, Government Code Section 56425(g) requires that LAFCo, as necessary, review and update the adopted sphere of influence boundaries on or before January 1, 2008 and every five years thereafter; and

WHEREAS, Government Code Section 56430 requires that a municipal service review be conducted prior to or in conjunction with a sphere of influence update; and

WHEREAS, LAFCo conducted a municipal service review of the services provided by the City of San Buenaventura and adopted written determinations as required by Government Code Section 56430 on November 14, 2012 for the services provided by the City; and

WHEREAS, the City staff has reviewed the changes proposed for this sphere of influence update and have no objections; and

WHEREAS, no change in regulation, land use or development will occur as a result of updating the City's sphere of influence; and

WHEREAS, at the times and in the manner required by law, the Executive Officer gave notice of the consideration of this action by the Commission; and

WHEREAS, the sphere of influence update action was duly considered at a public hearing on January 16, 2013; and

WHEREAS, the Commission heard, discussed and considered all oral and written testimony for and against the sphere of influence update including, but not limited to, testimony at the public hearing on January 16, 2013 and the LAFCo Executive Officer's staff report and recommendation;

NOW, THEREFORE, BE IT RESOLVED, DETERMINED AND ORDERED as follows:

(1) The Executive Officer's Staff Report and Recommendation for approval of the sphere of influence update for the City of San Buenaventura, dated January 16, 2013 is adopted.

(2) The Commission has considered the criteria set forth in Government Code §56425(e) and determines as follows:

a) *The present and planned land uses in the area, including agricultural and open-space lands.* – The sphere of influence update for the City of San Buenaventura is to provide for all areas currently developed and within the City boundary to be included in the City's sphere of influence, and to correct a previous mapping error. There will be no development, no change in land use and no impact to agricultural and open space lands as a result of the sphere of influence update.

b) *The present and probable need for public facilities and services in the area.* – No changes in public facilities or services provided by the City will result from this sphere of influence update. The City bases its public facilities and services on the extent of its existing infrastructure and its General Plan.

c) *The present capacity of public facilities and adequacy of public services that the agency provides or is authorized to provide.* – The sphere of influence update will not affect the present capacity of public facilities or the adequacy of the services provided by the City of San Buenaventura.

d) *The existence of any social or economic communities of interest in the area if the commission determines that they are relevant to the agency.* – The sphere of influence update will not affect any social or economic communities of interest in the area.

e) *The present and probable need for City sewer, municipal and industrial water, or structural fire protection services for any disadvantaged unincorporated communities within the existing sphere of influence.* – The Commission determined that the community of

Saticoy, located within the City's existing sphere of influence, is a disadvantaged unincorporated community (Commissioner's Handbook Section 3.2.5). Saticoy receives wastewater services from the Saticoy Sanitary District, an independent special district which serves only the community of Saticoy. Potable water services are provided by the City and customers are subject to the City's water surcharge for service provided outside of City limits. City policy generally precludes new or expanded water services greater than a ¾-inch meter, thus, limiting the amount of multi-family, commercial, and industrial development/redevelopment that can occur within the community. Law enforcement services are provided by the County Sheriff's Office and fire protection services are provided primarily by the City under a mutual aid agreement.

(3) The sphere of influence for the City of San Buenaventura is hereby updated to be the area shown as "proposed sphere of influence", as generally depicted on Exhibit A attached hereto.

(4) The Commission directs staff to have the official sphere of influence geographic information system data maintained for the Ventura LAFCo by the Ventura County Information Technology Services Department as the official sphere of influence record for the City of San Buenaventura updated consistent with this action.

(5) In accordance with the Executive Officer's determination, the Commission, as lead agency for the purposes of the California Environmental Quality Act (CEQA), hereby determines that the sphere of influence update for the City of San Buenaventura is exempt pursuant to Section 15061(b)(3) of the CEQA Guidelines.

(6) The Commission directs staff to file a Notice of Exemption as lead agency under Section 15062 of the CEQA Guidelines.

This resolution was adopted on January 16, 2013.

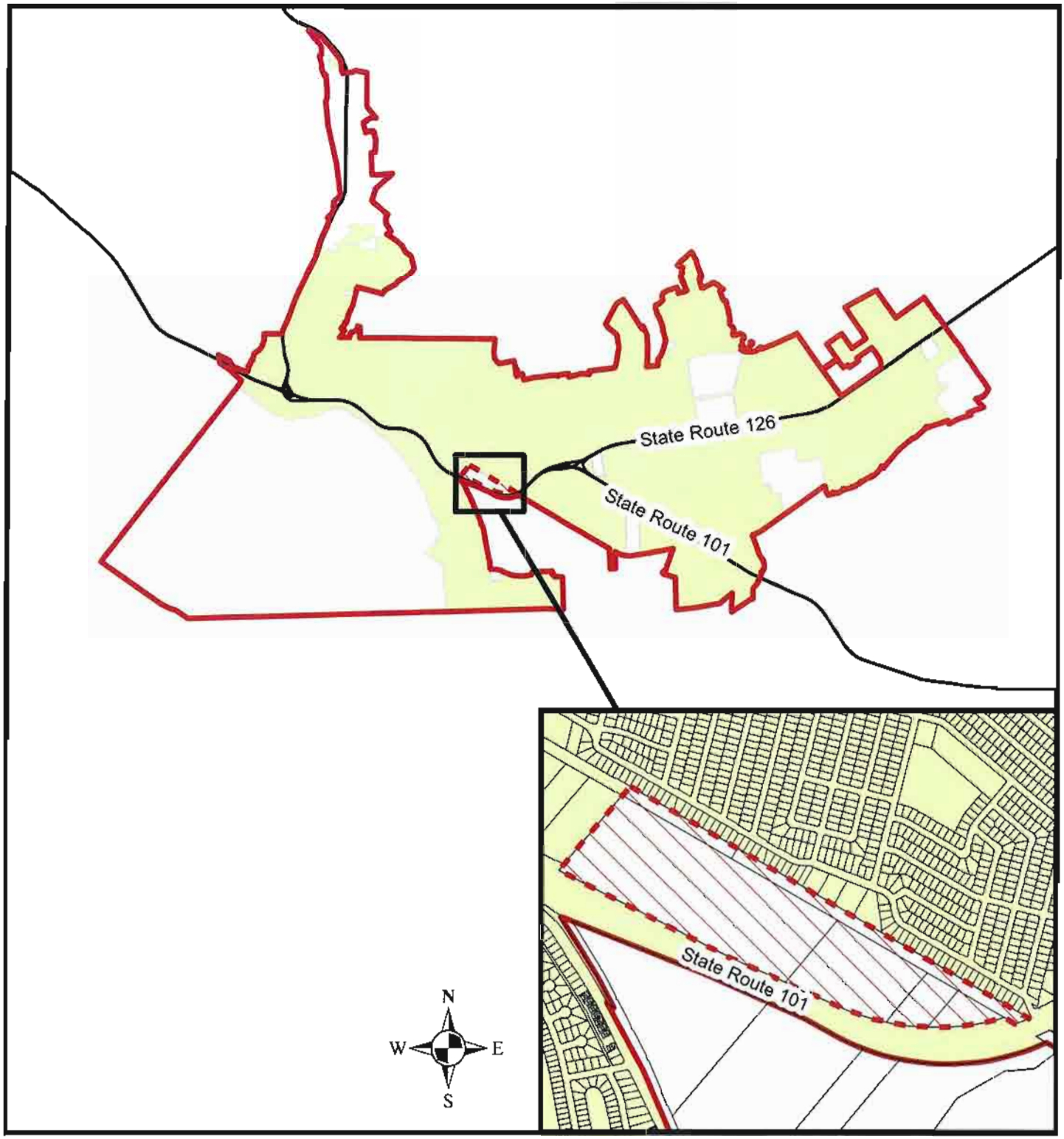
	AYE	NO	ABSTAIN	ABSENT
Commissioner Dandy	☐	☐	☐	☐
Commissioner Long	☐	☐	☐	☐
Commissioner Ford-McCaffrey	☐	☐	☐	☐
Commissioner Morehouse	☐	☐	☐	☐
Commissioner Parks	☐	☐	☐	☐
Commissioner Parvin	☐	☐	☐	☐
Commissioner Pringle	☐	☐	☐	☐
Alt. Commissioner Bennett	☐	☐	☐	☐
Alt. Commissioner Cunningham	☐	☐	☐	☐
Alt. Commissioner Freeman	☐	☐	☐	☐
Alt. Commissioner Smith	☐	☐	☐	☐

Dated:_____ _____

Chair, Ventura Local Agency Formation Commission

Attachments: Exhibit A

Copies: City of San Buenaventura
Ventura County Surveyor
Ventura County Geographic Information Systems Officer
Ventura County Planning Department



LAFCo 13-01S
City of San Buenaventura
Sphere of Influence Review/Update

Legend

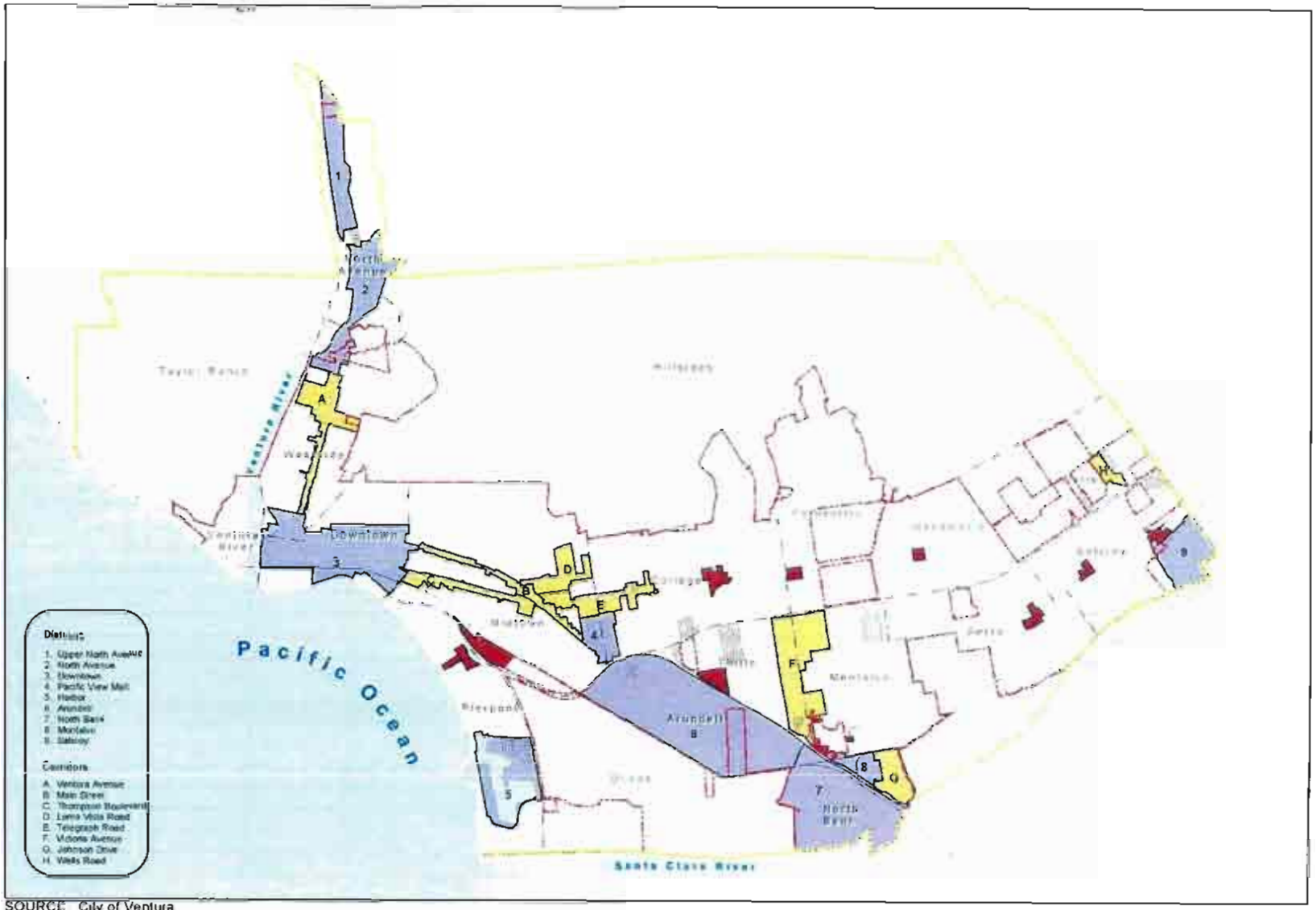
- Current Sphere of Influence
- Area to be Excluded from Sphere
- City of San Buenaventura

Table 3-1. Potential Development Based on Carrying Capacity of Land Area

Planning Designation	Allowed Density (du/acre)	Existing Development 2004					General Plan Capacity			
		Single Family Units	Multi Family Units	Comm./Ind. Sq. Ft.	Parcels	Acres	Vacant Parcels	Vacant Acres	Additional Potential[3] Units	Additional Potential[3] Sq. Ft.
Neighborhood Low	0-8	19,425	3,335	49,386	22,511	4,629	108	426	1,221	
Neighborhood Medium	9-20	1,163	8,965	149,513	4,414	1,061	32	116	4,859	
Neighborhood High	21-54	814	2,468	194,143	1,634	303	8	16	8,477	
Commerce[1]		257	490	4,995,248	1,366	808	95	108	7,892	22,328,276
Industry[2]		29	31	8,299,840	1,037	1,401	89	392	4,724	34,215,483
Public & Institutional		4	0	54,422	66	571				
Park & Open Space		6	0	15,491	264	11,693				
Agriculture		4	0	19,550	154	6,857				
Downtown Specific Plan	21-54	332	1,543	1,795,401	1,174	307	45	20	2,500	450,000
Harbor District		0	310	350,160	10	254	1	21	300	876,100
Total		**22,034**	**17,142**	**15,923,154**	**32,630**	**27,884**	**378**	**1099**	**29,910**	**57,869,859**

1. Commerce residential unit capacity is for property within a Corridor, District, or Neighborhood Center and assumes buildout to the maximum FAR and that 25% of floor area would be commercial (with the remainder residential).
2. Industry residential unit capacity is for property within a Corridor, District, or Neighborhood Center and assumes buildout to the maximum FAR and that 75% of floor area would be industrial (with the remainder residential).
3. "Additional Potential" assumes a historic buildout rate of 70% for both residential and non-residential.

Table 3-2. Predicted Development Intensity & Pattern	Residential Development (units)	Non-Residential Development (square feet)				
		Retail	Office	Industrial	Hotel	Total
DISTRICTS						
Upper North Avenue	100	10,000	50,000	150,000	-	210,000
North Avenue	50	10,000	50,000	250,000	-	310,000
Downtown Specific Plan	1,600	100,000	200,000	-	150,000	450,000
Pacific View Mall	25	25,000	-	-	-	25,000
Harbor	300	315,000	-	-	230,000	545,000
Arundell	200	25,000	300,000	1,000,000	-	1,325,000
North Bank	50	300,000	50,000	300,000	-	650,000
Montalvo	50	-	50,000	25,000	-	75,000
Saticoy	50	-	-	25,000	-	25,000
Subtotals (Districts)	**2,425**	**785,000**	**700,000**	**1,750,000**	**380,000**	**3,615,000**
CORRIDORS						
Ventura Avenue	800	40,000	100,000	50,000	-	190,000
Main Street	100	15,000	40,000	-	-	55,000
Thompson Boulevard	300	15,000	40,000	-	-	55,000
Loma Vista Road	25	15,000	40,000	-	-	55,000
Telegraph Road	250	15,000	40,000	-	-	55,000
Victoria Avenue	50	15,000	40,000	-	-	55,000
Johnson Drive	150	50,000	20,000	-	-	70,000
Wells Road	50	15,000	20,000	-	-	35,000
Subtotals (Corridors)	**1,725**	**180,000**	**340,000**	**50,000**	**0**	**570,000**
SPHERE OF INFLUENCE (SOI)/OTHER INFILL/NEIGHBORHOOD CENTERS						
101/126 Agriculture	200	-	-	-	-	-
Wells/Saticoy	1,050	-	-	-	-	-
Pierpont	100	30,000	-	-	-	30,000
Other Neighborhood Centers	100	-	-	-	-	-
Second Units	300	-	-	-	-	-
Underutilized	250	-	-	-	-	-
Vacant	450	165,000	50,000	-	-	215,000
Subtotals (Other Infill)	**2,450**	**195,000**	**50,000**	**0**	**0**	**245,000**
TOTAL INFILL	***6,600***	***1,160,000***	***1,090,000***	***1,800,000***	***380,000***	***4,430,000***
PLANNED AND PENDING DEVELOPMENTS						
Downtown	50	1,072	-	-	150,000	151,072
Ventura Avenue/Westside	238	7,086	-	27,000	-	34,086
Midtown	34	13,751	-	-	-	13,751
College (Telegraph/Loma Vista)	4	2,718	8,843	-	-	11,567
Telephone Road Corridor	256	-	54,785	-	-	54,785
Montalvo/Victoria	296	-	4,300	-	-	4,300
Saticoy/East End	840	7,950	5,600	-	-	13,550
Arundell	-	41,640	42,614	18,080	-	102,334
Olivas	-	7,160	7,066	390,053	-	404,279
Subtotals (Planned/Pending)	**1,718**	**81,377**	**123,214**	**435,133**	**150,000**	**789,724**
TOTAL (Infill+SOI/Other+Pending)	**8,318**	**1,241,377**	**1,213,214**	**2,235,133**	**530,000**	**5,219,724**

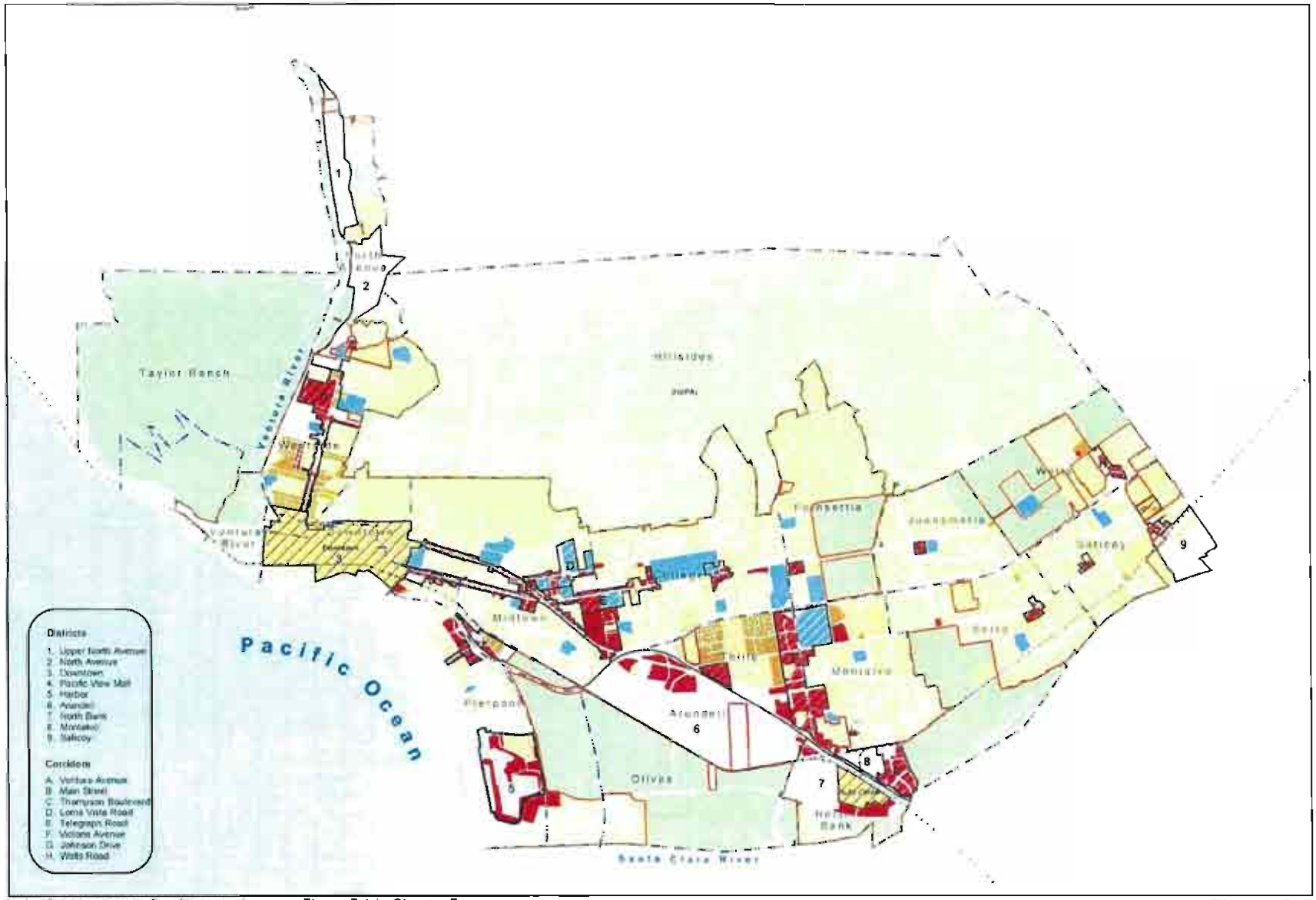


SOURCE City of Ventura

Infill Sites

- Corridor
- Neigborhood Center (NC)
- District
- City Limits
- Planning Boundary
- Planning Neighborhoods

Figure 3-1
Infill Areas



Note: Areas prone to flooding are shown on Figure 7-1 in Chapter 7.

Figure 3-5
GENERAL PLAN DIAGRAM

Neighborhood
- Low (up to 8 du/ac)
- Medium (9-20 du/ac)
- High (21-54 du/ac)

- Commerce
- Industry
- Public and Institutional

- Agriculture
- Parks and Open Space
- Specific Plan Area

- Corridors, Neighborhood Centers (NC)
- Districts

- City Limits
- Planning Communities
- California Coastal Zone Boundary

There are presently five water sources that provide water to the City water system.

- *Casitas Municipal Water District*
- *Ventura River Surface Water Intake, Subsurface Water and Wells (Foster Park)*
- *Mound Groundwater Basin*
- *Oxnard Plain Groundwater Basin (Fox Canyon Aquifer)*
- *Santa Paula Groundwater Basin*

Table 4.13-7 summarizes historic and projected water supply from these sources, as detailed in the 2000 City Urban Water Management Plan. The historic delivery values shown represent the capacity of available sources. The projected numbers in the table estimate available water supply levels under normal, non-drought conditions. Actual water supply levels in any given year may be significantly higher or lower than these averages.

Table 4.13-7
Historic and Projected Water Source Supply Availability
(Acre Feet)

Year	Surface Water		Groundwater				Total Water Supply
	Lake Casitas	Ventura River	Mound Basin	Oxnard Plain Basin	Santa Paula Basin	Saticoy Yard Well	
Historic							
1980	7,544	7,276	0	5,198	2,129	0	22,147
1985	9,099	5,493	2,360	6,172	46	0	23,170
1990	6,175	2,859	4,365	5,749	0	0	19,148
1995	1,622	9,042	2,169	2,603	2,594	0	18,030
1996	4,456	7,926	2,789	2,768	1,599	0	19,538
1997	7,089	7,052	213	3,452	2,025	0	19,831
1998	4,328	8,069	802	4,312	1,033	0	18,544
1999	7,061	6,419	3,955	1,621	1,669	0	20,725
2000	5,836	6,779	4,579	2,674	1,698	0	21,566
2001	6,292	5,727	4,030	905	2,006	0	18,960
2002	7,127	5,951	3,720	1,978	1,157	0	19,933
2003	4,874	6,722	5,546	2,898	316	0	20,356
Projected							
2005	8,000	6,700	4,200	4,400	3,000	0	26,300
2010	8,000	6,700	4,200	4,100	3,000	2,262	28,262
2015	8,000	6,700	4,200	4,100	3,000	2,262	28,262
2020	8,000	6,700	4,200	4,100	3,000	2,262	28,262

Source: City of Ventura Urban Water Management Plan, December 2000
City of Ventura 2004 Biennial Water Supply Report as amended, September 2004 (see Appendix F).

The City generally uses its water supplies in the following order: (1) Ventura River; (2) Lake Casitas; and (3) groundwater basins. Water is used in this order to maximize the amount of surface water that would otherwise be lost to runoff before using stored groundwater.

Table 4.13-8
Historic and Projected Water Production
(Acre Feet)

Year	Estimated Population Served	Per Capita Use (1)	Treated Water Production	Raw Water Production	Total Water Production
Historic					
1980	73,774	0.236	17,381	4,766	22,147
1990	94,856	0.177	16,831	2,317	19,148
1995	99,668	0.165	16,428	1,602	18,030
1996	100,482	0.180	18,038	1,500	19,538
1997	101,096	0.178	18,002	1,829	19,831
1998	101,610	0.165	16,775	1,769	18,544
1999	102,224	0.192	19,658	1,067	20,725
2000	103,238	0.198	20,437	1,129	21,566
2001	104,153	0.173	18,071	889	18,960
2002	105,267	0.180	18,965	968	19,933
2003	106,782	0.183	19,510	846	20,356
Projected					
2005	109,465	0.179	19,594	1,000	20,594
2010	115,774	0.179	20,724	1,000	21,724
2015	122,447	0.179	21,918	1,000	22,918
2020	129,504	0.179	23,181	1,000	24,181

Sources: City of Ventura Urban Water Management Plan, Dec. 2000
City of Ventura 2004 Biennial Water Supply Report as amended, September 2004 (see Appendix F).
(1) Per capita use excludes raw water and oil use.

Water Quality. The following terms are used to describe water quality:

- *Maximum Contaminant Level (MCL): The highest level of a contaminant allowed in drinking water. Primary MCLs are set as close to the Federal Public Health Goals or State Maximum Contaminant Level Goals as is economically and technologically feasible. Secondary MCLs are set to protect the odor, taste and appearance of drinking water.*
- *Primary Drinking Water Standard: MCLs for contaminants that affect health along with their monitoring and reporting requirements, and water treatment requirements.*
- *Maximum Contaminant Level Goal: The level of contaminant in drinking water below which there is no known or expected risk to the health; set by EPA.*
- *Public Health Goal: The level of a contaminant in drinking water below which there is no known or expected risk to health; set by the California EPA.*

Table 4.13-15
Projected Water Demand
Intensification / Reuse Only (Scenario 1)

	Residential		Non-Residential Development						Grand Totals
	Number of Units	Water (AFY)	Retail (sf)	Office (sf)	Industrial (sf)	Hotel (sf)	Total (sf)	Water (AFY)	Water (AFY)
Districts									
Upper North Avenue	100	50	10,000	50,000	150,000		210,000	70	120
North Avenue	50	25	10,000	50,000	250,000		310,000	105	130
Downtown	1,600	807	100,000	200,000		150,000	450,000	168	975
Pacific View Mall	25	13	25,000	0			25,000	7	20
Harbor	300	151	66,000			150,000	216,000	54	205
Arundell	200	101	25,000	300,000	1,000,000		1,325,000	444	545
North Bank	50	25	300,000	50,000	300,000		650,000	204	229
Montalvo	50	25		50,000	25,000		75,000	23	48
Saticoy	50	25	0		25,000		25,000	9	34
Subtotals (Districts)	**2,425**	**1,223**	**536,000**	**700,000**	**1,750,000**	**300,000**	**3,286,000**	**1,084**	**2,307**
Corridors									
Ventura Avenue	800	404	40,000	100,000	50,000		190,000	57	460
Main Street	100	50	15,000	40,000			55,000	15	66
Thompson Boulevard	300	151	15,000	40,000			55,000	15	167
Loma Vista Road	25	13	15,000	40,000			55,000	15	28
Telegraph Road	250	126	15,000	40,000			55,000	15	142
Victoria Avenue	50	25	15,000	40,000			55,000	15	41
Johnson Drive	150	76	50,000	20,000			70,000	20	95
Wells Road	50	25	15,000	20,000			35,000	10	35
Subtotals (Corridors)	**1,725**	**870**	**180,000**	**340,000**	**50,000**	**0**	**570,000**	**163**	**1,033**
SOI/Other Infill									
101/126 Agriculture	200	101					0	0	101
Wells/Saticoy	1,050	530					0	0	530
Pierpont	100	50	30,000				30,000	8	59
Other Neighborhood Centers	100	50						0	50
Second Units	300	151						0	151
Underutilized	250	126						0	126
Vacant	450	227	165,000	50,000			215,000	60	287
Subtotals (Other Infill)	**2,450**	**1,236**	**195,000**	**50,000**	**0**	**0**	**245,000**	**69**	**1,304**
Totals (Intensification/Reuse)	**6,600**	**3,329**	**911,000**	**1,090,000**	**1,800,000**	**300,000**	**4,101,000**	**1,316**	**4,645**
Planned and Pending Developments									
Downtown	50	25	1,072			150,000	151,072	84	110
Ventura Avenue/Westside	238	120	7,086		27,000		34,086	12	132
Midtown	34	17	13,751				13,751	4	21
College (Telegraph/Loma Vista)	4	2	2,718	8,849			11,567	3	5
Telephone Road Corridor	256	129		54,785			54,785	15	144
Montalvo/Victoria	296	149		4,300			4,300	1	151
Saticoy/East End	840	424	7,950	5,600			13,550	4	427
Arundell		0	41,640	42,614	18,080		102,334	30	30
Olivas		0	7,160	7,066	390,053		404,279	142	142
Subtotals (Planned/Pending	**1,718**	**867**	**81,377**	**123,214**	**435,133**	**150,000**	**789,724**	**295**	**1,162**
Totals (Intensification + Expansion + Pending)	**8,318**	**4,196**	**992,377**	**1,213,214**	**2,235,133**	**450,000**	**4,890,724**	**1,611**	**5,806**

2.3 Population

The City water service area is essentially an established community comprised primarily of residential areas with opportunities for infill development. Large commercial and industrial areas exist along Main Street, Harbor Boulevard, Telephone Road, Ventura Avenue, Telegraph Road and Victoria Avenue[2]. In 2005, the City of Ventura adopted the 2005 Ventura General Plan to redirect future growth toward 'Infill First' with an emphasis on encouraging more intense development of housing alongside commercial uses in the above mentioned commercial corridors, as well as Johnson Drive and Wells Road. The City's estimated population growth for the water service area is shown in Table 2-1. The population numbers reflect both the population within the City of Ventura limits as well as the population served by the public water system that is not within the City limits. Historical population data within the City is based entirely from the California Department of Finance Table E-4 Population Estimates for Cities, Counties, and the State with 2000 Benchmark. Historical population for the areas served by the water system that are outside of the City are based on the number of connections, multiplied by 2.57 persons per connection[3].

Future projections for areas within the City reflect a 0.88 percent annual growth rate based on the City's General Plan. Projections for areas served by the water system outside of the City are based on the historical annual growth rate of 0.1258 percent in the number of connections. Population estimates were extrapolated to fit 5 year increments. It is important to note that these figures are not intended to represent support for, nor reflect any commitment to, this level of growth. Rather, it is to provide a safe margin in planning for long-term water improvements that might be needed given the amount of growth that could be allowed under the City's 2005 updated General Plan as assessed in the certified EIR. Included for comparison is the EIR population projection for 2025 reflecting the two possible growth scenarios: (1) 1.14 percent annual population growth, which is equivalent to the annual growth rate in the City from 1984 to 2004; and (2) 0.88 percent annual population growth, which is equivalent to the annual growth from 1994 to 2004.

TABLE 2-1
POPULATION PROJECTIONS

	2010	2015	2020	2025	2030	2035
Projected Planning Area Population	113,478	118,416	123,575	128,963	134,592	140,472
General Plan EIR (0.88%)	-	-	-	126,153	-	-
General Plan EIR (1.14%)	-	-	-	133,160	-	-

Note: General Plan EIR only provides estimate for year 2025.

2.4 Existing and Target Per Capita Water Use

2.4.1 Base Daily Per Capita Water Use for SBX7-7 Reduction

As described in Senate Bill 7 of Special Extended Session 7 (SBX7-7), it is the intent of the California legislature to increase water use efficiency. The legislature has set a goal of a 20 percent per capita reduction in urban water use statewide by 2020. The requirements of

[2] City of San Buenaventura Water Master Plan, 2011.
[3] Based on City's General Plan Environmental Impact Report (EIR) dated 2005.

TABLE 2-5
PAST, CURRENT, AND PROJECTED WATER DEMANDS (AFY)

	Single-Family	Multi-Family	Commercial	Industrial	Institutional/ Governmental	Landscape	Petroleum Recovery Operations	Other	Total
2005	7,483	3,887	4,279	163	541	1,079	930	2,447	20,808
2010	7,006	3,678	3,384	64	495	1,044	368	1,312	17,351
2015	9,197	4,562	4,551	163	690	1,416	400	1,306	22,286
2020	9,615	4,761	4,749	170	720	1,478	400	1,363	23,256
2025	10,052	4,969	4,956	178	751	1,542	400	1,423	24,270
2030	10,508	5,185	5,173	185	784	1,610	400	1,485	25,330
2035	10,984	5,412	5,399	193	818	1,680	400	1,550	26,436

Note: 2005 and 2010 are actual demands. 2015 and beyond are projected.

TABLE 2-6
WATER SERVICE ACCOUNTS

	Single-Family	Multi-Family	Commercial	Industrial	Institutional/ Governmental	Landscape	Petroleum Recovery Operations	Other	Total
2005	22,834	2,269	2,537	15	193	222	2	2,966	31,038
2010	23,158	2,372	2,536	4	185	258	2	3,131	31,646
2015	25,627	2,545	2,733	7	200	279	2	3,375	34,769
2020	24,953	2,481	2,664	7	195	272	2	3,291	33,865
2025	26,095	2,590	2,781	7	204	283	2	3,434	35,396
2030	27,288	2,703	2,902	7	213	296	2	3,584	36,994
2035	28,534	2,821	3,029	8	222	309	2	3,741	38,665

Note: 2005 and 2010 are actual demands. 2015 and beyond are projected.

TABLE 3-1
SUMMARY OF WATER SUPPLY SOURCES

Water Supply Sources (AFY)	2010	2015	2020	2025	2030	2035
Existing Supplies						
Imported Wholesale Supplies						
Casitas Municipal Water District[a]	6,000	6,000	6,100	6,200	6,500	7,000
Supplier Produced Groundwater						
Mound Basin[b]	4,000	4,000	4,000	4,000	4,000	4,000
Oxnard Plain Basin[b]	4,100	4,100	4,100	4,100	4,100	4,100
Santa Paula Basin[b]	1,600	1,600	1,600	1,600	1,600	1,600
Supplier Produced Surface Water						
Ventura River (Foster Park)[b]	4,200	4,200	4,200	4,200	4,200	4,200
Recycled Water[c]	700	700	700	700	700	700
Transfers in	None	None	None	None	None	None
Exchanges in	None	None	None	None	None	None
Desalinated Water	None	None	None	None	None	None
Other	None	None	None	None	None	None
Total Existing Supplies	***20,600***	***20,600***	***20,700***	***20,800***	***21,100***	***21,600***
Planned Supplies						
Supplier Produced Groundwater						
Mound Basin (Well No. 2)[d]	0	0	0	0	0	0
Oxnard Plain Basin (Golf Course Well No. 7)[d]	0	0	0	0	0	0
Santa Paula Basin (Saticoy Well No. 3)[e]	0	1,400	1,400	1,400	1,400	1,400
Supplier Produced Surface Water						
Ventura River (Foster Park Wells Improvements)	0	0	2,500	2,500	2,500	2,500
Total Planned Supplies	***0***	***1,400***	***3,900***	***3,900***	***3,900***	***3,900***
Total Existing and Planned Supplies	***20,600***	***22,000***	***24,600***	***24,700***	***25,000***	***25,500***
FCGMA Groundwater Credit[f]	***30,000***	***22,000***	***22,000***	***22,000***	***22,000***	***22,000***

Notes:
(a) Estimated demand based on population growth within the Casitas service area served by Ventura Water .
(b) Average annual supply based on 2011 City of San Buenaventura Water Master Plan, Table V-14.
(c) Based on current and expected usage.
(d) Replacement wells for supply reliability.
(e) Well will allow full use of 1996 stipulated Judgment allocation.
(f) FCGMA Groundwater Credit is drought/reliability supply source; not a firm supply available for new development. 30,249 AF available for 2010 per Water Master Plan (See Oxnard Plain supply description, Section 3.3.1.2.) reduced to 22,000 AF by 2015 in the event of a drought or operational/production/treatment constraints from other supply sources.

3.2 Imported Supplies

The City has a contract Table A Amount of 10,000 AFY of State Water Project (SWP) water with DWR. However, there are no facilities to deliver this water to the City. The following describes the history of this allocation and the potential for future use of SWP supply.

In 1964, Ventura County Flood Control District contracted with the State of California for future delivery of up to 20,000 AFY of SWP water to Ventura County. In 1971, administration of the contract for SWP water was assigned to Casitas. The City executed an agreement in 1971 with Casitas and the Department of Water Resources (DWR) to allocate 10,000 AFY of the

B. EXISTING LAND USE

The City water service area is essentially a built-out community comprised primarily of residential areas. Large commercial and industrial areas exist along Main Street, Harbor Boulevard, Telephone Road, Ventura Avenue, Telegraph Road and Victoria Avenue. A large amount of land within the General Plan Boundary, over 11,500 acres, is dedicated to parks and open space.

Existing land use information was compiled from the 2005 General Plan. The various land use types and densities that are located within the City General Plan Boundary are listed in Table II-1.

Table II-1
Existing Land Use within City General Plan Boundary

Planning Designation	Allowed Density (du/acre)	Area (acres)
Neighborhood Low	0 – 8	4,629
Neighborhood Medium	9 – 20	1,061
Neighborhood High	21 – 54	303
Commerce/Mixed Use	N/A	808
Industry	N/A	1,401
Public and Institutional	N/A	571
Park and Open Space	N/A	11,693
Agriculture	N/A	6,857
Downtown Specific Plan	21 – 54	307
Harbor District	N/A	254
Total	-	**27,884**

Note: The difference in land use area stated in Table II-1 and Exhibit II-1 is due to the fact that Table II-1 does not include the area for vacant or additional potential parcels, however Exhibit II-1 does.

Refer to Exhibit II-1 at the end of this Section for the Land Use Map.

C. FUTURE LAND USE

The number of customers served from the City's water system is expected to increase due to planned future developments and changes in land use. Land use changes will impact the operation of the City's distribution system. Proper planning for these changes will enable the City to continue to meet demands, provide adequate fire protection and provide quality service to its customers.

Most of the land within the City's existing water service area is developed. Anticipated changes in land use will primarily occur through redevelopment of existing land and small developments

(in-fill projects) in the various vacant parcels scattered throughout the City. This section will be broken down to describe the anticipated near-term developments and redevelopments and the ultimate build-out of the City as identified by the 2005 General Plan.

1. Near-Term Developments and Redevelopments

The City's Community Development Department compiles proposed and current development projects throughout the entire City in a Pending Project Status Report. These projects are considered to be near-term because some level of planning has occurred and the projects are anticipated to be completed within the next 2-3 years (it should be noted that some of the projects identified below may have begun construction or have been completed at the time of finalization of this report). The majority of the projects are redevelopments of commercial land and new residential developments. Refer to Exhibit II-2 for the locations of the near-term projects as identified in the January 2006 Pending Project List and Appendix A for a list of the projects. See Table II-2 for a summary of the near-term land use.

Table II-2
Near-Term Land Use Summary

General Plan Land Use Category	Acreage	DU
Neighborhood Low (NL)	221	662
Neighborhood Medium (NM)	188	699
Neighborhood High (NH)	41	256
Commerce/Mixed Use (C)	78	459
Industry (I)	86	-
Public and Institutional (PI)	19	-
Parks and Open Space (POS)	440	-
Downtown Specific Plan (DTSP)	23	445
Total	**1,097**	**2,521**

A few of the larger near-term projects anticipated within the City water service area are listed in Table II-3.

Table II-3
Large Near-Term Development Project Summary

Project Name	Project Address	DU	Acreage	Land Use Category	Project Number
Parklands	Southwest corner of Wells Rd & Telegraph Rd	252	66.7	NM	RS-99
Parklands	Southwest corner of Wells Rd & Telegraph Rd	235	-	NL	RC-85
Harmony	South of Thille Rd @ Ringo St	182	15.8	NH	RC-61
Island View	NW Corner of Hill Rd and Moon Dr	120	26.9	NM	RS-87
The Grove	Copland Dr & Telephone Rd	75	25.6	NM	RS-98
Melody	Northwest corner of Telegraph Rd & Saratoga	74	15.7	NH	RC-64
Hails	Henderson Rd, West of Montgomery	172	40.1	NL	RS-92
Hails	Henderson Rd, West of Montgomery	60	-	NL	RC-70

2. Ultimate Build-out

The ultimate build-out is classified as projects expected to occur at some point in the future, but planning stages of the projects has yet to begin. These projects include the anticipated development of all vacant parcels within the City's potential water service area not included in the near-term development summary, as identified in the 2005 General Plan. The total area of vacant land that can be ultimately developed are summarized by Land Use Types in Table II-4. Further discussion of the demands generated by the build-out of all vacant lands is described in Section IV.

Table II-4
Existing Vacant Lands by Land Use (2005 General Plan Capacity)

Planning Designation	Allowed Density (du/acre)	Area (acres)
Neighborhood Low	0 – 8	426
Neighborhood Medium	9 – 20	116
Neighborhood High	21 – 54	16
Commerce	N/A	621
Industry	N/A	1,178
Public and Institutional	N/A	0
Park and Open Space	N/A	0
Agriculture	N/A	-
Downtown Specific Plan	21 – 54	30
Harbor District	N/A	41
Total	-	**2,428**

Table V-14
Summary of Current Water Supply

Water Supply Source	Historical Supply Projection (AFY)	Average Annual Supply (2000-2009) (AFY)	Present Operational Supply Constraint (AFY)
Casitas	4,960 – 8,000	6,200	6,200
Ventura River (Foster Park)	4,200 – 6,700	4,200	4,200
Mound Groundwater Basin	2,500 – 4,000	4,000	5,500 [1]
Oxnard Plain Groundwater Basin	4,100	4,100	6,775 [2]
Santa Paula Groundwater Basin	3,000	1,340	1,600 [3]
Total	**18,760 – 25,800**	**19,840**	**24,275**

[1] Assumes two wells operational, one well at 1,500 gpm and one at 2,000 gpm

[2] Assumes two wells operational at 2,100 gpm each.

[3] Assumes one well operational at 1,000 gpm.

B. POTENTIAL WATER SUPPLY

A water supply capacity evaluation is described later in this report (Section VIII). This section will briefly describe any planned or proposed projects which may affect the water supply sources for the City.

1. State Water Project

The City also has a 10,000 acre-foot per year allocation from the California State Water Project (SWP). The base contractual agreements concerning the City's annual entitlement to 10,000 acre-feet of SWP are: (1) the 1963 State Water Supply Contract of 20,000 acre-feet entitlement of SWP water between the Department of Water Resources (DWR) and Ventura County Watershed Protection District (VCWPD) known formerly as Ventura County Flood Control District (VCFCD); (2) the 1970 agreement between VCFCD and Casitas known formerly as the Ventura Municipal Water District that assigned the 20,000 acre-feet entitlement to Casitas; and (3) the 1971 agreements between Casitas and the City providing the City with an annual entitlement of 10,000 acre-feet and Casitas and United providing United with an annual entitlement of 5,000

VENTURA LOCAL AGENCY FORMATION COMMISSION

MUNICIPAL SERVICE REVIEWS

Nine Ventura County Cities

Cities of:

Camarillo
Fillmore
Moorpark
Ojai
Oxnard
San Buenaventura
Santa Paula
Simi Valley
Thousand Oaks

Prepared By

Ventura Local Agency Formation Commission
800 S. Victoria Avenue
Ventura, CA 93009-1850

Accepted November 14, 2012

2012 MUNICIPAL SERVICE REVIEWS

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INTRODUCTION

Local Agency Formation Commissions ("LAFCos"), which exist in each county in California, were formed for the purpose of administering state law and local policies relating to the establishment and revision of local government boundaries. As provided by what is now known as the Cortese-Knox-Hertzberg Local Government Reorganization Act of 2000 (California Government Code Section 56000 et seq.), LAFCos are responsible for achieving three primary objectives: encouraging the orderly formation and expansion of local government agencies; preserving agricultural land and open space resources; and discouraging urban sprawl. To accomplish their objectives, LAFCos are responsible for coordinating logical and timely changes in local government boundaries, conducting special studies that review ways to reorganize and streamline governmental structure and preparing a sphere of influence for each city and special district over which they have authority. A sphere of influence is a plan for the probable physical boundaries and service area of a local agency, as determined by LAFCo (Government Code §56076).

Beginning in 2001 each LAFCo was required to review and, as necessary, update the sphere of each city and special district on or before January 1, 2008, and every five years thereafter (Government Code §56425(g)). Prior to updating a sphere of influence, LAFCo is required to conduct a municipal service review (service review" or "MSR"). California Government Code §56430(a) provides that MSRs consist of written determinations relating to the following seven factors:

1. Growth and population projections for the affected area.
2. The location and characteristics of any disadvantaged unincorporated communities within or contiguous to the sphere of influence.
3. Present and planned capacity of public facilities, adequacy of public services, and infrastructure needs or deficiencies including needs or deficiencies related to sewers, municipal and industrial water, and structural fire protection in any disadvantaged, unincorporated communities within or contiguous to the sphere of influence.
4. Financial ability of agencies to provide services.
5. Status of, and opportunities for, shared facilities.
6. Accountability for community service needs, including governmental structure and operational efficiencies.
7. Any other matter related to effective or efficient service delivery, as required by Commission policy.

Municipal service reviews are:

- The written determinations adopted by a LAFCo for the services provided by cities and special districts.
- Not applicable to counties, except for special districts governed by a county board of supervisors.
- May include studies of private providers of public services, such as private water companies or public utilities regulated by the state Public Utilities Commission.
- Not investigations. While authorized to prepare studies relating to their role as boundary agencies, LAFCos have no investigative authority.

Between 2002 and 2007, the Ventura LAFCo completed 21 MSRs and 57 sphere of influence reviews/updates among 10 cities and 50 special districts. The first MSR for the cities was completed in 2007.

The MSRs contained in this report examine each of the cities in Ventura County except the City of Port Hueneme. The City of Port Hueneme is surrounded by the City of Oxnard on three sides and the Pacific Ocean on the fourth, and the City boundary and sphere of influence are co-terminus. As there is no further opportunity for the City to expand beyond its current boundary and sphere of influence, LAFCo has determined that no sphere of influence review or MSR is necessary.

The information used to prepare this service review report was obtained from several sources, including:

- 2012 MSR Questionnaire - Each city was requested to complete a questionnaire, which collected general information about the city (contact information, governing body, financial information, etc), as well service specific data.
- City Budgets – Information regarding services and funding levels was obtained from the adopted budgets of each city.
- General Plans – Each city's General Plan provided information regarding land use, populations, and service levels.
- City Documents – Various city documents were used to obtain supplementary information relating to service provision, including, but not limited to, 2010 urban water management plans, wastewater master plans, and water master plans.
- City Websites – Provided information primarily regarding parks and recreation, fire protection, and police services.
- City Staff – City staff provided information that was either not available or not clear in the above documents.

The 2007 MSR prepared for the cities utilized financial information obtained from *The Cities Annual Report* published annually by the State Controller. The Annual Report is a comprehensive listing of each agency's revenue and expenditures specific to municipal services. At the time that the 2012 MSRs were being prepared, the latest Cities Annual Report that was available was for fiscal year 2009-10. Thus, it did not provide any information for the current or previous two fiscal years and its use would not have adequately portrayed the current fiscal realities of each city.

This report contains nine city MSRs, one in each of the nine main sections. Each of the nine sections is divided into four subsections, which include:

- Profile – This subsection contains a summary profile of important information for each city, including contact information, the governing body, financial information, and staffing levels;
- Growth and Population Projections – This subsection provides past, current, and projected population for each city. As necessary, a discussion of future anticipated development is provided;
- Review of Municipal Services – This subsection contains a discussion of the municipal services that each city provides; and
- Written Determinations – This subsection contains the recommended determinations for each of the seven mandatory factors for each city.

The appendices include:

- Appendix A – This appendix provides comparison tables summarizing key information discussed in the MSRs, including each city's geographic area, population, services that are provided, and funding amount for specific services.
- Appendix B – This appendix provides a discussion on the challenges that each city faces to fund future street maintenance services.

The result of this report will be the adoption of determinations by LAFCo, via a separate resolution for each city addressing each of the seven mandatory factors, based on the recommendations in the Written Determinations subsection of each MSR. Everything else in this report should be considered as background information.

CITY OF SAN BUENAVENTURA
PROFILE

Contact Information	
City Hall:	501 Poli Street, Ventura, CA 93001
Mailing Address:	PO Box 99, Ventura, CA 93002
Phone Number:	(805) 654-7800
Web Site	www.cityofventura.net
E-mail	*firstinitiallastname*@ci.ventura.ca.us

Governance Information	
Date Incorporated	March 10, 1866
Organization	City Charter
Form of Government	Council - Manager
City Council	• Seven member city council; members elected at-large to staggered, four year terms of office; elections held in odd numbered years; Mayor elected by the city council to a two year term • The city council regularly meets on Monday each week, except during August and on holidays. The meetings begin at 6:00 p.m. City Council meetings are broadcast live on the City's government cable TV channel

Population & Area Information

	Population	Area (sq. mi.)
City	107,166 [1]	21.99
Sphere of Influence	Not available	35.44[2]

Services

Floodplain Management	Parks
Community Development	Police
Fire	Sewers (collection & treatment)[3]
Emergency Medical Services	Streets & Highways (inc. storm drains)
General Government	Street Lighting
Golf Courses	Street Trees & Landscaping
Libraries	Water
Parking Facilities	

[1] CA Dept. of Finance estimate Jan. 1, 2012
[2] Includes approximately 10.07 square miles of Pacific Ocean
[3] The Montalvo Community Services District provides these services for the Montalvo Community

Staffing – Full Time Equivalent Positions[1]

Departments	2008-09	2009-10	2010-11	2011-12	2012-13
- General Government					
City Attorney	7.00	7.60	7.10	7.10	7.30
City Manager/City Clerk	18.50	10.75	7.00	7.00	8.00
Finance and Technology	47.75	46.50	46.50	49.00	47.75
Human Resources	13.00	12.75	12.75	12.00	12.25
- Community Development[2]	33.50	28.90	46.75	46.90	46.90
- Parks, Recreation & Community Partnerships[3] (Community Services)	32.25	32.25	62.25	65.00	56.25
- Public Safety					
Fire[4]	112.00	103.75	74.00	74.00	83.00
Police	185.25	172.00	161.00	1610	165.00
- Public Works	226.50	217.60	177.50	177.50	83
- Ventura Water	0	0	0	0	98.60
Total	**675.75**	**632.10**	**594.85**	**599.5**	**608.05**

Public Agencies with Overlapping Jurisdiction

Casitas Municipal Water District
Fox Canyon Groundwater Management Agency
Montalvo Community Services District
Saticoy Sanitary District
South Coast Area Transit
United Water Conservation District
Ventura County Air Pollution Control District
Ventura County Transportation Commission
Ventura County Watershed Protection District
Ventura Port District
Ventura Regional Sanitation District
Ventura Unified School District

[1] Source: City of San Buenaventura staff, September 27, 2012
[2] The 2010-11 increased staffing is primarily due to relocation of the Building and Safety division from the Fire Department to the Community Development Department
[3] The 2011-12 increased staffing is primarily the result of department restructuring
[4] The 2010-11 reductions due to reduction of 9 sworn personnel and the reorganization which moved building and safety functions to Community Development

Summary Financial Information[1]

Revenues

	2009-10 Actual	2010-11 Actual	2011-12 Actual	2012-13 Adopted	2013-14 Adopted
General Fund					
General Government					
City Attorney	1,063,789	368,941	457,156	0	0
City Manager/City Clerk	37,440	34,126	3,593	1,100	1,100
Finance and Technology					
- Property tax	20,647,117	17,747,281	19,862,975	21,205,522	19,552,847
- Sales tax	14,598,479	13,749,457	14,231,683	14,359,979	15,197,873
- Utility users tax	9,019,830	8,719,233	8,774,362	8,963,885	8,674,953
- Franchise tax	3,713,057	2,984,316	3,278,468	4,089,964	4,346,250
- Transient lodging	3,707,592	3,477,798	3,431,094	3,500,743	3,500,743
- Transfers - other funds	2,315,080	3,208,128	1,108,790	1,843,613	1,619,310
- State motor vehicle license	8,480,754	8,194,617	8,342,441	7,841,913	7,945,913
- Other revenue	14,702,434	13,988,296	11,736,134	17,301,011	17,731,005
Human Resources	18,859	12,238	6,120	300	300
Community Development	1,065,929	909,352	1,533,323	1,933,684	1,229,585
Parks, Recreation, & Community Partnerships	2,218,786	2,219,923	2,692,310	2,549,919	2,572,919
Public Safety					
Fire	2,984,246	1,200,614	1,050,412	1,229,241	1,132,241
Police	4,101,850	2,401,356	2,038,697	2,115,300	2,115,300
Public Works	1,011,388	968,014	138,934	132,666	157,666
Total General Fund	**89,686,630**	**80,183,690**	**78,686,492**	**87,068,840**	**85,778,005**
Total Building & Safety Fund	--	**1,985,918**	**2,308,762**	**1,741,385**	**1,726,099**
Ventura Water[2]					
Wastewater	--	--	--	19,782,428	20,428.911
CIP - Wastewater	--	--	--	11,115,000	4,865,000
Water	--	--	--	23,586,955	25,345,631
CIP - Water	--	--	--	19,896,497	10,850,000

[1] City of San Buenaventura Adopted Budget for Fiscal Years 2012-13 & 2013-2014 and Adopted Budget for Fiscal Year 2011-12

[2] Ventura Water became operational in 2011

Expenditures

	2009-10 Actual	2010-11 Actual	2011-12 Actual	2012-13 Adopted	2013-14 Adopted
General Fund					
General Government					
City Attorney	2,202,140	1,304,185	1,331,314	1,711,112	1,622,315
City Council	240,580	210,876	195,057	231,421	299,091
City Manager/City Clerk	2,265,694	1,776,925	1,150,956	1,537,376	1,502,960
Finance and Technology	10,766,376	10,087,345	12,561,756	16,809,442	11,729,298
Human Resources	1,952,090	958,777	758,217	1,048,815	1,001,014
Community Develop.	4,601,367	3,629,692	5,030,789	5,461,141	5,247,886
Parks, Rec, & Comm. Partnerships	6,484,203	6,348,738	11,096,801	11,861,865	11,953,828
Public Safety					
Fire	19,648,534	15,715,345	14,421,806	15,308,562	15,947,264
Police	30,024,089	27,852,555	27,310,957	27,416,970	28,747,808
Public Works	13,938,077	12,449,124	6,034,469	7,405,073	7,726,541
Total General Fund	**89,921,010**	**79,029,377**	**79,892,122**	**88,791,777**	**85,778,005**
Total Building & Safety	--	**2,077,472**	**2,222,923**	**1,741,385**	**1,726,099**
Ventura Water[1]					
Wastewater	--	--	3,252,299	19,782,428	20,428,911
CIP - Wastewater	--	--	127,718	11,115,000	4,865,000
Water	--	--	4,312,605	23,586,955	25,345,631
CIP - Water	--	--	0	20,697,789	10,850,000

[1] Ventura Water became operational in 2011

GROWTH AND POPULATION PROJECTIONS

City Annual Growth Projections

According to the US Census, from 2000 to 2010, the City increased in population from 100,916 to 106,433. The California Department of Finance estimates the City's population to be 107,166 as of January 1, 2012. Thus, from 2000 to 2012, the City grew by an estimated 6,250 people, or 6.19 percent. This 6.19 percent growth rate over 12 years equates to an estimated average annual growth rate of 0.52 percent. The following table reflects the City's projected population in 5 year increments based on this estimated rate of growth. The table also reflects the annexation of the community of Montalvo to the City in 2012:

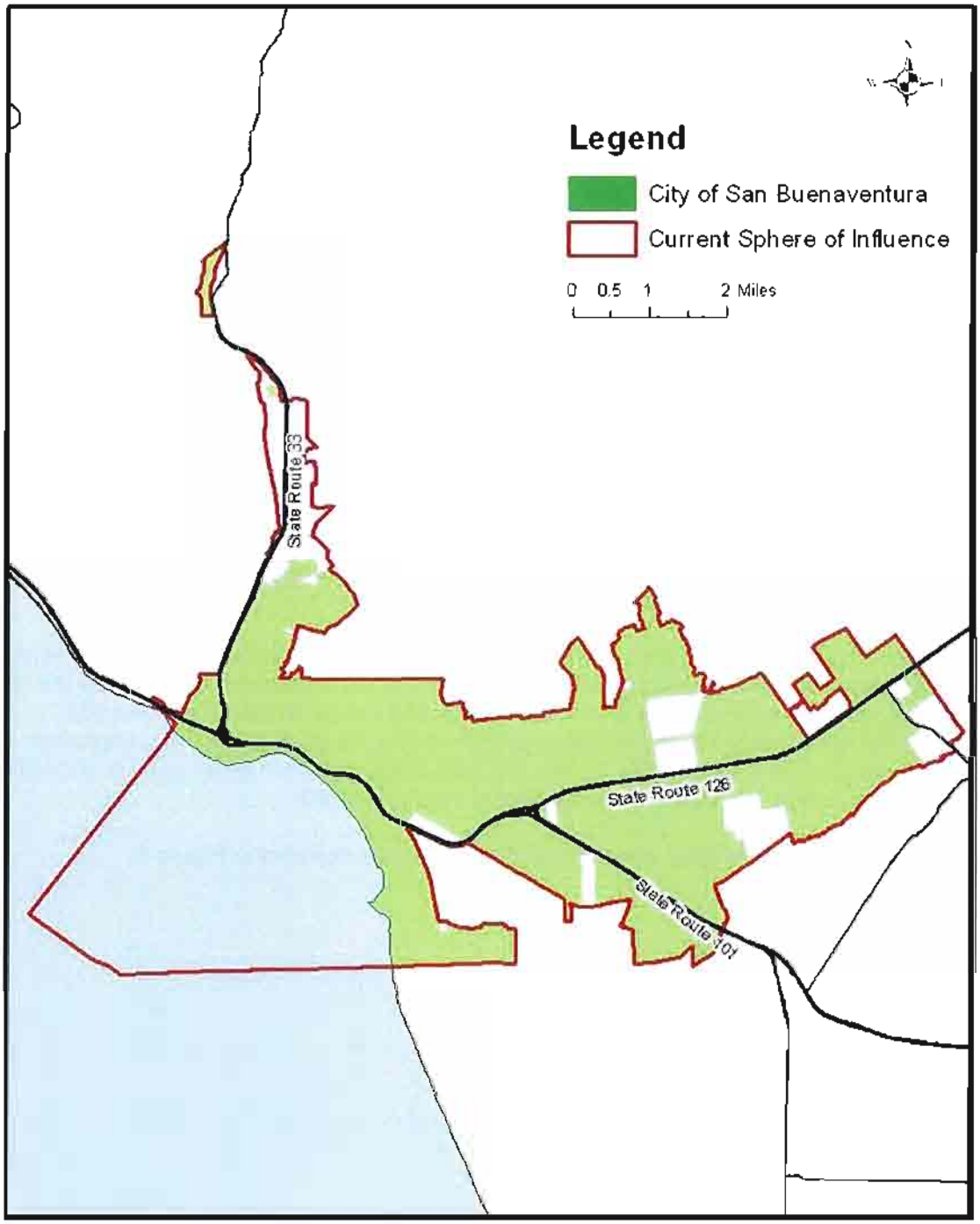
	2012	**2015**	**2020**	**2025**	**2030**
City Population	107,166	108,847	111,706	114,641	117,653
Montalvo	632	632	632	632	632
Total Population	**107,798**	**109,479**	**112,338**	**115,273**	**118,285**

The City updated its General Plan in 2005. The EIR prepared for the update included population projections based on an annual growth rate of 0.88 percent (average from 1994-2004) and a 2004 population of 104,952. The projections used in the General Plan would result in an estimated 2012 population of approximately 112,500, substantially higher than the current estimate by the Department of Finance. Thus, it appears that the anticipated growth rate projected in the General Plan EIR is overestimated based on the most recent population estimate from the California Department of Finance.

According to City Planning staff, the City has approved 2,434 residential units that have not yet been constructed. Using the average 2.57 person per household identified by the US Census, development of these units would add 6,255 people to the City. If the 685 residential units that are currently being considered for approval are, in fact, approved, it would add another 1,760 people. When the total population from these units is added to the current population, it results in a population of nearly 116,000.

The City's current boundary and sphere of influence are depicted in Figure 6.

Figure 6: City of San Buenaventura Sphere of Influence



REVIEW OF MUNICIPAL SERVICES

The following review of City services is based on provisions of state law requiring LAFCo to make determinations regarding the present and planned capacity of public facilities, the adequacy of public services, infrastructure needs and deficiencies and the City's financial ability to provide these services.

A. Fire Services

The City's Fire Department is an "all risk" department providing emergency medical response (paramedic), fire prevention, fire suppression, hazmat inspection/response, ocean rescue, and urban search and rescue throughout the City. Ambulance services are provided via a County contract with American Medical Response.

Fire Stations

The City operates 6 fire stations, each of which contains a fire engine company. In addition, a paramedic is assigned to each engine. Each station is located within a primary response area, or sector:

Sector 1 – Includes the west end of the City and western portion of downtown
Sector 2 – Includes eastern downtown, midtown and the harbor area
Sector 3 – Generally includes the northern-central area of the City
Sector 4 – Generally includes the southern central area of the City
Sector 5 – Generally includes the southeast portion of the City
Sector 6 – Includes the eastern portion of the City

According to responses to the MSR questionnaire, in addition to these primary response sectors, the Fire Department has entered into a contract with the County to provide initial response to the "North Ventura Avenue" area located outside City boundaries. Mutual aid agreements also provide for fire response to all areas located outside of the City. In addition, the City has entered into a reciprocity agreement with the City of Oxnard to provide emergency mutual aid.

Response Times

	Goal	Average Time	Percentage of Responses Meeting Goal
Non Emergency	No goal	2011: 6 min. 56 sec. 2012 (1st quarter): 6 min 32 sec	Not tracked
Emergency	Under 5 min. 90% of the time	2011: 5 min. 11 sec. 2012 (1st quarter): 4 min. 48 sec.	2010: 48% 2011: 48% 2012 (1st quarter): 58%

In 2010 and 2011, on average the City met its response time goal for less than half of all emergency calls. That percentage increased substantially at the beginning of 2012. The inability to meet the response time goal more than half the time in 2010 and 2011 appears to the be directly related to the City's closure of the fire station in Sector 4 in 2010 due to budgetary constraints. As a result of this closure, staffing levels fell to those of 1974 and

response times in the eastern half of the City met the City's goal only 16 percent of the time[1]. In mid 2011, the City was awarded a $2.3 million grant from the Department of Homeland Security to reopen the fire station. However, in order to receive the grant, the City had to contribute an additional $1.2 million. The City estimates that the $3.5 million would fund operation of the fire station for approximately three years ($1.2 million per year). The decreased level of service was a significant concern for the Ventura LAFCo during its consideration of a 2011 annexation proposal to the City (LAFCo 11-06 Parklands), so much so that LAFCo conditioned its approval on the City's acceptance of the $2.3 million grant. In late 2011 the City identified a source of funding for its share of the cost, received the grant, increased staff by 9 firefighter/medic positions, and reopened the fire station in January 2012.

Current Staffing Levels
The following Fire Department staffing levels are currently provided:

Administration	1 Fire Chief 1 Management Analyst 1 Secretary
Operations	1 Assistant Fire Chief 1 Battalion Chief - Training 3 Battalion Chiefs 1 EMS Coordinator 1 Secretary 21 Fire Captains 21 Fire Engineers 24 Firefighter/paramedics
Prevention	1 Fire Marshal 1 Secretary 2 Fire Prevention Specialists 1 Fire Prevention Technician 2 Hazmat Inspectors

The *Ventura Fire Department and Police Department Operational Details Report*, (ODR) dated February 15, 2012, was prepared to assist the City in understanding various operational aspects of the Fire Department. It included an analysis of the City's Fire Department staffing levels. According to the ODR, 25 Fire Captains, 25 Fire Engineers, and approximately 28 Firefighter/Paramedics are needed to sufficiently staff the City's six fire stations. In addition to responding to calls, this level of staffing allows for adequate time for incident documentation, apparatus and station maintenance, training, and various administrative tasks. It also minimizes the use of overtime to backfill minimum staffing slots due to personnel vacancies or personnel who are on various types of leave. The ODR recommends that either the Department be staffed with sufficient employees so that a capacity exists to frequently cover the absence of one shift worker without requiring overtime; or provide additional budgeted overtime to cover staff vacancies when needed. However, the ODR notes that excessive overtime can lead to staff "burnout".

[1] Ventura LAFCo 11-06 staff report, dated October 19, 2011

Costs
The adopted 2012-13 budget allocates $15,308,562 from the General Fund for fire services, an increase on nearly $900,000 from the last year's budget. The per capita cost for 2012-13 is approximately $142.

Future Staffing Levels

According to the City's response in the 2012 MSR questionnaire, the federal grant and required matching funds that enabled the Sector 4 fire station to reopen will fund operation of the fire station through November 2014. In order to avoid the substantial decrease in fire protection services in 2015 and beyond, the City will need to identify alterative long-term funding sources to keep all existing fire stations operational.

If the increased service demands anticipated from the over 8,000 estimated residents resulting from currently approved and proposed development projects are considered, the ODR staffing level recommendation would need to be further increased.

B. Library Services

The City of Ventura is served by two public libraries: the E.P. Foster Library, located downtown, and the Avenue Library, located on the west side of the City on Ventura Avenue. The libraries are administered and staffed by the Ventura County Library System.

Due to budget constraints, the H.P Wright Library, which provided services to the eastern portion of the City, was closed in November 2009. In May 2012 the City adopted a Library Strategic Plan, which identifies a 5-year plan during which current services/facilities are to be enhanced and a new library branch is to be constructed to serve the east side of the City by 2017.

Costs
According to the Library Strategic Plan, the amount of revenue received from property taxes is $17 per capita. The City provides an additional $90,000 per year and the County Library System provides an additional $350,000 in funding, bringing the per capita spending to almost $24. The national and state average per capita spending for library services is $48 and $33, respectively.

C. Police Services

The City's Police Department provides a wide variety of law enforcement services, including patrol, traffic enforcement, SWAT, school resource officers, investigations, and dispatch.

Current Staffing Levels

Administration	1 Chief 1 Assistant Chief 3 Secretaries 1 Civic Engagement Specialist
Field Operations	3 Commanders 8 Sergeants 8 Corporals 67 Police Officers

Investigations	1 Commander 2 Sergeants 22 Detectives 3 Police Services Officers 1 Crime Analyst
Dispatch	1 Sergeant 4 Corporals 12 Dispatchers 2 Police Service Officers
Records	1 Supervisor 10 Records Specialists 2 Dictation clerks
Professional Standards	1 Commander 2 Sergeants 1 Police Service Officers
Traffic	1 Sergeant 1 Corporal 4 Officers
Business Services	1 Business Services Officer 1 Payroll Specialist

In 2008, the City funded 134 sworn officer positions, for a ratio of 1 officer to approximately 794 residents (using 2010 population). Beginning In 2009, the number of officers funded by the City was reduced to 122, for a ratio of 1 officer per 878 residents. The City subsequently experienced a 24 percent increase in violent crime, as well as substantial increases in gang activity and other criminal behavior between 2010 and 2011. In fact, according to the City's website, in 2011 the City had the highest per capita violent crime rate in the County despite having one of the highest officers to resident ratios in the County.

For fiscal year 2012-13, the City has budgeted for an additional five sworn officers, for a total of 127 sworn officers, a ratio of 1 officer per 849 residents. An additional two officers are anticipated to be added next fiscal year.

Response Times

	Goal	Percentage of Responses Meeting Goal in 2011
Non Emergency	No goal	Not measured
Emergency	Under 5 min. 90% of the time for Priority 1 calls	62%

Operational Costs

For the current fiscal year, $28,510,749 was allocated for police services, of which $27,416,970 is to come from the General Fund. The total per capita cost for police services for the current fiscal year is $264.

Future Staffing Levels

In order to maintain the current ratio of 1 officer per 849 residents for approved and proposed residential development, an additional 9.5 sworn officers will be required. Without these additional officers the ratio of officer to resident would be 1 to 911, which is lower than the 2009 ratio that corresponded to a spike in violent crime. In order to maintain the current staffing ratio of one officer per 844 residents for the projected population in 2030, a total of 139 sworn officers will be required.

D. Recreation and Park Services

The City provides a wide variety of park facilities and recreational programs, services, and activities for City residents and nearby communities. Non-City residents who participate in recreational programs are charged an additional $5.00 for programs costing $25-$75 and $10 for programs costing more than $75.

Park Facilities
The City General Plan identifies three type of parks: 'Neighborhood Parks' are typically under 8 acres in size and primarily serve a specific residential area; 'Community Parks' provide specialized recreational opportunities for more than one neighborhood and can include formal sports fields, courts, and recreational buildings; 'Citywide Parks' provide recreational opportunities that draw a wide range of ages and interest groups throughout the City. The City also operates special use parks and linear parks.

The table on the following page is a list of all parks and facilities operated by the City.

	Acres	Play-ground	Basket-ball	Tennis Courts	Soft-ball	Sports Fields	Trails
Neighborhood Parks							
Barranca Vista	8.7	•					
Blanche Reynolds	3.4	•					
Cemetery Memorial	7.1						
Chumash	6.1	•					
Downtown Mini	0.4						
Hobert	7.1	•					
Juanamaria	5.0	•	•	•			
Junipero Serra	2.7						
Marion Cannon	5.0		•				
Mission	1.5						
Montalvo Hill	7.0	•	•				
Ocean Avenue	1.3	•	•				
Plaza	3.7	•					
Promenade	1.0						•
Thille	5.0	•	•				
Community Parks							
Fritz Huntzinger Sports*	18.3				•	•	
Ventura Community	100				•	•	•
Westpark	7.3	•	•			•	
Citywide Parks							
Arroyo Verde	129.3	•					•
Camino Real	38.2	•	•	•	•	•	•
Grant	107.3						
Harry A. Lyon	10.7		•	•	•	•	
Marina	15.3	•					
Special Use							
Albinger Archeological	0.9						
Eastwood	0.7						
Linear Parks	46.0						•
Olivas Adobe Historical	22.5						
Ortega Adobe	0.3						
Seaside Wilderness	24.0						•
Surfers Point at Seaside	3.4						

The City provides approximately 589 acres of developed park facilities. According to the City General Plan, the City parkland standard is to provide 10 acres per 1,000 residents. To meet this standard for a current population of approximately 108,000, 1,080 acres would need to be provided.

The City also operates the Ventura Avenue Adult Center at which seniors can receive various services or participate in classes and activities, as well as two recreation centers, and two golf courses.

Recreation Programs
Among the parks and recreation programs offered by, or in conjunction with, the City are:

- Youth and adult sports classes, clinics, camps and leagues including basketball, golf, soccer, softball, volleyball and fitness programs
- Aquatics programs and activities
- Special interest and life enrichment classes for youth, teens and adults
- Arts and crafts programs, dance, music, and other creative classes
- Various cultural events
- Senior services, including computer, recreational, social, health, and fitness programs

E. Solid Waste Services

Solid waste services are provided via franchise agreements with E.J. Harrison & Sons. The City funds a number of services related to solid waste, including managing contracts, customer service, waste reduction programs, and hazardous waste disposal.

F. Streets, Highways and Drainage

According to the City's 2012 MSR questionnaire responses, the City is a direct provider of street construction and maintenance and street lighting services. Street sweeping and landscape maintenance are provided via contract. The City estimates that it has 1,240 paved lane miles.

According to the transmittal letter for the City's proposed 2012-13 budget, the City "is failing to keep up with repair of streets, sidewalks, storm drains, alleys, parks, public buildings and facilities."

Street Maintenance
City's 2012-13 General Fund budget allocates $1,193,473 for pavement maintenance, or $962.48 per lane mile. The allocation for street pavement maintenance has dropped steadily from approximately $1.5 million in 2009. According to City staff, based on the latest data, in order for the City to maintain a good Pavement Condition Index (PCI) average of 75, a one-time investment of $27 million is needed and $9.6 million annually thereafter. Annual funding levels (including Gas Tax) are at $3.9 million for street resurfacing and preventive maintenance, which means the City would need an additional $5.7 million per year.

According to the adopted budget, Gas Tax revenues will provide approximately $16.3 million in capital improvements for streets, including street repaving, slurry seal, and bike lane improvements.

Street Lighting
A total of $2,076,338 is allocated for both street lighting and traffic signal maintenance. This includes $1,368,760 for Street light District 36, which provides for maintenance and operation for the Southern California Edison-owned street lights. Currently, the General Fund allocates $487,124 toward the maintenance of the City's Street light District 36.

Stormwater
The City provides stormwater and flood control services to comply with the Ventura Countywide Municipal Stormwater National Pollutant Discharge Elimination System (NPDES) permit. The City provides public outreach, illicit discharge response and abatement, public infrastructure maintenance, new development discharge controls, and construction site pollution controls. The 2012-13 budget allocates $738,990 toward this program, a per capita cost of $6.90. An additional $904,784 is allocated for stormwater utility maintenance.

Street Sweeping
Street sweeping services are provided via contract with a private provider. Residential streets are swept once per month. Commercial and industrial streets are swept twice per month. Downtown streets and major thoroughfares are swept three to five times per week.

G. Water Services

The City supplies potable water to all areas within the City. It also provides potable water to unincorporated areas outside the City, including North Ventura Avenue, Saticoy, and the Saticoy Country Club community. Customers outside the City pay a surcharge of $0.73 dollars per each 750 gallons of water.

Current Potable Water Demand and Supply
According to the City's 2010 Urban Water Management Plan (UWMP), water demand in 2010 was 17,351 acre feet per year, substantially lower than the 2005 demand of 20,808 acre feet. This reduction in demand is likely attributable to a variety of water conservation efforts during the drought, which ended in 2011 (indeed, the UWMP projects that water demand for 2015 will be 22,286 acre feet). For demand projection purposes, the UWMP assumes a daily per capita use of 168 gallons, which is the average demand from 2000-2009. Using a current population estimate of approximately 108,000, current demand within the City is estimated to be 20,324 acre feet per year. Overall demand would be expected to be higher when considering the 2,000-3,000 inhabitants and commercial/industrial uses in Saticoy and the North Ventura Avenue area. However, based on the City's water billing records for the City's water service area and an assumed 6.5 percent increase due to unaccounted for water uses, total demand in 2011-12 is estimated at 17,242 AF[1].

According to City staff[2] and the UWMP, the City's current water supply sources are as follows:

Casitas Municipal Water District	5,000 acre feet per year
Groundwater from City wells	9,700 acre feet per year
Surface water (Ventura River)	4,200 acre feet per year
Recycled water	700 acre feet per year
Total	19,600 acre feet per year

Thus, current water demand within the City service area appears to consume approximately 88 percent of the current total supply.

[1] Memo from Ventura Water Water Resource Manager, Susan Rungren, to LAFCo Executive Officer, Kim Uhlich, dated October 30, 2012
[2] Ibid

Future Potable Water Demand and Supply
The UWMP estimates that the population in the City's water service area will increase to 140,272 by 2035, resulting in a demand of 26,436 acre feet per year (AFY). However, state law requiring a per capita reduction in water demand by 2020 results in a target demand of 22,345 by 2035.

According to the UWMP, the City will have constructed an additional groundwater well by 2015 that will allow the City to increase pumping from the Santa Paula Groundwater Basin from the current 1,600 AFY to its full 3,000 AFY year allocation. The City also anticipates that, by 2020, it will complete improvements to wells drawing water near the Ventura River that will provide an additional 2,500 AFY. Based on these estimates, the City's anticipated water supplies by 2035 are as follows:

Casitas Municipal Water District	5,000 acre feet per year
City-pumped groundwater	11,100 acre feet per year
Surface water (Ventura River)	6,700 acre feet per year
Recycled water	700 acre feet per year
Total	23,500 acre feet per year

Anticipated water supply in five year increments through by 2035 is as follows:

City's Anticipated Water Supply (AFY)

2012	2015	2020	2025	2030	2035
19,600	21,000	23,500	23,500	23,500	23,500

According to the City Planning Division, there are 2,170 residential units that have been approved, but are not yet built, and 264 units currently under construction, for a total of 2,434 units. Using the 2.57 average persons per household identified by the 2010 Census, these 2,434 residential units will house approximately 6,255 people. At 168 gallons per capita per day, the anticipated water demand from these units would be 1,177 AFY, for a total demand of 18,419 AF. Thus, currently, 94 percent of the City's water supply has been allocated to existing and approved development. In addition, another 685 residential units are currently being considered for approval, which would result in an additional 331 AFY of demand for a total of 18,750 AFY, or 96 percent of current supply.

It should also be noted that during drought conditions, the UWMP estimates that supply from the Ventura River would be reduced by 700 AF during the second year of drought and 2,200 AF the third year. In addition, pursuant to a 1996 stipulated judgment, in multi-year drought conditions groundwater supply from the Santa Paula basin must be reduced from 3,000 AFY to 1,141 AFY, a reduction of 1,859 AF. Additional groundwater pumping could provide 1,500 AF. Therefore, according to the UWMP, during drought conditions, the City's water supply could be reduced by as much 2,559 AFY. It appears that during drought conditions, the City may not have adequate supplies to meet normal demand in upcoming years and measures would need to be put in place to reduce demand.

The City is exploring a number of measures to increase supply and/or reduce demand, including using additional reclaimed water from the Ventura Water Reclamation Facility, partnering with the Ojai Valley Sanitary District for use of reclaimed water, various conservation measures and public education, implementation of the City's Water Efficiency plan, continued implementation of the City's Reclaimed Water Policy, and the possible

development of a water rights ordinance. The effectiveness of these measures has yet to be determined and the timeframes for their implementation are unclear.

H. Wastewater Services

The City provides wastewater conveyance and treatment services to approximately 98 percent of the residences within in the City as well as McGrath State Beach Park and the communities along the coast north of the City within Ventura County Service Area No. 29. The City anticipates taking over wastewater treatment services from the Montalvo Community Service District in the near term and the Saticoy Sanitary District in the long term. The City's wastewater collection system consists of approximately 285 miles of gravity sewers ranging in size from 4 to 42 inches, approximately 5 miles of force mains, 11 wastewater lift stations, and the Ventura Water Reclamation Facility (WRF), a tertiary treatment plant. The collection system sewers convey flows generally from east to west and north to south, culminating at the Ventura Water Reclamation Facility for treatment.

Wastewater Demand, Treatment, and Conveyance
The City's 2010 Wastewater Treatment Master Plan evaluated the condition of the wastewater conveyance system. It identified a number of existing, short-term, and ultimate (General Plan build-out) system deficiencies in the collection system and the projected costs to correct them, as follows:

- Existing – 339 pipe segments totaling 86,500 feet ($36,400,000)
- Near term – 233 pipe segments totaling 61,760 feet ($16,400,000)
- Ultimate – 318 pipe segments totaling 81,800 feet ($21,500,000)

These deficiencies are located throughout the City and include both mainlines and large trunk lines.

According to the 2012 MSR questionnaire responses, the WRF has a treatment capacity of 12.1 million gallons of wastewater per day and currently treats an average of 8.63 million gallons per day. According to the City's 2010 Wastewater Treatment Master Plan, the City's treatment plant has a permit-rated capacity of 14.0 million gallons per day, however, many of the facilities at the treatment plant are operating beyond a typical design life and the conditions of the facilities were not assessed as part of the Master Plan. Additional assessments of these facilities will be necessary and depending on their condition, a comprehensive replacement program may need to be developed before the plant can be expanded to a 14.0 million gallon per day treatment capacity.

According to the Wastewater Master Plan, near-term development within the City and in areas outside the City but within the City's wastewater service area will increase the volume of wastewater flows to approximately 11.4 million gallons per day, or 94% of the current capacity of the treatment facility. Build-out of the current General Plan and demand within the anticipated service area is projected to generate 13.0 million gallons per day, exceeding the treatment plant's current capacity.

In 2011, the City entered into a long term settlement of pending legal challenges to the discharge of wastewater into the Santa Clara River estuary. It commits the City to invest in new facilities to divert 100 percent of the wastewater to "beneficial uses" in coming decades. Funding to accomplish this goal and provide for the necessary infrastructure will be derived from increased rates to customers.

WRITTEN DETERMINATIONS

A. Growth and population projections for the affected area

According to the US Census, from 2000 to 2010, the City increased in population from 100,916 to 106,433. The California Department of Finance estimates the City's population to be 107,166 as of January 1, 2012. Thus, from 2000 to 2012, the City grew by an estimated 6,250 people, or 6.19 percent. This 6.19 percent growth rate over 12 years equates to an estimated average annual growth rate of 0.52 percent. The following table reflects the City's projected population in 5-year increments based on this estimated rate of growth. The table also reflects the annexation of the community of Montalvo to the City in 2012:

	2012	2015	2020	2025	2030
City Population	107,166	108,847	111,706	114,641	117,653
Montalvo	632	632	632	632	632
Total Population	**107,798**	**109,479**	**112,338**	**115,273**	**118,285**

The City updated its General Plan in 2005. The EIR prepared for the update included population projections based on an annual growth rate of 0.88 percent (average from 1994-2004) and a 2004 population of 104,952. The projections used in the General Plan would result in an estimated 2012 population of approximately 112,500, substantially higher than the current estimate by the Department of Finance. Thus, it appears that the anticipated growth rate projected in the General Plan EIR is overestimated based on the most recent population estimate from the California Department of Finance.

According to City Planning staff, the City has approved 2,434 residential units that have not yet been constructed. Using the average 2.57 person per household identified by the US Census, development of these units would add 6,255 people to the City. If the 685 residential units that are currently being considered for approval are, in fact, approved, it would add another 1,760 people. When the total population from these units is added to the current population, it results in a population of nearly 116,000.

B. The location and characteristics of any disadvantaged unincorporated communities within or contiguous to the sphere of influence

As defined by Section 56033.5 of the Government Code, a "Disadvantaged Unincorporated Community" (DUC) is a community with an annual median household income that is less than 80 percent of the statewide annual median household income. The Ventura LAFCo has determined that the community of Saticoy, abutting the City to the southeast and located within the City's current sphere of influence, is a DUC. The following demographic information was obtained from the 2010 Census:

Population:	1,029
Median Household income:	$21,343
Poverty rate:	28.4%
Race:	87% Hispanic

Saticoy receives wastewater services from the Saticoy Sanitary District, an independent special district which serves only the community of Saticoy. Potable water services are

provided by the City and customers are subject to the City's water surcharge for service provided outside of City limits. City policy generally precludes new or expanded water services greater than a ¾-inch meter, thus, limiting the amount of multi-family, commercial, and industrial development/redevelopment that can occur within the community. Law enforcement services are provided by the County Sheriff's Office and fire protection services are provided primarily by City under a mutual aid agreement.

C. Present and planned capacity of public facilities, adequacy of public services, and infrastructure needs or deficiencies

Fire services:

- The City operates six fire stations which serve the City and nearby unincorporated communities.
- The closure of Fire Station 4 in 2010 resulted in substantial reductions in response times for emergency services to approximately the eastern half of the City. In 2011, the City obtained funding to reopen the fire station through most of 2014. However, the availability of funding for this station beyond 2014 is uncertain at this time.
- The current level of staffing does not appear to be sufficient to provide personnel adequate time to perform their duties and to maintain adequate emergency response staffing without incurring substantial overtime costs.

Library services:

- Library services are provided by two libraries, both of which are located on the west end of the City. The city has adopted a 5-year plan with the goal of improving services and constructing a new library to serve the east side of the City.
- Per capita library spending is below the national and state averages.

Police services:

- The City provides a high ratio of sworn officers to residents.
- Recent reductions in police staffing correlated to a significant increase in violent crime in the 2011. The City has budgeted for an additional five sworn police officers and plans for another two officers next fiscal year.
- In order to maintain the current ratio of sworn officers to residents for approved and proposed residential development, an additional 9.5 sworn officers will be required.

Recreation and parks services:

- The City provides a wide range of park facilities and recreation programs.
- The City's goal is to provide 10 acres of park space per 1,000 residents. To meet this goal for the current population, 1,080 acres would need to be provided.
- The City provides 589 acres of developed park facilities.

Solid waste services:

- The City has entered into franchise agreements with a refuse collection company for solid waste collection and disposal services. Customers are billed directly by the service provider for these services.
- The City funds a number of additional solid waste-related services to encourage recycling, hazardous waste collection, and community beautification and enhancement.

Streets and highways:

- The City provides street and landscaping maintenance and storm drain maintenance services. Street sweeping services are provided as part of the franchise agreements with solid waste providers. A large majority of street lighting in the City is owned and maintained by Southern California Edison and is funded by the City. The City does maintain street lights owned by the City.
- Maintenance of City streets is significantly underfunded and likely to result in continued deterioration of City streets.

Potable water:

- The City provides potable water to the City and to areas adjacent to the City.
- It appears that current demand within the City's water service areas is 88 percent of current total supply.
- It appears that the water demands from approved, but not built, development will increase demand to 94 percent of current supply.
- It appears that currently-proposed development would increase water demand to 96% of current supply.
- It appears that anticipated reductions in supply during drought conditions will result in current and future normal water demand exceeding supplies, requiring implementation of measures to reduce demand.

Wastewater:

- The City provides wastewater collection and treatment services to the City and to adjacent unincorporated areas.
- The City's collection system currently experiences capacity deficiencies. In addition, the City has identified short-term capacity deficiencies and deficiencies at buildout of the General Plan.
- The City's Treatment Plant has adequate capacity to accommodate current wastewater flows. Anticipated wastewater flows from buildout of the General Plan will exceed the current capacity of the City's treatment plant. Additional assessment must occur in order to demonstrate that expansion of the treatment facility is feasible.

D. Financial ability of agencies to provide services

- Long-term funding needed to keep all currently operating fire stations open beyond 2014 has not been identified.
- In order to maintain the current Police officer-to-resident staffing ratios for new and proposed development, an additional 9.5 sworn officers are required. It is unclear how these positions will be funded.
- The City has identified funding shortfalls of up to $5.7 million per year for maintenance services necessary to prevent further deterioration of City streets.
- The costs to address the current deficiencies identified in the City wastewater collection system are projected to exceed $36 million. The source of funding and the timing of the improvements have not been identified.
- Sewer system improvements needed to accommodate near term and ultimate future growth and development is projected to cost approximately $38 million. The source of funding and the timing of the improvements have not yet been identified. In addition, the cost to construct the infrastructure necessary to divert wastewater for "beneficial uses" per the City's legal settlement has not been identified.

E. Status of, and opportunities for, shared facilities

- No other obvious additional opportunities for shared facilities were noted.

F. Accountability for community service needs, including governmental structure and operational efficiencies

- The City is locally accountable through an elected legislative body, adherence to applicable government code sections, open and accessible meetings, dissemination of information, and encouragement of public participation.
- The City's website contains a significant amount of information on the current and previous City budgets, services and programs, City happenings and activities, public meetings, development activities, and City documents. Current and past City Council minutes and agendas are posted and agenda items are linked to staff reports.
- Meetings of the City Council are broadcast live on the City's cable channel. Archived videos of past meetings are available for viewing on the City's website.
- To achieve operational efficiencies for storm water quality purposes, the City is covered under the County's National Pollutant Discharge Elimination System permit.

G. Any other matter related to effective or efficient service delivery, as required by Commission policy

- No other matters were identified.

ATTACHMENT D: DEVELOPMENT ENTITLEMENT REPORT 2005-2012
(Approved, Under Construction and Built Projects)

	2005 Retail (sf)	2012 Retail (sf)	% Projected	2005 Office (sf)	2012 Office (sf)	% Projected	2005 Industrial (sf)	2012 Industrial	% Projected	2005 Hotel	2012 Hotel	% Projected	2005 Total Non-Residential	2012 Total Non-Residential	% Projected	2005 Residential Dwelling Units	2012 Residential Dwelling Units	% Projected
DISTRICTS																		
Upper North Avenue	10,000	0	0	50,000	0	0	150,000	0	0	0	0	0	210,000	0	0	100	0	0
North Avenue	10,000	0	0	50,000	0	0	250,000	0	0	0	0	0	310,000	0	0	50	0	0
Downtown Specific Plan	100,000	18,807	19	200,000	123,665	62	0	0	0	150,000	0	0	450,000	142,472	32	1,600	449	28
Pacific View Mall	25,000	16,981	68	0	7,434	743,400	0	0	0	0	0	0	25,000	24,415	98	25	0	0
Harbor	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	330,000	0	0	545,000	21,360	4	300	300	100
Arundell	25,000	11,626	47	300,000	2,320	1	1,000,000	55,687	6	0	0	0	1,325,000	69,635	5	200	0	0
North Bank	300,000	30,282	10	50,000	0	0	300,000	394,029	131	[illegible]	0	0	650,000	424,311	65	50	0	0
Montalvo	0	0	0	50,000	0	0	25,000	0	0	0	0	0	75,000	0	0	50	0	0
Saticoy	0	0	0	0	0	0	25,000	0	0	0	0	0	25,000	0	0	50	0	0
Subtotals (Districts)	785,000	98,998	13	700,000	133,419	19	1,750,000	449,116	26	380,000	0	0	3,615,000	681,833	19	2,425	749	31
CORRIDORS																		
Ventura Avenue	40,000	7,029	18	100,000	7,300	7	50,000	0	0	0	0	0	190,000	14,329	8	800	240	30
Main Street	15,000	6,082	41	40,000	593	1	0	0	1	0	0	0	55,000	6,675	12	100	46	46
Thompson Boulevard	15,000	17,716	118	40,000	0	0	0	0	0	0	0	0	55,000	17,716	32	300	34	11
Loma Vista	15,000	5,100	34	40,000	341,660	854	0	0	0	0	0	0	55,000	346,760	630	25	0	0
Telegraph Road	15,000	0	0	40,000	0	0	0	0	0	0	0	0	55,000	0	0	250	0	0
Victoria Avenue	15,000	0	0	40,000	0	0	0	0	0	0	0	0	55,000	0	0	50	154	308
Johnson Drive	50,000	840	2	20,000	0	0	0	0	0	0	0	0	70,000	840	1	150	0	0
Wells Road	15,000	25,000	167	20,000	0	0	0	0	0	0	0	0	35,000	25,000	71	50	173	346
Subtotals (Corridors)	180,000	61,767	34	340,000	349,553	103	50,000	0	0	0	0	0	570,000	411,320	72	1,725	647	38
SPHERE OF INFLUENCE/SOI/OTHER INFILL/NEIGHBORHOOD CENTERS																		
101/126 Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0
Wells/Saticoy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,050	594	66
Pierpont	30,000	20,230	67	0	0	0	0	0	0	0	0	0	30,000	0	0	100	138	138
Other Neighborhood Centers (includes Seaward/Allessandro+College/ Day+Gateway Plaza+Victoria Plaza+Bristol+Kimball/Telegraph+Petit/Telephone+Telephone/ Cachuma+Saticoy)	0	20,965	2,095,600	0	0	0	0	0	0	0	87,000	8,888,900	0	107,965		100	0	0
Second Units	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	55	18
Underutilized	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	250	0	0
Vacant	165,000	0	0	50,000	0	0	0	0	0	0	0	0	215,000	0	0	450	0	0
Subtotals (SOI/Other Infill/NC)	195,000	41,195	21	50,000	0	0	0	0	0	0	87,000	8,888,900	245,000	107,965	44	2,450	887	36

	2005 Retail (sf)	2012 Retail (sf)	% Projected	2005 Office (sf)	2012 Office (sf)	% Projected	2005 Industrial (sf)	2012 Industrial	% Projected	2005 Hotel	2012 Hotel	% Projected	2005 Total Non-Residential	2012 Total Non-Residential	% Projected	2005 Residential Dwelling Units	2012 Residential Dwelling Units	% Projected
Planning Communities (Not included within District/Corridor/Center above)																		
Downtown	1,072	0	0	0	0	0	0	0	0	150,000	0	0	151,072	0	0	50	0	0
Ventura Ave/Westside	7,086	0	0	0	0	0	27,000	0	0	0	0	0	34,086	0	0	238	0	0
Midtown	13,751	0	0	0	0	0	0	0	0	0	0	0	13,751	0	0	34	3	9
College (Telegraph/Loma Vista)	2,718	0	0	8,843	1,761	20	0	0	0	0	0	0	11,561	1,761	15	4	14	350
Telephone Road Corridor	0	0	0	54,785	0	0	0	0	0	0	0	0	54,785	0	0	256	0	0
Montalvo/Victoria	0	0	0	4,300	0	0	0	0	0	0	0	0	4,300	0	0	296	0	0
Saticoy/East End	7,950	56,102	706	5,600	0	0	0	0	0	0	0	0	13,550	56,102	414	840	220	26
Arundell	41,640	0	0	42,614	0	0	18,080	0	0	0	0	0	102,334	0	0	0	0	0
Olivas	7,160	0	0	7,066	0	0	390,053	0	0	0	0	0	404,279	0	0	0	0	0
Pierpont	0	912	91,200	0	0	0	0	0	0	0	0	0	0	912	91,200	0	0	0
Serra	0	0	0	0	1,000	100,000	0	0	0	0	0	0	0	1,000	100,000	0	232	23,200
Thille	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	12,000
Wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Westside	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	163	16,350
Subtotal (Planning Communities)	81,377	57,014	70	123,208	2,761	2	435,133	0	0	150,000	0	0	789,718	59,775	8	1,718	752	44
TOTAL	1,241,377	258,974	21	1,213,208	486,733	40	2,235,133	449,116	20	530,000	87,000	16	5,219,718	1,280,823	25	8,318	3,035	36

Gustorf, Kevin

From: Rungren, Susan <srungren@venturawater.net>
Sent: Tuesday, January 08, 2013 2:45 PM
To: Gustorf, Kevin
Cc: Rungren, Susan
Subject: Fwd: Ventura utility section

fyi

Susan Rungren
Principal Engineer
Ventura Water
(805) 652-4523

From: "Chandra Chandrashaker" <cchandrashaker@ci.ventura.ca.us>
To: "Susan Rungren" <srungren@ci.ventura.ca.us>, "Betsy Cooper" <bcooper@ci.ventura.ca.us>
Cc: "Lucho Rodriguez" <lrodriguez@ci.ventura.ca.us>
Sent: Tuesday, January 8, 2013 2:36:25 PM
Subject: Fwd: Ventura utility section

Susan,

Here are the water demand factors for non-residential uses identified in the GP EIR. Chandra

---

From: "Joe Power" <JPower@rinconconsultants.com>
To: "Chandra Chandrashaker (cchandrashaker@ci.ventura.ca.us)" <cchandrashaker@ci.ventura.ca.us>
Sent: Tuesday, January 8, 2013 9:53:48 AM
Subject: FW: Ventura utility section

Chandra:

Below are the water demand factors from the General Plan EIR. The same factors were used citywide.

Joe

From: Mike Swan [mailto:mswan@psomas.com]
Sent: Tuesday, January 08, 2013 9:43 AM
To: Joe Power
Subject: RE: Ventura utility section

Joe –

I was not able to find the exact final table included in the document you sent but I did find some preliminary water demand projection worksheets that included the demand factors and I tested them in the tables you provided and they worked. So here are the demand factors used:

Residential 450 gpd/du

Retail	250 gpd/ksf
Office	250 gpd/ksf
Industrial	315 gpd/ksf
Hotel	500 gpd/ksf

ksf = thousand square feet

We had some other demand projections that were acreage-based but these should work with the tables you referenced.

Call if you have any questions.

Michael D. Swan, PE
PSOMAS | *Balancing the Natural and Built Environment*
Senior Project Manager
Water & Wastewater Infrastructure
3 Hutton Centre Drive Suite 200
Santa Ana CA 92707 714.751.7373
Direct 714.481.7979

From: Joe Power [mailto:JPower@rinconconsultants.com]
Sent: Monday, January 07, 2013 3:41 PM
To: Mike Swan
Subject: Ventura utility section

Hi Mike:

Those tables are 4.13-15 through 4.13-20 in the attached document. Thanks.

Joe Power
Principal

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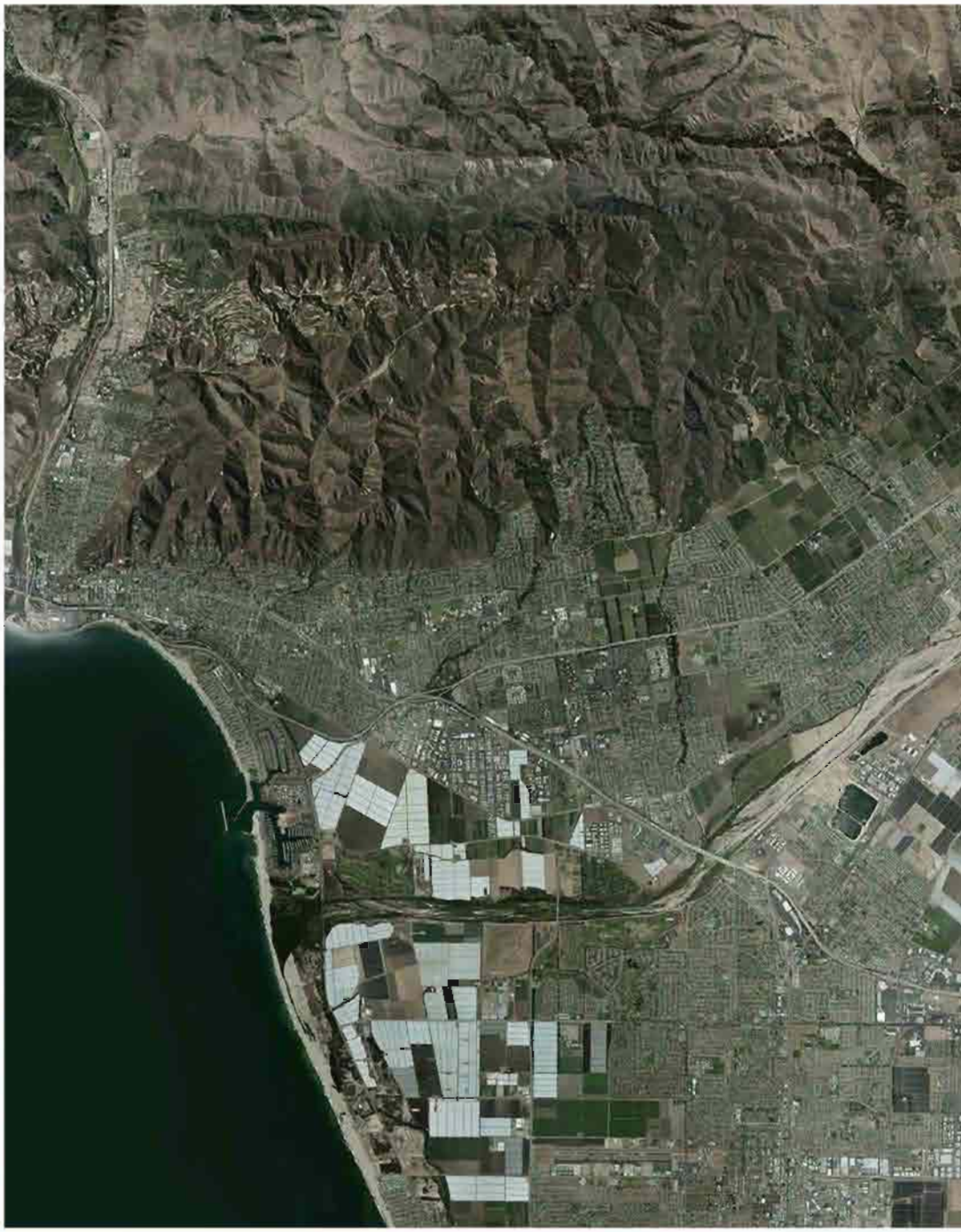

Calculating Constant-Reliability Water Supply Unit Costs

Gary Wolff, P.E., Ph.D.[1]

Abstract

Water planners facing a choice between water "supply" options (including conservation) customarily use the average unit cost of each option as a decision criterion. This approach is misleading and potentially costly when comparing options with very different reliability characteristics. For example, surface water, desalinated seawater or recycled wastewater, and some outdoor demand management programs have very different yield patterns. This paper presents a method for calculating constant-reliability unit costs that adapts some concepts and mathematics from financial portfolio theory. Comparing on a constant-reliability basis can significantly change the relative attractiveness of options. In particular, surface water, usually a low cost option, is more expensive after its variability has been accounted for. Further, options that are uncorrelated or inversely correlated with existing supply sources – such as outdoor water conservation -- will be more attractive than they initially appear. This insight, which implies options should be evaluated and chosen as packages rather than individually, opens up a new dimension of yield and financial analysis for water planners.

Keywords

Reliability, value of reliability, portfolio theory, water supply planning, drought planning, integrated resource planning, water conservation, uncertainty, adjusted unit costs.

[1] Principal Economist and Engineer, The Pacific Institute, 654 13th Street, Oakland CA 94612, Telephone: 510 251 1600, Mobile: 510 823 3935, Facsimile: 251 2203, gary_wolff@pacinst.org

Introduction

Water planners commonly estimate an average unit cost for each water supply option (including conservation measures) by dividing average annual total yield of the option by annual average total cost (the sum of average annual fixed plus variable costs).[2] Lower unit cost options are preferred on a financial basis, although other decision criteria are also used (e.g., see Bureau of Reclamation 1983 or DWR 2005). A time sequence of new facilities is often planned based on anticipated growth of demand, with new facilities brought on line in time to prevent a supply shortfall under appropriate hydrologic (e.g., dry-year rainfall) or other (e.g., average reservoir yield) assumptions. Facilities with lower estimated average unit costs are typically built first.

This procedure is understandable and often appropriate when water supply options do not vary enormously in availability. Two source watersheds with very different rainfall patterns might have similar variation in annual water availability if there are appropriately sized reservoirs in each watershed. Similarly, the variation in availability between a surface water reservoir and a groundwater aquifer might not be that different if the reservoir is large relative to annual demand.

However, annual availability may also vary significantly between options. Consider a run-of-the-river system on an intermittent stream as compared with a deep groundwater aquifer. Furthermore, when demand grows more rapidly than supply, there is an implicit

[2] Since variable costs tend to rise over time, planners often compare "levelized average costs" over the planning horizon (e.g., 30-50 years).

decline in the adequacy or reliability of a variable water source because the frequency with which demand exceeds supply increases. In addition, new sources of supply, such as surface and groundwater from previously unutilized watersheds or aquifers, desalinated seawater, recycled wastewater, and demand management programs often have very different patterns of availability than traditional surface water supplies.

Retirement fund and water managers face a similar challenge. Each must deliver a minimum quantify of something (money or water) every year while the source of that something (e.g., securities markets or nature) varies randomly. Fortunately, random variation can be at least partially characterized with statistics. Of course past investment success is not a prediction of future performance; just as past hydrologic patterns (at least since modern records became available) are not necessarily predictive of future patterns in a world whose climate is changing. Nonetheless, retirement managers who use the statistical tools of portfolio theory are much more successful than those who ignore such considerations.[3] This paper shows water planners how to improve their performance by applying a mathematical adaptation from financial portfolio theory.

What Is Water-Supply Reliability and How Do We Measure It?

Water-supply reliability is an important characteristic of all municipal systems. For example, California's water utilities invest substantial amounts of money to reduce the risk of supply interruptions due to earthquakes. They understand that the cost to their customers of supply disruptions is often far greater than the cost of improved system

[3] Markowitz (1952) provided the first mathematically rigorous analysis of the value of diversification in investment portfolios. There have since been thousands of peer-reviewed articles on this subject.

reliability. Similarly, dams and reservoirs are widely used to reduce the risk of supply interruption due to dry weather. Other threats to water supply reliability include climate change, changes in runoff patterns as more impermeable surfaces are created by land development, changes in water quality or environmental regulations, variation in important cost factors (e.g., interest rates, labor, or energy), legal issues related to water rights or contracts for water deliveries, and cultural and political factors.

There is no widely accepted method for measuring water-supply reliability. The simplest method is to measure the risk of projected supply falling below projected demand, on average. For example, a system with a reliability level of 95% implies that supply will meet or exceed demand 19 years out of 20. This approach has the advantage of being simple. However, like most simple approaches, it has drawbacks. The most notable one is that it does not measure the severity of the water shortfalls. One can imagine a system with reliability of 90% that is more desirable than another system with reliability of 95% because the shortfalls in water supply in the first system are very small while the less frequent shortfalls in the second system are very large.

Nonetheless, for the discussion below we use this definition because it allows a clear discussion of an important issue. The reliability percentages presented in the numeric illustration are intended as a summary statistic for all of the uncertain issues mentioned above, although in practice many of these factors are very difficult to quantify accurately.

How Do We Measure or Account for the Value of Reliability?

Economists typically address this question by assessing customer willingness to pay for a slightly reduced chance of water shortages. For example, suppose the chance of a water shortage that would require rationing is 1 in 20 in any given year, but an investment in a new reservoir can reduce that chance to 1 in 21. If additional water isn't needed (except in severe drought), then customer willingness to pay for the reservoir is a measure of the value customers place on increased reliability. Numerous economic studies have found high willingness to pay to avoid drought-related or other restrictions on water use; ranging from $32 to $421 dollars per household per year (Griffin and Mjelde 2000, Carson and Mitchell 1987, Howe, et.al. 1994, Barakat and Chamberlin 1994), in year 2003 dollars. When the estimated quantity of water use foregone due to a drought restriction is multiplied by the probability (frequency) of the drought scenario investigated, these annual household WTP estimates imply a reliability value to residential customers as high as about $4,000 per acre-foot (Raucher et al., 2005).

This approach, unfortunately, doesn't help answer our question. Customers don't need to know <u>how</u> reliability will increase in order to value it. Customers aren't saying anything about the relative value of different options for increasing reliability. They're just saying that more reliability – regardless of how it is achieved – has a value. Consequently, we developed a method for adjusting estimated average unit costs of water supply options, including conservation and end-use efficiency, to obtain "constant-reliability unit costs" that fairly compare supply options with different uncertainty characteristics. Our approach is quite different than that presented in papers that quantify the value of

reliability (e.g., Howe, et.al. 1994). We do not quantify the value of reliability, but instead estimate the costs of options when they are sized to provide equal reliability.

Our method involves a two-step process. In the first step, water managers define the level of reliability benefit they want to maintain or achieve. For example, they might want to ensure that enough water is available to meet demand in 19 out of 20 years, on average. We call this a reliability level (R) of 95%. In the second step, they create an "apples to apples" comparison of options by adjusting average unit costs ($/unit of water) to get constant-reliability unit costs. The following example illustrates the method. The relevant math is presented in Appendix A.

Constant-Reliability Unit Costs Illustrated

Suppose a community is served by a run-of-the-river water supply. Figure 1 shows the maximum supply available from the river for human extractive purposes[4] each year as having a normal distribution. Although flow data usually follows distributions other than normal,[5] the normal distribution is useful for an illustration. The method presented in this paper can be applied to any statistical distribution.[6]

Insert Figure 1 here

[4] That is, in-stream flows required by law have been subtracted from gross flow before drawing this graph.
[5] The Pearson Type III distribution, for example, is often used for extreme events like floods and droughts.
[6] A reviewer of this paper remarked that a water system he once worked with had a hydrologic probability of annual shortage of only 1 in 3,000. However, it once experienced an ice clog in the main water treatment supply pipeline, and when operators went to activate a bypass valve to bring water from a backup source, the valve broke. At the worst point in time, only hours of treated water remained. Ideally, the probability of supply failure from events like this will be included in the statistical distributions representing supply from each option. But some uncertainty cannot be quantified.

In the normal distribution, the average supply is the most common amount. Low and high supplies are increasingly rare as they get further from the average. The relative "flatness" of the bell is described by the coefficient of variance (V): the standard deviation (SD) divided by the mean (A). The larger the coefficient of variance, the flatter the bell; and the more variable is the annual supply available for human extractive purposes in percentage terms.

The average (S_A) and critical (S_C) year supplies are represented by tick marks on Figure 1. We define critical year supply as the supply that is just large enough to satisfy critical year demand (D_C). Critical year demand is usually higher than average year demand because outdoor water use will increase when rainfall is below average or temperature is above average. Because maximum water available for supply will decrease when weather is drier, critical demand will always equal maximum water available for supply at some quantity. That quantity is the critical supply = critical demand shown in the Figure.

The figure shows critical supply at "Z (R)" standard deviations below average supply. This number is related to the reliability of existing supply, and will vary from system to system. A property of the normal distribution is that in about 5% of the years, flow will be less than the lower tick mark when it is located 1.65 standard deviations below the mean. That is, if Z(R) has value of 1.65, the figure shows a system reliability of 95% (shortage about 1 year in 20).

If the system had another reliability level, say 84%, the critical supply would be 1.00 standard deviation below average supply. The appropriate multiplier (e.g., 1.65, 1.00, etc.) for a chosen reliability level is found from a table (or formula) that is present in most statistics textook:[7] the area under one tail of the standard normal distribution (expressed as a number between 0 and 1) as a function of the standard normal variable. The relevant area under one tail is equal to one minus the reliability level (e.g., 1.00 - 0.95 = 0.05). The multiplier is equal to the value of the standard normal variable that is paired with this area (e.g., a tail area of 0.05 implies 1.65; a tail area of 0.16 implies 1.00).

Assume for our example that average annual maximum supply is 100,000 kilolitres (kL) and the standard deviation of annual maximum supply is 10,000 kL. This implies that the coefficient of variance of the supply is 10% (10,000/100,000). Under these assumptions, the lower tick mark in Figure 1 has value 84,000 kL per year. Suppose critical demand (and therefore the critical supply level) is projected[8] to grow to 90,000 kL over the next decade. As critical demand grows, reliability will decrease. The likelihood of a water shortage will increase from 1 in 20 (95% reliability) to 1 in 6 (84% reliability) as the part of the bell curve left of critical supply grows from 5% to 16%. One of the standard jobs of water managers is to prevent reliability from deteriorating too much. But how they augment supply or manage demand growth in response to their projection of demand growth affects reliability in ways that are often not fully understood or evaluated.

[7] For example, Table A-3 in Khazanie (1990).
[8] A water demand projection is based on many factors, including projected growth in population and employment in the service area, changes in water distribution or use technologies, etc.

Suppose they want to maintain reliability at 95%. This is the first step in the planning process – chose a design reliability level based on the willingness of customers to pay for reliability. Second, the planner will consider various options for new supply and conservation measures sufficient to satisfy customer needs. The amount of physical water or conservation required to do this in a critical year is the difference between projected critical demand (PD_C) and existing critical demand (D_C). This has been labeled S_N in Figure 1, and in our example is 6,000 kL. If a supply option were to provide exactly this amount in every year, the planner should procure S_N of new supply. Water from advanced treatment processes (e.g., desalinated seawater or recycled wastewater) has this characteristic if treatment facilities are designed with enough redundancy to prevent downtime other than for regularly scheduled maintenance.[9]

But if the yield from a water supply or conservation option is variable from year to year, the planner must procure enough of it to have S_N available 19 out of 20 years or reliability will fall. For example, when the chosen option is a surface water source, the amount available in an average year must be greater than S_N in order to ensure S_N is available in the critical, drier-than-average year.

The amount of water supply greater than S_N that has to be purchased depends on two factors. First, higher standard deviations of annual yield from the new surface water source imply that more water needs to be procured to ensure adequate water in a critical

[9] Some indoor water conservation measures may also have this characteristic of supplying exactly D_N every year if they are designed carefully. While the issue of "savings decay" in water conservation has been hotly debated, the author believes savings decay can be eliminated or made quite small by carefully specifying water-use efficiency devices.

year. Second, lower correlations of annual yield between the new source and the existing source imply that less of the new source will be required, on average, to ensure S_N is available when water from the existing source is at or below the lower tick mark in Figure 1. That is, if the new source is wet when the existing source is dry, one can procure less than S_N on average and still get S_N when the existing source is at its critical, drier-than-average level.

What this means is that comparing unit costs for options based on the average amount of water each option will deliver leaves out an important piece of the economic picture. Suppose for illustration purposes that advanced treatment of a low-quality water,[10] a new surface water supply, and outdoor conservation, all have an average unit cost of US$1.00 per kL. Ignoring reliability impacts, there is no financial difference between these sources. But a constant-reliability comparison of unit costs (Figure 2), as described below and mathematically in Appendix A, will show substantial financial differences.

Insert Figure 2 here

For the purpose of this illustration, we've assumed that advanced treatment is neither variable from year to year nor correlated with the existing water source. Consequently, a facility designed to deliver 6,000 kL per year[11] will satisfy the growth in demand in all years: average, critical, or otherwise. The average cost per unit is the same as the cost per unit in the critical and all other years.

[10] This could be seawater desalination, brackish water desalination, wastewater reclamation, or other processes. The average unit cost provided is generic and does not represent any particular technology.
[11] After allowing for normal interruptions in operation such as downtime for maintenance.

However, we've assumed that the new surface water supply is perfectly correlated with the existing surface water supply (has a similar pattern of wet and dry years), but is more variable. Then ensuring the 6,000 kL of new supply that will be needed in a critical year requires that the new source be sized to deliver more than 6,000 kL of water each average year, just as the old source was capable of providing 100,000 kL on average but only 84,000 kL with the desired level of reliability. If the new surface water source has a coefficient of variance of 20%, the water planner will need to procure 8,955 kL in an average year to ensure 6,000 in the 95% reliability design year (8,955 – 1.65 x 0.2 x 8,955 = 6,000). This in turn implies that each unit of water during drought will cost US$1.49 per kL on a constant-reliability benefit basis (US$1.00/ (1 – 1.65 x 0.2)). On a reliability-adjusted basis, this option is 49% more costly than it first appeared.[12]

If an outdoor water conservation measure were to save more water during dry weather,[13] its constant-reliability unit cost would be less than the assumed US$1.00 per kL. If it were perfectly counter-correlated with the current surface water source, and had a coefficient of variation of 10%, its constant-reliability unit cost would be $0.86 per acre-foot ($1.00/(1+1.65 x 0.1)). Since the current water source has been assumed to have a coefficient of variance of 10%, this 14% adjustment in unit cost is purely the result of the

[12] Stated differently, the utility could pay 49% more *per average unit* of water from the advanced treatment facility (US$1.49/US$1.00=149%) compared to each *average* unit in the new surface water alternative -- and provide the same economic benefit at the same cost to customers. Note that the premium is not in total, but per unit. The smaller advanced treatment facility is just as good as the larger surface water facility at reliably providing 6,000 kL in the critical year, so a *per unit* premium is justified.

[13] For example, laser leveling, drip or micro-spray irrigation, evapo-transpiration (ET) controllers, adjustments in sprinkler heads to improve distribution uniformity, all reduce the percent of applied water that percolates or evaporates. Since applied water goes up during dry weather, these measures will save more water during drought than during average or wet weather. Auto-rain shut-off devices, in contrast, save more water when it rains than when it is dry.

counter-correlation. Conventional sensitivity analysis of the financial impact of the variability in yield from the option would miss this adjustment entirely.

Stated in terms of yield, ensuring 6,000 kL of water in the critical year would require outdoor conservation measures sized to deliver only 5,150 kL in an average year. The counter-correlation implies that during a drought where maximum supply from the current surface water source is 1.65 standard deviations below its mean, outdoor conservation would save 1.65 standard deviations above its mean, which equals 6,000 kL when the mean is 5,150 kL and the standard deviation is 515 kL (10% of the mean).

Conclusion

Accounting for variance and correlation between water supply sources – as is done for securities when managing a portfolio of financial assets – is clearly important. Water supply planners who do not consider these factors might think options are similar in cost when they are in fact quite different once reliability benefits of the options are equalized. Worse yet, an apparently inexpensive source might turn out to be very expensive on a constant-reliability basis, or an apparently expensive source might turn out to have the lowest unit cost once reliability is considered.

The method presented in this paper is a powerful starting point for quantitative evaluation of the cost implications of uncertainty in water supply and demand management options. For the first time in the published water literature, it quantitatively evaluates these impacts on a portfolio rather than individual option basis. An option that is attractive

when combined with an existing water supply in one setting might be unattractive if combined with a different existing water supply in a different setting. The correlation between the yields of options is a new dimension of overall yield and financial analysis for water planners. For water supply portfolios with numerous sources, as is the case in some regional systems, quantifying the impacts of these correlations may lead to surprising outcomes and changes in water supply plans.

Application of the method may be hindered, however, by data limitations or patterns that are difficult to describe via normal or other statistical distributions. As many a financial planner has found, the mathematics of portfolio theory do not guarantee superior investment results. One must struggle with the data and other decision criteria every time an investment decision is made. Nonetheless, better or additional tools have value.

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Appendix A: Constant-Reliability Unit Cost Adjustment

Finding constant-reliability unit costs involves a two-step process. First, a constant-reliability-benefit standard must be specified. When supply is modeled as normally distributed, the standard normal variable (Z) will be a function of the reliability design standard (R) the planner chooses (e.g., 95%). Mathematically, this means that the annual average of the supply portfolio (P) minus the standard normal variable times the standard deviation of the supply portfolio must be equal to projected future critical demand:

(1) $A(P) - Z(R)SD(P) = PD_C$

The average supply of a portfolio is the sum of the average supplies of its components. If the portfolio has only two components[14] – existing supply (E) and a new supply or demand management program (N), the average supply of the portfolio is:

(2) $A(P) = A(E) + A(N)$

$$\text{Where} \quad A(x) = \frac{1}{n}\sum_{i=1}^{n} Q_{xi}$$

$x = A \text{ or } N$

$n = \text{the number of years of annual yield data for each option}$

$Q_{xi} = \text{the annual yield in year } i \text{ from option } x$

[14] The mathematics for three or more components is a straightforward extension of the equations shown here. However, there will not be a unique answer when three or more components are involved. Instead, one would find numerous pairs of components two and three that would combine with existing supply to satisfy projected demand and the reliability design standard. Choosing between these pairs would require a straightforward but journal-space-consuming third planning step – cost minimization – to select from among the many possible portfolios that satisfy demand with suitable reliability.

The standard deviation of a portfolio depends on the standard deviation and average of each component, the correlation between the components, and the percentage of water from each component. The standard deviation of a portfolio is the square root of the variance of the portfolio. The appropriate formula (modified by the author from Tucker et. al. 1994) when two components are involved is:

$$(3)\quad V(P) = \sqrt{W(E)^2 V(E)^2 + W(N)^2 V(N)^2 + 2W(E)W(N)Rho(E,N)V(E)V(N)}$$

$$Where \quad W(E) + W(N) = 1$$

$$W(x) \equiv \frac{A(x)}{A(P)}$$

$$V(x) \equiv \frac{SD(x)}{A(x)}$$

$$Rho(E,N)\, is\, the\, correlation\, coefficient\, between\, E\, and\, N$$

Formulas for the standard deviation (SD) and correlation coefficient (Rho) are provided in any statistics textbook. One can calculate these summary statistics for each water supply option using any spreadsheet program. Combining (1), (2) and (3) yields:

$$(4)\quad \sqrt{\left(\frac{A(E)}{A(P)}\right)^2 V(E)^2 + \left(\frac{A(N)}{A(P)}\right)^2 V(N)^2 + 2\left(\frac{A(E)}{A(P)}\right)\left(\frac{A(N)}{A(P)}\right) Rho(E,N)V(E)V(N)} = \frac{A(P) - PD_C}{Z(R)A(P)}$$

$$Where \quad A(P) = A(E) + A(N), as\, above$$

If one specifies a reliability standard (R) and projected critical year demand (PD_C), and knows the average existing supply (A(E)), the coefficients of variance of the existing and new sources of supply (V(E) and V(N)), and the correlation coefficient between supplies (Rho(E,N), equation (4) will contain only one unknown (A(N)). This is the average new

supply required to ensure that the chosen reliability standard (e.g., 95%) will be achieved. A(N) can be found by assuming a value for A(N), seeing how close or far apart the left and right hand sides of the equation are, and iteratively adjusting the assumed value until the value of A(N) that solves the equation is found.

For example, in this paper, we have specified R=95% (which implies Z(R) = 1.65) and PD_C=90,000 kL, and assumed A(E)=100,000 kL, V(E)=0.10, and D_C=84,000 kL. Then the A(N) that solves (4) under various assumptions about the supply options is:

Table A-1: Sample Calculations

Option	**V(N)**	**Rho(E,N)**	**A(N)**
New Surface Water	0.2	1.0	8,955 kL
Advanced Technology	0.0	0.0	6,000 kL
Outdoor Water Conservation	0.1	-1.0	5,150 kL

Finally, the constant reliability unit price for each option is found by multiplying the average unit cost for each option by the ratio of A(N)/ S_N. When A(N) equals growth in critical demand (S_N)[15], as with desalination and similar options, the average unit cost for that water supply option is also the constant-reliability unit cost. When A(N) is greater than or less than S_N , as with the surface water and outdoor conservation examples, the constant-reliability unit cost for each option is higher or lower than the average unit cost for that option, respectively.

[15] Recall that S_N = equals PD_C-D_C. In our example, 6,000 kL = 90,000 kL – 84,000 kL.

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Figure 1: Yield Uncertainty For a Run-of-the-River Water Supply

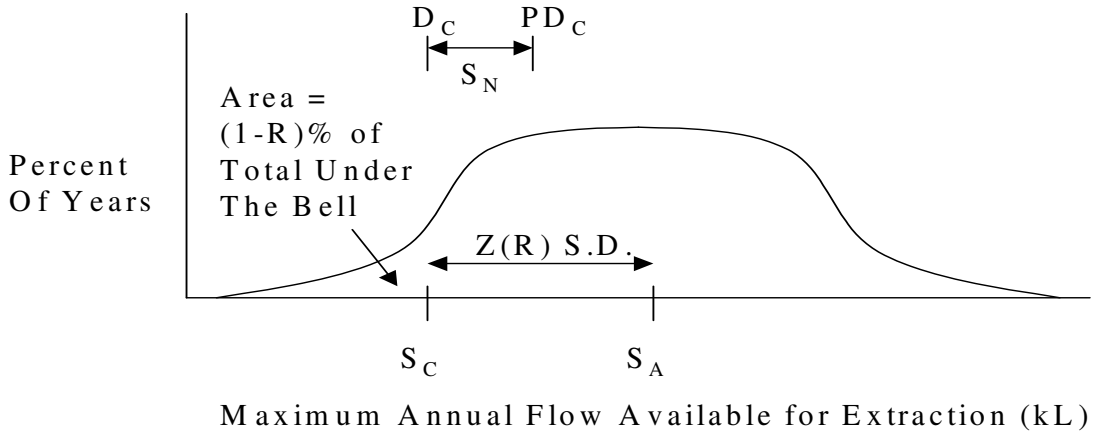
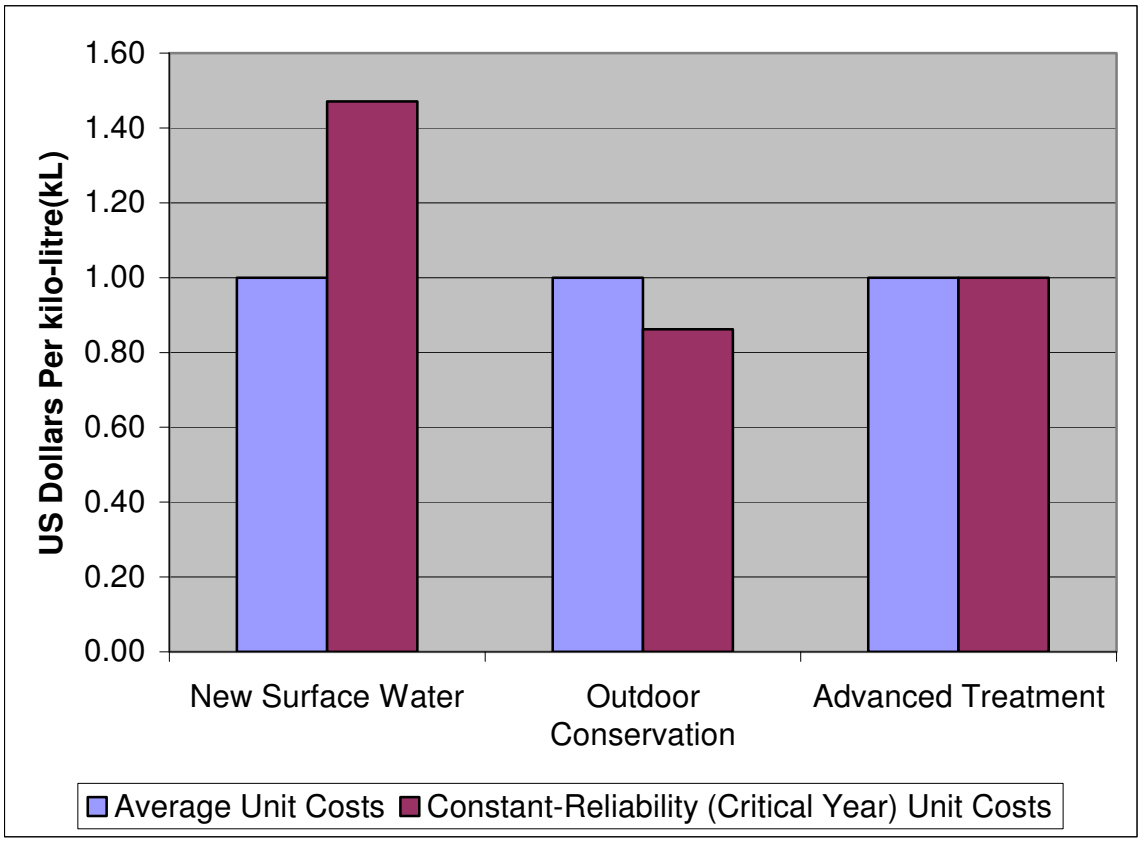
Figure 2: Illustration of Average and Constant-Reliability Unit Costs