NORTH COAST INTEGRATED REGIONAL WATER MANAGEMENT PLAN

North Coast Integrated Regional Water Management Plan Proposition 84 Round 1 Implementation Grant

Priority Project Technical Documents: Plans and Specifications

402 - Ackerman Creek Habitat Restoration, Pinoleville Pomo Nation

- Ackerman Creek Habitat Enhancement Plan
- *Arundo* Removal Technical Guide. Sotoyome Resource Conservation District. 2010
- California Department of Fish and Game. California Salmonid Stream Habitat Restoration Manual Volume II, Part XI Riparian Restoration Practices, October 2003.

Ackerman Creek Habitat Enhancement Plan

Pinoleville Pomo Nation

Riparian Habitat Enhancement Ackerman Creek

Riparian Enhancement Zone

- Minimum
- Medium (100 feet)
- Maximum (300 feet)
- Himalayan Blackberry Locations
- Giant Reed Locations
- Pinoleville Pomo Nation Property
- Mendocino County Parcels

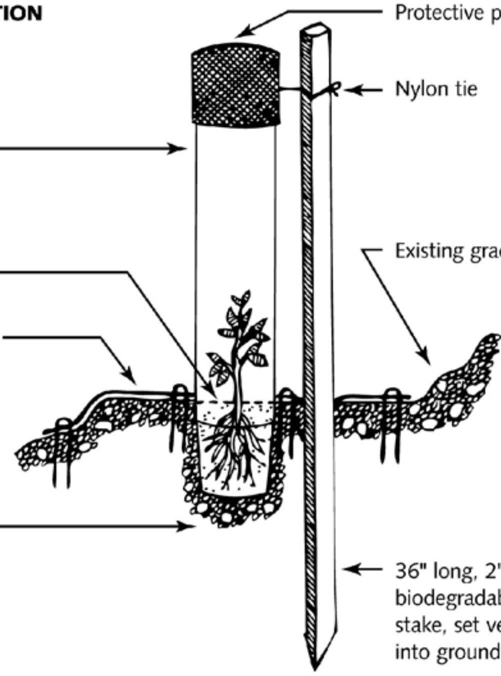
Data sources:

Pinoleville Pomo Nation
West Coast Watershed
Circuit Rider Productions
USDA NAIP Imagery, 2004
Mendocino County

WEST COAST WATERSHED

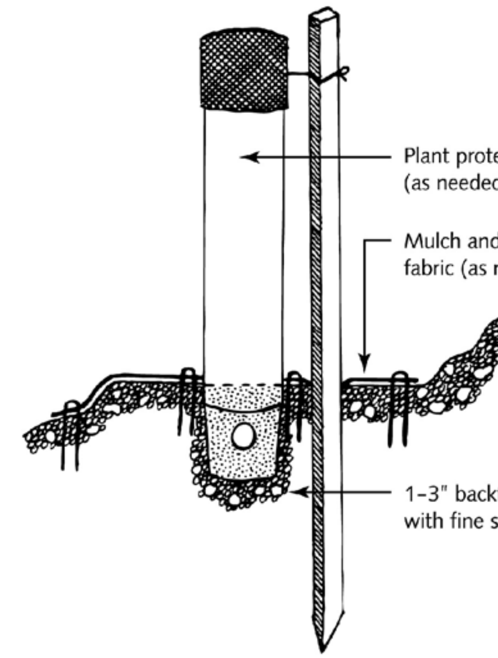
Prepared by:
West Coast Watershed

PLANT PROTECTION TUBE INSTALLATION
(not to scale)



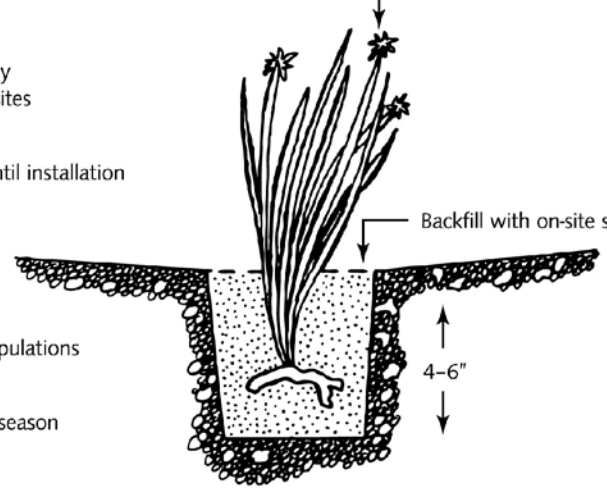
DIRECT SEED PLANTING DETAIL
(not to scale)

- Install native seeds from oaks, buckeye, bay or walnut from November–February
- Install when soil is moist to 10"
- Seed depth at installation = 1-3", depending on species
- Protect plant as needed with plant protection tube and/or fabric mulch *(see Plant Protection Shelter Detail)*



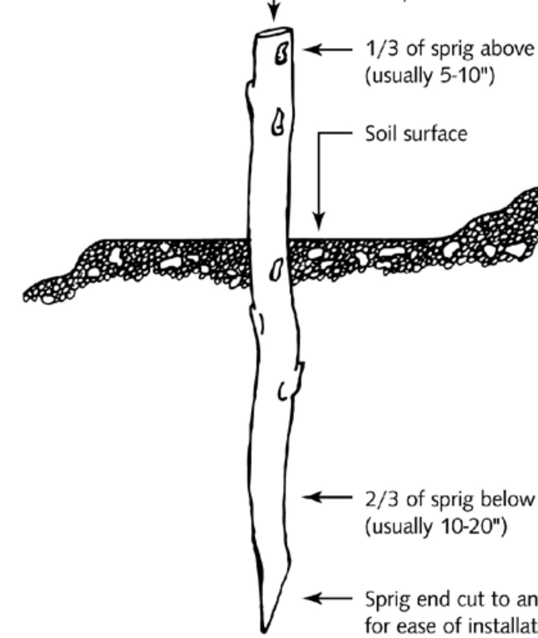
EMERGENT VEGETATION INSTALLATION
(not to scale)

- Excavate planting area
- Collect emergent plants from healthy populations on adjacent or nearby sites
- Keep emergent plants moist and protected form time of collection until installation
- Install emergent plants on same day as collected
- Collect emergent plants in discontinuous small areas to avoid excessive disturbance to existing populations
- Planting shall occur November-April during the dormant/quasi-dormant season



DORMANT WILLOW SPRIG INSTALLATION
(not to scale)

- Install in areas with a year round source of moisture
- Install only during full dormancy (normally December–January)
- Remove branches prior to installation
- Insert with buds pointing upward



Ackerman Creek Habitat Restoration Plan

Pinoleville Pomo Nation

Revegetation Details

Prepared by:
West Coast Watershed

REVEGETATION NOTES

1. Planting shall be installed in January, once rainfall has moistened the soil to a depth of 10 inches or greater. Planting shall be completed by March.

2. Planting technique shall be predominantly liner-sized seedlings, emergent transplants, direct and dormant willow cuttings (see Planting Details).

3. The planting will be installed by qualified restoration ecologists.

4. No individual plant locations are shown. The final design will be developed in the field by qualified restoration ecologists. Each planting spot shall be marked in the field with a color coded (to species) surveyor flag. Flags shall remain at each planting spot after plant installation.

5. Plants will require frequent irrigation during the first dry season after planting. Irrigation should begin in April and continue into October. Approximately one to two gallons of water shall be applied directly to the plant during each irrigation visit. Watering interval shall be 7 to 10 days depending on weather conditions. A temporary, above-ground drip irrigation system using a pump placed in the stream may be used to accomplish irrigation goals. Hand watering from a truck-mounted water tank is also an option. Subsequent irrigation will take place less frequently, and will be determined based on an assessment of the planting after the first year.

6. Plants should have all weeds removed from within the planting tube at least once in the spring and the fall of each year. Protective tubes and weed mats shall be removed after three to five years, depending upon plant maturity.

7. Regular monitoring of the planting site – including collection of data on plant survival, vigor and any potential problems with revegetation site viability – will be performed yearly, and summarized in a report.

8. Himalayan blackberry (*Rubus discolor*) is a highly invasive noxious weed that is present on the site, and should be removed from all planting zones prior to native plant revegetation. Wherever possible, alternatives to herbicide shall be used. These alternatives may include tarping and hand removal. If herbicides are used to accomplish invasive plant removal, the work shall be performed under the supervision of the landowner or a licensed applicator, and all required laws and label directions shall be followed. Care shall be taken to avoid damage to native plants. The site should be carefully monitored for re-infestations of invasive species, and follow-up measures taken to avoid re-invasion.

WEST COAST WATERSHED

Prepared by:
West Coast Watershed

Scientific Name	Common Name	Number	Flag Color	Container Size	Installation Method *	Spacing (on center)	Weed Mat & Staples	Tubes & Stakes
TREES								
Acer macrophyllum	big leaf maple			supercell	Plant protection tube installation	10-12'	yes	yes
Acer negundo	box elder			supercell	Plant protection tube installation	10-12'	yes	yes
Aesculus californica	California buckeye			direct seed	Plant protection tube installation	7-9'	yes	yes
Fraxinus latifolia	Oregon ash			supercell	Plant protection tube installation	10-12'	yes	yes
Junglans californica var. hindsii	California black walnut			supercell	Plant protection tube installation	10-12'	no	no
Quercus agrifolia	Coast Live Oak			supercell	Plant protection tube installation	10-12'	yes	yes
Quercus lobata	valley oak			supercell	Plant protection tube installation	10-12'	yes	yes
Umbellularia california	California bay laurel			supercell	Plant protection tube installation	10-12'	yes	yes
SHRUBS								
Baccharis pilularis	coyote brush			supercell	Plant protection tube installation	4-6'	yes	yes
Calycanthus occidentalis	Spicebush			supercell	Plant protection tube installation	4-6'	yes	yes
Rosa californica	California rose			supercell	Plant protection tube installation	4-6'	yes	yes
Salix sp.	Willow			sprig	Sprig installation	4-6'	no	yes
EMERGENTS								
Carex sp.	Sedge			transplants	Emergent vegetation installation	1-2'	no	no
Juncus sp.	rush			transplants	Emergent vegetation installation	1-2'	no	no
TOTAL PLANT NUMBER								

* See Revegetation Details

Ackerman Creek Habitat Restoration Plan

Pinoleville Pomo Nation

Preliminary Plan List

Prepared by:
West Coast Watershed

Sotoyome RCD's Technical Guide for *Arundo donax* Removal on the Russian River and its Tributaries

December 2010

What is *Arundo* and how do you Identify it?

Arundo donax is a thick-stemmed plant in the grass family, resembling bamboo, that grows up to 30 feet tall. It forms many-stemmed clumps, spreading from thick, knotty roots called rhizomes (RYE-zomes) that grow horizontally, not downward. The root masses can spread over several acres, quickly forming large colonies that displace other plants. The stems of *Arundo* are tough and hollow, divided by nodes like bamboo. The pale green or blue-green leaves clasp the stem with a heart-shaped base. They are up to 1 foot long and arranged alternately along the stem (not opposite each other), each leaf pointing 180 degrees from the next one. In many areas, *Arundo* produces a tall plume-like flower-head at the top of its stems. Its stems often fade to brown during winter or drought. *Arundo* can be confused with bamboos and corn, and young stems can resemble some large grasses such as ryegrass and common reed (Phragmites). *Arundo* typically grows in riparian areas and floodplains. It can be found on wet streambanks, gravel bars, or dry banks far from permanent water. It prefers gently sloping streams over steeper, smaller, creek channels. Scattered colonies can be found in other moist sites such as springs, upper areas of coastal watersheds, drainage ditches, along rice field levees, and residential landscaping.

Important Biological and Ecological Facts About *Arundo*

In North America, *Arundo* is not known to produce fertile seed. It nonetheless spreads very rapidly by vegetative means. One method involves the rhizomes, which grow outward to expand a colony's size. The most common method is when rhizome fragments (as small as a few inches) are dispersed downstream during high stream flows. Fragmented pieces of rhizomes and stems take root, forming new plants and colonies. Removal efforts should begin upstream and work downstream to eliminate re-infestation of cleared areas.

Arundo is one of the fastest growing land plants in the world. During warm months with ample water, *Arundo* stems may grow up to four inches per day! *Arundo* is highly flammable during most of the year, creating a fire hazard for other vegetation, buildings, and people. It is fire-adapted, meaning it resprouts from its roots after fire. Thus, *Arundo* encourages fire along streams, and fires then spread *Arundo* further through the landscape, displacing other plant species. *Arundo* provides virtually no food or habitat for native species of wildlife. The stems and leaves contain several toxic or unpalatable chemicals which probably protect it from most native insects and other grazers. Therefore, areas taken over by *Arundo* harbor very few native animals. Because they cannot eat it, native animals do not help control the spread of *Arundo*.

Techniques for Eradication

Different methods may be needed to control *Arundo*, depending on the size of the infestation, the amount of cane debris that must be dealt with, the terrain, the season, and whether the canes are mixed with desirable native plants. Where infestations are disparate and highly intermixed with native vegetation, as is the case for the tributaries of the Russian River, hand removal crews operating chainsaws and brush cutters have proven to be the best means of removal followed by herbicide application. Removal of *Arundo* at this scale, while time-consuming and costly, is the only way to conduct complete removal without impacting native riparian vegetation.

Where infestations are dense, and contain little or no native vegetation, such as the mainstem of the Russian River in Alexander Valley, mowing with heavy equipment, followed by herbicide application has proven to be the most effective technique. Mowing *Arundo* with heavy equipment is not applicable along the tributaries of the Russian River because *Arundo* is highly interspersed within the riparian vegetation and because of slope issues along the bank of the creek. Additionally, heavy equipment mowing should not be done within close proximity to the top of bank because of permit restrictions, safety issues, and to maintain bank stability. Cut canes should always be directed away from the watercourse to prevent canes from falling down the bank. Regardless of the removal method used, it is important that all *Arundo* clumps are clearly flagged and property boundaries are identified before any initial work begins. It is very important that all field crews stay within the project boundaries. Prior to accessing the project sites, the property owners or designated contact (such as the vineyard manager), are notified.

Eradicating *Arundo* is usually a multi-year effort. Three or more years of monitoring and re-treatment of the site may be necessary, depending on size and age of the infestation and other variables. Likewise, costs are highly variable depending on the slope of the site, the ease of access, who is doing the work, and the disposal method. Consider the effects of your work in the riparian zone on fish migration and bird nesting. This issue is critical, especially when rare, threatened, or endangered species may be present. Bird nesting is from about March to around July. Anadromous fish migrate from the ocean back to their home streams at various times throughout California. Consult the US Fish and Wildlife Service, the CA Department of Fish and Game, or the National Marine Fisheries Service to find out if protected species, especially salmon, steelhead, or other anadromous fish, may be present at your site. If they are, work carefully according to any guidance the agencies provide.

Cut, Resprout, and Spray (Foliar Herbicide Application)

The technique: This method requires removal of the canes, allowing the roots to resprout, and following up with foliar sprays. The "Cut" aspect of this method can be done with a heavy equipment mower in areas with large, pure stands of *Arundo*. Handcrews are needed in areas that are intermixed with native vegetation or where there are slope or access issues.

Equipment needs:
Mainstem Russian River: The majority of the *Arundo* infestations along the mainstem should be removed with the use of heavy machinery. The use of heavy machinery requires a licensed operator.

Russian River Tributaries: Cutting should be done with loppers, a chainsaw, or a power brushcutter. Chainsaws work well for some, but the fibrous stems can clog or derail the chain. A tight, sharp chain is crucial. Loppers are safest. Cutting the canes can be done by hand or power tools depending on the size of infestation. **Note**: Wear gloves. *Arundo* stems and leaves are sharp and can cut skin. The surfaces are abrasive. Avoid cutting canes at sharp angles. The cut edges can cause injury if someone falls on them. Watch the ends of the canes you are handling, so as not to hit or cut someone.

Personnel requirements:
For safety purposes and efficiency, a trained two person crew consisting of an equipment operator and a field assistant are needed during heavy equipment mowing. The field assistant is responsible for insuring the equipment operator avoids all native vegetation including hidden tree roots, and scoping out terrain and topography changes on site. In addition, the field assistant is responsible for moving and stacking the cut *Arundo* stalks as the mower is operating.

At least two people are required for hand removal efforts depending on the size of the infestation and the size of the site. Generally, it is most effective when at least one crew member is cutting *Arundo* while another team member clears and piles the cut canes. Use of power tools requires more space and therefore limits the number of workers in a given area. One person (preferably more) trained in the use and handling of herbicides is needed to spray (see Requirements for Herbicide Applicators).

Timing: The best time to cut *Arundo* to force resprouting is during the spring and summer.
The cutting should occur early in the growing season to allow time for resprouting in the same year. Follow-up spray should be scheduled when regrowth is still small and easy to reach, approximately two months after cutting. Foliar spray can be effective throughout *Arundo's* growing season, but fall is optimal. Over head spraying should not be done. The *Arundo* should be cut when it is approximately 2-4-feet tall.

Side-effects: The greatest risk when spraying standing *Arundo* is the potential for spraying desirable vegetation, particularly if there is wind. To eliminate over-spray, tarps can be used to cover desirable vegetation. Also, the branches of willows or other larger shrubs and tress can be trimmed back if they are very close to *Arundo* so that these plants have no contact with the herbicide. **Note**: If the average wind speed is over 6 mph, you should use the "Cut and Paint" technique described below. All handling, staging and application procedures should follow the herbicide label precautions and the CEQA document and permit guidelines.

Cost: Costs can be highly variable depending on slope, the degree of adjacent desirable vegetation and the scale of the *Arundo* infestations. In general the first year of removal is the most costly because it includes cutting the canes and herbicide application. In considering a budget for Arundo removal, money must be allotted for at least two years of follow up spraying after the initial removal.

Success rate: Foliar application has been found to be 50% effective the first year and 75% effective the first year and may take 3 years for complete eradication. Effectiveness depends on the herbicide mixture used, weather conditions, the time of year, and the amount of leaf coverage.

Appropriate use: The cut, resprout and foliar spray method is very effective and can be applied when there is adjacent vineyard land or native vegetation, assuming the described safety precautions are implemented to eliminate over head drift.

Cut and Paint

The technique: This method entails cutting the stalks off and applying an imazapyr-based herbicide directly to the stump. Sometimes, the canes are first removed by cutting the stalks off 1 to 2 feet from the ground. With the area cleared of canes, access is safer and easier. The stumps are then re-cut to within 2" or 3" from the ground and treated with herbicide. It is very critical to only re-cut what can be treated within a couple of minutes. The longer the wait, the less likely the cut plant will draw the herbicide down into its roots. Cut the canes off squarely to make herbicide application easier and to avoid dangerous spikes jutting out of the ground.

Equipment needs: Loppers, chainsaws, or brushcutters can be used to cut the canes. A paint brush or sponge dauber can be used to apply herbicide **(see Herbicide Usage and Handling)**. Use marking dye such as Markit, available at hardware stores, mixed with the herbicide to differentiate treated stems from untreated. A brush or spray-bottle is easily obtained. On larger jobs, a dauber may prevent back pain, since the applicator can stand upright while using it instead of bending over. A dauber can be made by adapting a standard watering wand: Remove the metal screen at the watering end, and replace it with a circular piece of sponge. Use fixtures available at a hardware store to make a tight cap for the handle end. Fill the wand with herbicide. A rubber squeeze-bulb, attached with hose-clamps on the handle end, will give better control of the flow of herbicide. Forestry Suppliers (1-800-647-5368) has a dauber-type device for sale called the Sideswipe Pro ($38.50).

Personnel requirements: A large group can do the initial cutting and removal of canes. Power tools require more space and therefore limit the number of workers in a given area. At least two people need to work together so that one crew member can cut the canes while the other quickly paints the freshly cut stumps One person trained in the use and handling of herbicides is needed to supervise all herbicide applications (see Requirements for Herbicide Applicators).

Timing: Cut Stump application can be done throughout the growing season, although effectiveness may be best when herbicide is applied in late summer or early fall before the plants enter dormancy. Application of herbicide should be done within approximately 2 minutes after re-cutting for best results.

Side-effects: There is a risk of spillage when using undiluted herbicide. Exercise caution when handling open containers; avoid carrying them onto the site. Using a sponge dauber poses very little risk to surrounding vegetation. Capped sponge applicator wands are the least likely to spill and more efficient than brushing.

Cost: Very little herbicide is wasted with this precise application method, but a greater volume and a higher concentration of herbicide is needed to complete the job. Non-target losses are avoided and follow-up is minimal. Property owners can save significantly by doing the work themselves. In general, the cut and paint method is more time consuming and costs more for labor and herbicide than the cut, resprout and foliar spray method.

Success rate: This method's effectiveness ranges from 50% to 75% in the first year. Expect complete eradication to take up to 3 or more years. The highly variable success rates are due to factors including the herbicide used, weather conditions, the time of year, and the thoroughness of coverage.

Appropriate use: This method should really only be used when average wind speed is greater than 6 mph, or when applying herbicide to *Arundo* patches that are in close proximity (10 feet or less) to a stream or other waterbody. It may also be used when there is a high concern for mortality of native vegetation due to stray herbicide from hand pump sprayers. This method is also ideal in remote or hard to reach areas. Return trips are minimized and it is not necessary to pack in heavy tools. It is appropriate for supervised volunteer groups because it is simple and is safe to work in close proximity. This method is not appropriate for larger stands of *Arundo*, due to its time-consuming nature and its associated labor costs.

A Comparison of Techniques for Eradication

Method	Best Use	Timing	Tools	Permits	Advantages	Disadvantages
Cut, Resprout and Spray	Mowing: Pure stands. Large infestations, with little native vegetation. Hand removal: Best for infestations intermixed with native vegetation	Cut in spring to summer. Spray regrowth in late summer/early fall when plant energy is transferred to roots	Mowing: Mechanized Mower Hand removal: Loppers or power brush cutter (steel-blade weed whacker). imazapyr-based herbicide appropriate for foliar application. Sprayer with directional nozzle.	DFG 1600 permit, 401 Regional Water Board Permit, County Ag Commission permit for pesticide application by non-landowner	Mowing: Fastest removal technique for large, pure stands of *Arundo*. Hand removal: Low soil disturbance. Less risk of non-target herbicide drift than when spraying full grown canes. Can use volunteers for cutting cane.	Mowing: Based on topography, distance from the top of the slope and extent of native vegetation; mowing activity is limited Both techniques: Takes a minimum 3 years of annual herbicide applications. Risk from drift and run-off to non-target plants.
Cut and Paint	Appropriate when average wind speed is greater than 6 mph, or when applying herbicide to *Arundo* patches that are 10 feet or less to a stream or other waterbody	Anytime during growing season. Best in late summer/early fall when plant energy is transferred to roots	Loppers or power brush cutter. Full-strength imazapyr-based herbicide. Wand or paintbrush applicator.	DFG 1600 permit, 401 Regional Water Board Permit, Fire permit if burning debris, County Ag Commission permit for pesticide application by non-landowner	Low soil disturbance. Low risk of non-target herbicide drift. Can use volunteers for cutting cane. Volunteers can work near applicator.	Requires a more concentrated application of imazapyr-based herbicide. Time consuming with larger stands and therefore the labor can be costly. Can require herbicide applications for at least 3 years

Herbicide Application Notes

Herbicide Application Method

Originally, herbicide application was a cut and paint technique, but this treatment method proved extremely time-consuming, cost prohibitive for long term project success, and in some cases was not as effective as foliar spraying. Additionally, foliar spraying can be applied during and outside of cut and paint desired application periods and can still be effective. Foliar spraying with imazapyr herbicide will usually require up to three years of treatment. For landowners not willing to allow herbicide use on their property, tarping areas of cut *Arundo* for one to two years for at least six months per year has proven an effective technique for controlling *Arundo.* Due to the high cost associated with materials and with deploying, monitoring, and maintaining the tarps, this option, while successful, is not the standard approach to *Arundo* treatment. When applying Imazapyr to regrowth at least 80% of the foliage should be treated.

Herbicide Use Issues

Arundo grows so aggressively that effective eradication efforts usually rely on a systemic herbicide such as Imazapyr, the active ingredient in Habitat®. Unlike contact-type herbicides that only kill the above-ground portion of plants, a systemic herbicide is absorbed by plant leaves and stems and is then transported to the plant's root system where it kills the entire plant, roots and all. Imazapyr is considered non-toxic to birds, mammals, fish, honeybees, aquatic invertebrates, and non-vascular aquatic plants, as determined through toxicity testing conducted by the EPA as part of its re-registration. It does not appear to bioaccumulate in these species (USEPA, 2006).

Herbicide Use and Handling

Pesticide safety training is advised for all applicators. Always read and follow specific label directions and safety precautions. Be extremely careful with open containers of herbicide. Ensure that herbicides are applied at concentrations that are considered safe for biological resources within and adjacent to the project area. Application should be done on dry days to avoid spreading the chemical where it's not wanted. Consult the National Weather Service and allow at least **four days** of dry weather before application of herbicide. If it rains within 24 hours of herbicide application, retreatment is necessary. When Arundo is 10 horizontal feet or less from an active channel, Imazapyr should be painted on rather than sprayed to eliminate run-off from entering a waterway. Herbicide applications should follow the guidelines set forth in the 401and 1600 permits and the CEQA document.

Requirements for Herbicide Applicators

The use of herbicides to remove Arundo on your own property generally does not require permits or other approvals. However, this may depend on the herbicide that will be used, the size of the project area and whether the applicator is the landowner. If you plan to use herbicides to control Arundo, you should contact your county Agricultural Commissioner's office for more information. If a volunteer group or an individual other than the property owner or a licensed applicator applies herbicide, that person or a representative of the group must have pesticide safety training, obtain a pesticide operator identification number, get a pest control recommendation, obtain a letter of authorization from the landowner, and file a monthly use report with the county Agricultural Commissioner's office. Have a licensed pesticide applicator conduct or oversee herbicide applications.

Removal and Disposal of *Arundo* Debris

Removing *Arundo* canes from the immediate work-site is a chore in itself on some sites. A choke chain or rope can be used to tie a bundle of canes before they are cut to prevent them from falling in the creek and to facilitate removal. A winch or a vehicle can be used to pull large bundles up steep slopes. Rope or twine can be used to bundle cut canes to ease hand removal. A tarp can be used to gather up smaller pieces and drag them to a disposal area. Minimize trampling of native vegetation by establishing marked trails. Methods can depend on the degree of the infestation, accessibility of the cut canes and preferences expressed by the landowner.

Composting: A method for disposal is leaving cut canes on the ground to decompose. This method is ideal for remote areas and where there is room to spread out the canes. It is very important that the canes are spread out so that they dry out and do not resprout. Also the pile should be stacked far enough above the high water line so that the canes are not spread into the waterway and brought downstream. Also, the canes should stacked and piled where there is no chance that the canes would cause damage to adjacent structures or vineyards during a flood.

Chipping: The canes can be chipped on site, out of the creek, with a brush or tree chipper. It can then be piled and used on site. *Arundo* is fibrous and can get caught in the cutting blades of lightweight chippers. It will chip better when dry and brittle.   When the *Arundo* is finely chipped it can be used as a mulch for various landscaping purposes. Also, a chipper should be used where large infestations have been removed and where there are large amounts of biomass. Often there can be a combination of chipping portions of the more accessible cut canes and leaving a portion of the canes to decompose on the forest floor.

Burning: The cut canes can be burned in a pile, but there are several restrictions. A burn permit must be secured from the fire department during the fire season and may be difficult to obtain. The burn area must be containable and far from brush and overhanging trees. The Air Quality Management District requires that any material to be burned must dry out for 60 days prior to igniting. The District must be contacted to confirm a burn day. Burning can be an ideal way of disposing of the canes if you have time to wait for the material to dry and for an appropriate burn day.

Dumping: Hauling and dumping large volumes of *Arundo* cuttings is time-consuming and can be expensive. Many cities and some counties have programs for pick-up of yard waste. Some disposal companies and dumps do not accept *Arundo* because it can be difficult to chip. Off site removal is recommended when other options are unavailable.

Revegetation After *Arundo* Removal

Areas that are stripped of *Arundo* may look devastated. The surest and cheapest way to restore native riparian vegetation is to let natural succession and flooding bring in appropriate plant material. Leave the site alone for one or two rainy seasons to see how well “passive” restoration will work. In riparian sites, the stream’s high flows will generally carry fresh sediment and new native plants to the lower streambanks naturally. Nearby native vegetation will often fill available spaces. This process is periodic and may take several years to complete. Often, natural processes will revegetate the lower part of the bank, but “active” methods are sometimes necessary to revegetate the higher, drier areas with native species such as oak trees, upland shrubs, and native perennial grasses. Keep in mind several considerations when considering whether to do “active” revegetation.

- You may want to postpone revegetation until you have achieved complete *Arundo* eradication, since it may be difficult to avoid harming desirable plants during follow-up herbicide treatments.

- If you are downstream of *Arundo* infestations, or near other invasive riparian plant species such as Himalayan blackberry, tree of heaven, vinca (periwinkle), or ivy, prompt revegetation with natives maybe necessary to prevent re-invasion of your site.

Revegetation costs are extremely variable, depending on the needs of the site, the intensity of planting, size of the area planted, and the labor source. If you've decided to actively restore the site, plan your project carefully. Restoration of native plant communities is an art and science unto itself, which cannot be adequately communicated in this document.

It is expected that a high level of natural recruitment processes typically in place in these disturbance-prone areas will be sufficient to recolonize the areas of removed *Arundo.* If removal of *Arundo* constitutes a risk of streambank instability, willow cuttings, cottonwoods, and alders will be installed to decrease the chance of bank loss and sediment inputs. Erosion from *Arundo* control is not expected, as mulch from removal activities is placed back onto the removal area, covering any bare soil that may result. Should bare soil be exposed, this area will be seeded with native grass and mulched.

To maximize fish and wildlife habitat, your long-term objectives should be to eventually shade the stream, stabilize the ground surface with native plants (not annual grasses), and provide a multi-leveled structure of greenery, from small shrubs to tall trees.

These sources may provide information or implementation:

- Local chapter or state office of the California Native Plant Society.
- Nurseries specializing in locally native species.
- Look for ecological restoration services in the yellow pages listings for Environmental, Conservation and Ecological Organizations, or Environmental and Ecological Services.
- Society for Ecological Restoration, California Chapter (SERCAL), at www.sercal.org or SERCAL, 915 L Street, #C-104, Sacramento, CA 95814, (805) 634-9228.

Monitoring

Effectiveness monitoring of removed *Arundo* to determine treatment success is a vital part of this control effort. At the site level, monitoring information is collected pre- and post- removal. This may be based on mapping the locations of the *Arundo,* taking photo documentation, and documenting native plant cover. Also, monitoring canopy cover and bank conditions can be used to demonstrate improvements to water quality and aquatic habitat and the scope of follow up treatments.

Russian River *Arundo donax* Removal and Riparian Restoration Program

The Sotoyome Resource Conservation District (RCD), in partnership with Mendocino County RCD and Circuit Rider Productions, Inc., developed a program to address the *Arundo* infestation, starting at the top of the watershed and working downstream, removing and treating *Arundo donax* populations throughout the basin. Building on the past success of this program the Sotoyome RCD continues to lead the control of *Arundo* in the Russian River watershed increasing overall riparian function and aiding in the species recovery of listed plants and animals throughout the region. Landowner support, a key component of this program, has grown as more awareness about the importance of riparian habitat has increased and the availability of cost share opportunities and programmatic permits have become available.

A great benefit of working with the Sotoyome RCD for *Arundo donax* removal is that the landowner can work under the RCD's permits, and avoid having to navigate through the complicated permitting process. The Sotoyome RCD can also assist with post-treatment monitoring, which is a very important step to ensure successful removal of *Arundo*. The RCD is a great resource for landowners to take advantage of, and will continue outreaching and assisting new landowners in order to continue the success of the *Arundo* removal program.

References

Newhouser, M., Cornwall, C., Dale, R. 1999. *Arundo: A Landowner Handbook*. California State University, Sacramento, Media Services. Pages 1,2 10, 13 - 15, and 17 - 19.

USEPA. 2006. Reregistration Eligibility Decision for Imazapyr. Available at: http://www.epa.gov/oppsrrd1/REDs/imazapyr_red.pdf

CALIFORNIA SALMONID STREAM HABITAT RESTORATION MANUAL

PART XI

RIPARIAN HABITAT RESTORATION

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ACKNOWLEDGEMENTS

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PART XI. RIPARIAN HABITAT RESTORATION

INTRODUCTION

Natural riparian habitat includes the assortment of native plants that occur adjacent to streams, creeks and rivers. These plants are well adapted to the dynamic and complex environment of streamside zones.

Approximately 95% of the historic riparian habitat has been lost in California, making way for cities, agriculture, mining and other development. The riparian area provides one of the richest habitats for large numbers of fish and wildlife species which depend on it for food and shelter. Many species, including coho and Chinook salmon, steelhead, yellow-billed cuckoo and the red-legged frog, are threatened or endangered in California. Others are rapidly declining.

Most landowners wish to protect their riparian resources while optimizing the value and productivity of their property. These two goals sometimes seem to conflict. An understanding of riparian habitat and stream processes can help landowners conserve riparian resources, and still manage their property productively, and even enhance their property value.

California residents, landowners, land managers, and agencies are increasingly interested in conserving and enhancing watersheds and implementing management practices that are more fish friendly. The riparian corridor is the critical interface between terrestrial and aquatic systems. Increasing numbers of individuals and community groups are involved in habitat conservation and restoration projects in riparian areas. Part XI is intended to encourage and help facilitate the stewardship and restoration of riparian habitat in California watersheds.

In addition to providing basic information about riparian corridors, this Part is intended to assist agencies, landowners, schools and community groups with the planning and implementation of native plant revegetation projects. A plant identification section at the end of Part XI provides detailed descriptions and photographs of plants commonly found along central and north coast California rivers and streams.

STREAM PROCESSES AND RIPARIAN HABITAT

The plant species found in riparian communities differ widely depending upon the character of the watershed and the stream's location within the watershed. The composition of a riparian community is determined by many things, including the reach type, stream slope (gradient), channel confinement, aspect, light availability, water availability, flooding and soil conditions.

For example, at the headwaters of a stream, the gradient is often steep and the riparian vegetation may not vary from the surrounding forest plant community. Further downstream, as the gradient decreases, the riparian corridor begins to differ from the surrounding forest plant community. The riparian canopy is often dominated by trees such as alder, ash, maple, box elder, and oaks, while the surrounding forest may be dominated by conifers. In alluvial areas, sunny openings on gravel bars often provide habitat for species such as mulefat and willow.

Different age classes and species of riparian habitat at different elevations

Streams and their tributaries often cut through broad alluvial valleys. In these alluvial zones, where the substrate is dominated by sand, gravel and silt, the stream freely moves (meanders) back and forth over time, creating and removing riparian habitat naturally. The ability of the stream to move through this meander corridor is what allows the development of diverse riparian forests. Streams in these alluvial areas may have historically included a broad floodplain mature forest with backwater sloughs, oxbow lakes and floodplain wetlands. These diverse habitat features are important for salmonids and other wildlife. Riparian corridors that are wide enough to allow for stream meandering should require little maintenance over the long term. A substantial riparian zone can help to reduce erosion damage to adjacent lands, as well as filter sediment and pollutants. However, due to the high value of agricultural lands as well as the proximity of urban development and other land uses, natural stream movement may not be possible in all managed watersheds.

Russian River meander corridor

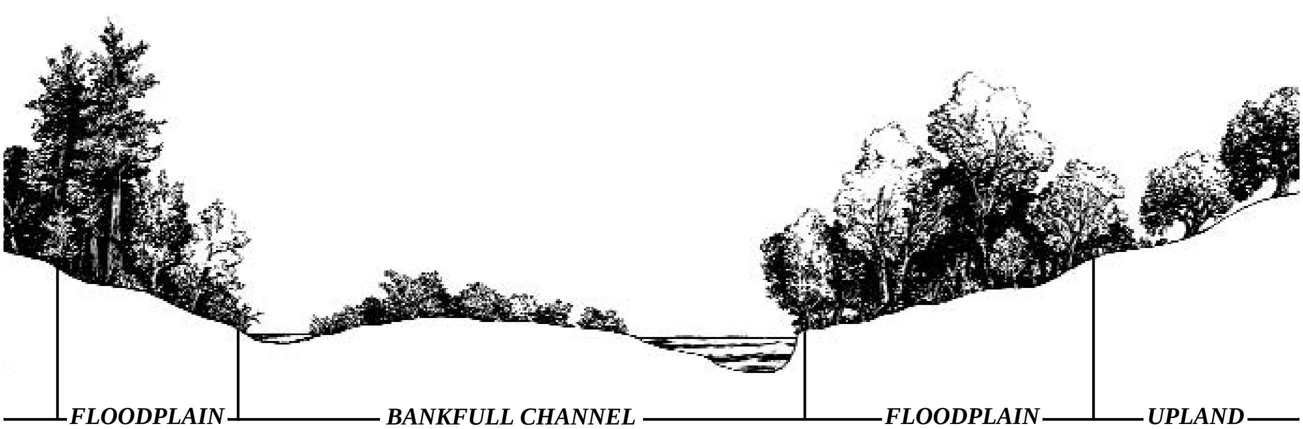
Within the bankfull channel (an area which is regularly flooded), plants are adapted to high levels of flood disturbance during the winter, while tolerating the hot, dry conditions of the gravel bars during the summer. Very few species have the ability to survive in this harsh channel environment; those that do include alder, willow, cottonwood and mulefat. They are called pioneer species, because they colonize recently disturbed sites.


Bankfull channel with small seedlings of pioneer species

The seeds of cottonwood and willow float through the air in the spring just as the water level is beginning to recede. Millions of seeds land on moist gravel bars and germinate there. As the summer progresses, the roots of these tiny seedlings follow the receding water table. Those plants that cannot stay connected to the water table face certain death on the desert-like gravel bar. Those plants that survive the summer drought and winter flood cycle will grow at incredible rates, up to 15 feet per year. As they grow, these pioneer species may begin to trap sediments, and can influence the movement of the stream.

The floodplain is elevated above the bankfull channel and is characterized by many more species than found in the bankfull channel. Floodplain areas support plants that are less adapted to flood scour and do not require as much summer moisture.

Floodplain riparian forests are some of the most important, *and the most impacted*, habitats in California. Intact riparian forests tend to be a dense tangle of large trees in the over-story, and smaller trees, vines, downed wood, and various herbs and fungi in the under-story. The diversity of plants and complexity of habitats in these mature riparian forest zones supports an incredible number of animal species.



Representative cross-section of riparian area

FISH AND WILDLIFE VALUES OF RIPARIAN HABITAT

Salmonids (including coho, Chinook and steelhead) rely on healthy riparian habitat. Riparian trees shade the stream channel, helping to cool the water and retain high levels of dissolved oxygen. Native streamside vegetation provides leaf litter which is eaten by many aquatic insects. These insects are in turn consumed by fish. Roots of riparian plants provide fish with shelter from predators. When large riparian trees fall into the stream, they supply an important structural element in creeks and rivers which helps form pools, sort the substrate, and provide shelter for fish and other aquatic organisms.

Salmonid

Riparian zones along intermittent streams also provide salmonid habitat. Coho salmon and steelhead spawn in the upper reaches of streams and their tributaries while they are flowing in winter. The fry emerge and migrate down to the perennial reaches before the tributaries dry up in summer. These tributaries also serve as important sources of food, spawning gravel, and woody debris that are flushed into the mainstem of a stream during storms. Therefore, alterations to the riparian zones of these seasonal tributaries can have a significant impact on salmonids.

Salmonid

In addition to the important role they play in the salmonid life cycle, riparian areas support an abundance of other wildlife species. Over half of the reptiles and three-fourths of the amphibians in California, including the western pond turtle, red-legged frog and various tree frogs, live in riparian areas. Large numbers of migratory and resident birds rely on streamside habitat. Over one-hundred native species of land mammals are dependent on the riparian zone, including raccoons, ringtails, and river otters. Black-tailed deer utilize riparian zones for fawning.

Pacific tree frog (Hyla regilla)

In an intact riparian corridor, there is a layering effect of plant sizes, shapes and ages that promotes wildlife diversity. A mature riparian forest has a low layer of groundcover, an intermediate layer of shrubs and small trees, and a high canopy of trees and vines. These different layers provide many sites for shelter and food for birds, insects and mammals. In addition, large trees will mature and die, leaving standing snags that provide habitat for cavity nesting birds and other terrestrial wildlife.

Finally, riparian areas act as wildlife corridors, providing important routes for the movement of aquatic species (fish, amphibians, insects), land animals (reptiles and mammals), and birds within a watershed. Stream corridors can be thought of as the circulatory system of the watershed, allowing terrestrial wildlife and fish to migrate up and downstream.

Bobcat

HUMAN VALUES OF RIPARIAN HABITAT

Riparian habitat provides many benefits to streamside landowners. For example, a wide strip of riparian vegetation can offset flood damage to adjacent agricultural lands by acting as a filter for trees and other debris that may wash in during large floods. Riparian vegetation also traps fine sediments and other pollutants contained in terrestrial runoff, thereby preserving instream water quality. Because of their deep roots and dense growth, riparian trees, shrubs, and grasses provide excellent protection against bank erosion, helping to stabilize streambanks.

In addition to assisting with flood protection and erosion control, riparian vegetation may play a role in integrated pest management. Cavity nesting riparian bird species such as kestrels and owls prey on rodents. Other cavity nesting birds such as wrens, tree swallows, oak titmice and bluebirds may help reduce populations of pest insects. Bobcats, coyotes and foxes also use riparian areas to prey on rodents.

Indigenous cultures have relied upon riparian plants for thousands of years, using streamside and wetland plants for basketmaking, as a source of food, and for medicinal purposes.

Kestrel

HUMAN IMPACTS TO RIPARIAN HABITAT

More than 95% of the historic riparian forests in California have been lost due to land use change since European settlement. Logging, urban development, dams, water diversions, gravel mining, and agriculture have all contributed to this loss.

The straightening of creeks for commercial, residential and agricultural activities, and floodplain development, has reduced the width and maturity of the riparian zone, and accordingly changed the river's form through erosional and depositional processes. Dams retain sediment, cut off critical salmonid spawning habitat and may either augment or reduce the natural flow regime. These changes have contributed to the decline of wild salmonids. California rivers once meandered across their forested floodplains, overflowing their banks as a result of winter rains, thus creating a complexity of habitat types. Currently many rivers and creeks have been severely confined, degraded and simplified, resulting in a significant loss of salmonid habitat and biological diversity in general.

Non-Native Invasive Plant Species

Humans have modified riparian areas throughout California in a variety of ways. One of the more serious impacts to native habitats is the introduction of non-native plant and animal species. Invasive plants are a topic of increasing concern for landowners and conservationists. Exotic or non-native plants, such as giant reed (*Arundo donax*) and tamarisk, have spread rapidly and taken over thousands of acres of streamside habitat. These invasive species exclude native vegetation, may increase fire danger and often use large amounts of water, decreasing available resources for fish, wildlife and humans.

Exotic plants usually do not support the same diversity of wildlife found in native riparian forests. If plants such as giant reed or periwinkle dominate the riparian zone, native riparian plants cannot become established. When this happens, the habitat values are often degraded or lost. For example, when an invasive grass such as giant reed becomes established in a riparian area, out-competing native trees such as bay laurel, cottonwood and big leaf maple, the long term consequence is that the large woody debris, shade canopy and leaf litter provided by native species are lost. This results in changes in stream temperature and modification of instream structure and the aquatic food chain. The once complex riparian forest that provided shade, food and structure for salmonids and other species is transformed into a monoculture of grass with very little habitat value. Because riparian species are not especially long lived (20-80 years is typical) invasive species can have extremely negative effects on riparian areas in a relatively short period of time.

Giant reed (Arundo donax)

The following species are common exotic invasive plants found in northern and central California riparian areas, and are pictured in Appendix XI-B:

Common Name	Latin Name	Plant Type
acacia	*Acacia* spp.	tree
cape ivy	*Delairea odorata*	vine
English ivy	*Hedera helix*	vine
eucalyptus	*Eucalyptus* spp.	tree
fennel	*Foeniculum vulgare*	herb
floating primrose	*Ludwigia peploides*	emergent/aquatic
giant reed	*Arundo donax*	grass
Himalayan blackberry	*Rubus discolor*	vine
pampas grass	*Cortaderia selloana*	grass
pepperweed	*Lepidium latifolium*	herb
periwinkle	*Vinca major*	vine
poison hemlock	*Conium maculatum*	herb
tamarisk	*Tamarix* spp.	shrub/tree
teasel	*Dipsacus fullonum*	herb
tree of heaven	*Ailanthus altissima*	tree
yellow star thistle	*Centaurea solstitialis*	herb

Agricultural/Riparian Interface: Pierce's Disease

Pierce's Disease is a fatal disease of grapevines caused by the bacterium *Xylella fastidiosa* which is transmitted by the blue-green sharpshooter insect (*Graphocephela atropunctata*). Certain riparian plants are hosts for the bacteria as well as feeding and breeding hosts for the blue-green sharpshooter. These plants include both native and non-native species and are listed below. In the past, a common practice was to remove all riparian plants adjacent to vineyards in an effort to reduce the incidence of Pierce's Disease. Recent practices have changed to reflect a more surgical approach to removal that only focuses on those plants that are systemic hosts for the bacteria. In systemic host plants, the *Xylella* bacteria spreads systematically throughout the plant after being bitten by the insect. However, in propagative host plants, the bacteria remain at the point of infection and do not spread systemically. Propagative host species are therefore not a high priority for removal. Species such as the invasive, non-native periwinkle (*Vinca major*) are systemic hosts for the bacteria and a breeding/feeding host for the blue-green sharpshooter. These plants are a high priority for removal from an economic perspective, and their removal benefits native riparian habitat as well.

Periwinkle (Vinca major)

The following perennial plants are the major breeding hosts for the blue-green sharpshooter and most are systemic hosts of Pierce's Disease in Napa, Sonoma, and Mendocino counties. Removal of these species has been shown to significantly reduce the number of blue-green sharpshooters in riparian areas and adjacent vineyards (The Pierce's Disease/Riparian Habitat Workgroup, 2000):

NON-NATIVE HOST PLANT LIST

Common name	Latin name
Himalayan blackberry	*Rubus discolor*
periwinkle	*Vinca major*
wild grape*	*Vitis* sp.

* (escaped cultivar or *Vitis californica* hybrid)

NATIVE HOST PLANT LIST

Common name	Latin name
blue elderberry	*Sambucus mexicana*
California blackberry	*Rubus ursinus*
California grape	*Vitis californica*
mugwort	*Artemisia douglasiana*
mulefat	*Baccharis salicifolia*
stinging nettle	*Urtica dioica*

Himalayan blackberry (Rubus discolor)

Mugwort (Artemesia douglasiana)

For more information on the complex topic of Pierce's Disease in north coast streams, visit *www.cnr.berkeley.edu/xylella*, or call your local University of California Cooperative Extension office.

CONSERVATION AND MANAGEMENT OF RIPARIAN HABITAT

Riparian zone in winter with leafless deciduous trees

Many landowners already have intact, healthy riparian corridors on their properties and simply want to preserve these areas in their present state. Others may have riparian areas that are in need of management, due to problems with invasive plants, Pierce's Disease or changes from upstream and downstream land uses. Many landowners are also interested in active restoration of native riparian habitats. The following sections discuss methods for preserving, managing and restoring healthy riparian corridors.

Conserving Riparian Habitat

Healthy riparian corridors require little maintenance over the long term. A stream system that has enough room to move around will sustain a diversity of plant and animal species. Leaving the stream enough elbow room may also protect adjacent land uses from excessive erosion or flood damage.

For those landowners who wish to preserve the integrity of their riparian zones, regular monitoring is recommended. Monitoring can be as simple as walking the stream yearly or seasonally, assessing changes in the stream after a storm or checking for invasive plants or trash that may have been carried in during a flood. More detailed habitat inventory methods are described in Part III of the *California Salmonid Stream Habitat Restoration Manual.*

Conservation of riparian habitat can also be accomplished by placing an easement over the stream corridor. Some conservation easements provide permanent deed guidelines for riparian land uses. Placement of a conservation easement may also provide a tax benefit to the landowner. Some land trust organizations purchase easements from willing sellers.

For more information about conservation easements and land trust organizations, visit the Land Trust Alliance website at www.lta.org.

Managing Riparian Habitats

Vegetation Management

In some cases, active management of the riparian zone may be required. Landowners who have concerns about Pierce's Disease may choose to remove certain plants from the riparian areas adjacent to their farming operation. Additionally, invasive plants, such as giant reed, ivy or tamarisk, should be removed before they become a significant problem.


Manual cutting of giant reed biomass

Surgical removal of native and non-native plants along with re-planting of natives is preferred to the wholesale removal of all riparian habitat. While planning for any riparian vegetation project, contact the Department of Fish and Game for technical assistance. Depending on the project, permits may be required from several different local, state or federal agencies. See Part VI for more information on permits.


Riparian forest invaded by periwinkle

The following non-toxic treatments require a significant commitment of time and labor. These treatments need to be based on an understanding of each plant's physiology (i.e., timing of flowering, size and structure of the root system, etc.). For example, a species such as yellow star thistle may be partially controlled by mowing, but the mowing treatment must take place prior to seed development, or it will cause seed dispersal and make the problem worse. Root removal options will vary according to the species. Young tamarisk or tree of heaven seedlings can be pulled using hand tools, but mature plants may require heavy equipment, potentially a cause of excessive disturbance and siltation in the riparian zone. Disturbed areas should be treated to prevent siltation to the stream. Species such as Himalayan blackberry and periwinkle may have extensive root systems that are difficult to track down and remove. Burning may be accomplished with a backpack torch, but can only take place when there is no threat of wildfire. Tarping is usually implemented after the rainy season has ended. Tarps are then removed prior to the next rainy season. Removal of undesirable plants should be followed with a revegetation program using appropriate native plants which may help to prevent recolonization by other invaders.

There are a variety of non-toxic ways to remove unwanted plant species, and each option should be thoroughly evaluated. Listed below are some non-toxic control options for a variety of invasive non-native plant species. In general, invasive species control will take several years, and will require very careful monitoring and removal of re-growth to ensure success.

Common Name	Latin Name	Removal Options
acacia	*Acacia* spp.	root removal
cape ivy	*Delairea odorata*	root removal
English ivy	*Hedera helix*	root removal, burning
eucalyptus	*Eucalyptus* spp.	root removal
fennel	*Foeniculum vulgare*	root removal, mowing, burning
giant reed	*Arundo donax*	tarping, hand removal (gravel bars)
Himalayan blackberry	*Rubus discolor*	root removal, burning
pampas grass	*Cortaderia selloana*	root removal
pepperweed	*Lepidium latifolium*	root removal, mowing
periwinkle	*Vinca major*	root removal, tarping
poison hemlock	*Conium maculatum*	root removal, mowing, burning
tamarisk	*Tamarix* spp.	root removal, burning
teasel	*Dipsacus fullonum*	root removal, mowing
tree of heaven	*Ailanthus altissima*	root removal
yellow star thistle	*Centaurea solstitialis*	root removal, mowing, burning

If herbicide is being used for the control of invasive plants, extra care should be taken to avoid impacts to the aquatic environment, as well as overspray onto native vegetation. Soils in the riparian zone are very porous. The absolute minimum effective amount of herbicide (per the label) should be used, as excess herbicide is likely to be transported through the air or soils into the stream. Certain herbicides are specially formulated to be less toxic to aquatic organisms and are more appropriate for use in or near aquatic environments. Consultation with your local Agricultural Commissioner's office is required by law.

The following websites provide additional information about invasive species and control options:

http://www.caleppc.org (California Exotic Pest Plant Council)
http://www.cdfa.ca.gov/phpps/ipc/noxweedinfo/ (California Department of Food and Agriculture)
http://ceres.ca.gov/tadn/ (Team Arundo del Norte)
http://endeavor.des.ucdavis.edu/weeds/ (CalWeed Database)

Large Woody Debris

Riparian trees that fall into the stream play an important role in the aquatic system. They provide structure to the stream environment, helping to form pools as well as habitat for a variety of organisms. Large woody debris is an important factor in the recovery of salmonid populations. It is, therefore, desirable to retain a wide riparian corridor with large trees that may be recruited into the stream.

Historically, the approach by many agencies and landowners has been to keep the stream channel clean and open, by removing any log debris accumulation. It was believed that these large trees presented a passage problem for fish. It has since been recognized that fish, especially salmonids, are capable of passing over or through most debris accumulation. Substantial retention of sediment above debris accumulation may indicate a potential fish passage problem. Streams with large woody debris provide good quality salmon habitat.

Large woody debris creates pool habitat

Streamside landowners are understandably concerned that large fallen trees may divert the stream towards their banks, causing massive erosion and loss of land. In these cases, large trees are often removed from the system prior to the next flood event. In recent years, there has been a trend towards modification of large debris accumulation, rather than complete removal. An example of this might include pruning tree limbs and allowing the trunk to remain in the stream. This approach allows for the habitat benefits associated with large woody debris, while resolving problems such as fish passage. Contact the California Department of Fish and Game for more information on this topic. See Part VII on barrier modification and log structures for habitat enhancement.

Large woody debris provides structure to the stream environment

RESTORATION OF NATIVE RIPARIAN HABITATS

Natural Regeneration and Exclusionary Fencing

Riparian systems are often capable of rapid natural regeneration after a disturbance such as a flood, fire or other event causing modification to the landscape. The gravel bars and banks in the bankfull channel will often revegetate on their own within a year or two, provided there is an upslope or upstream source of seeds or plant material. Floodplain areas may take significantly longer and may warrant active revegetation to jump start the natural regeneration process.

Stream floodplain being grazed by livestock

In areas that are being grazed by livestock or are heavily impacted by other native grazing herbivores, exclusionary fencing can give the streambank enough protection to re-create healthy stands of native vegetation. Fencing may be temporary, maintained just long enough to allow native trees and shrubs to re-establish (ten years is often adequate).

Exclusionary fencing along stream headwaters

If fencing is used to allow for the regeneration of riparian habitat, it should be set back far enough to allow the stream to meander and create a diversity of habitat. Fences placed too close to the stream corridor may be damaged during high flows, wasting time and money.

Fencing design, including type of wire, gauge and spacing must be specific to the types of animals you are attempting to exclude. Many fencing supply stores have this information and can help you with construction specifics. Alternative water sources for livestock should be devloped to keep them out of the stream channel. If conditions require that livestock access the stream for pasturing or crossing between pastures, use specialized floating fences (which span the channel) to limit such access. When funding restoration projects, the Department of Fish and Game requires a riparian management plan to be developed and signed by the landowner. For more detailed information on exclusionary fencing, see Part VII.

Erosion Control

Large flood events may create the need for erosion control work in the riparian zone to prevent excess siltation into the stream or loss of land. Whenever possible, a vegetative method for reducing erosion such as bioengineering is preferable to a structural approach such as riprap. Structural approaches to stream bank erosion such as riprap tend to fix the stream in one place, exclude riparian vegetation, and prevent the natural movement that creates diverse habitats. Structural approaches are often more expensive, require permits, and may damage neighboring properties. Over the long term, structural approaches tend to fail or require excessive maintenance. If a structural approach is unavoidable, native vegetation should be incorporated into the structure. Bioengineering will increase the effectiveness of the erosion control method and provide some habitat value as well. See Part VII for descriptions of bioengineering.

Installation of erosion control

Planning and Implementing a Successful Revegetation Project

Revegetation using native plants is effective for enhancing habitat for numerous fish and wildlife species, as well as reducing upslope erosion and sedimentation to streams. Revegetation may include:

- broadcast seeding of native grass or forbs on hillslopes
- instream sprigging of dormant willow cuttings to increase cover and reduce bank erosion
- installation of plants propagated in a native plants nursery
- transplanting of emergent species such as rush, tule or sedge
- direct seeding of native species such as oaks or buckeyes.

The landowner, project personnel, or watershed organization should become acquainted with the stream processes and natural habitat of the area to create a plan that works within the local riparian ecosystem. While planning for any riparian vegetation project, contact the Department of Fish and Game or the Natural Resources Conservation Service for technical assistance. Depending on the project, permits may be required from several different local, state or federal agencies.

Tree shelter installation

Creating and implementing a revegetation project can be a complex process, taking four to six months for design and approval, and several additional months for implementation. In some cases, involving a consultant or watershed group with expertise in the process can save time and be more cost effective. See Part VI for more information on permits.

Riparian Revegetation Project Planning

A successful revegetation project will:

- establish a diversity of native plant types and plant species in the riparian area
- provide fish and wildlife habitat
- reduce erosion
- require minimal annual management.

Revegetation should attempt to replicate the natural system.
In the riparian zone, different species are adapted to distinct microsites, often based on elevation and proximity to the stream. Planning of a riparian revegetation project should take into account where each species occurs in the natural system. It can be helpful to draw a cross-sectional diagram of the riparian zone showing where different species occur. This can help determine planting sites based on elevation above the bankfull channel.

Diverse riparian and upland habitat

In general, container planting in the bankfull channel is not recommended.
If there is a severe bank erosion problem, or the system has lost all upstream sources of seed, some active channel revegetation may be warranted. Since the bankfull channel is subject to regular flooding, installed plants are likely to wash out prior to establishing a root system. Willows, whether as sprigs, a willow mattress or willow wall, are adapted to this flood prone environment, and can be an effective, relatively inexpensive way to stabilize a streambank or introduce cover to the stream. Plants installed in the bankfull channel should not have protective hardware, as it will likely be lost to flooding.

Seeds, cuttings or transplants should be collected as close as possible to the project site.
Local collection of plant material ensures that only genetically appropriate plants (i.e., those that are adapted to local conditions) will be used on site. Introduction of plant material from outside of the project watershed is not recommended. The use of local plant material usually results in higher survival rates.

Valley oak (Quercus lobata) an important native seed

Sources for Native Plant Material

Appropriate, site specific native plants are one of the most important aspects of a successful riparian restoration project. Project planning may need to begin up to 18 months in advance to obtain those species that must be grown in containers. For example, a particular species may have seed that ripens in July. After treatment of the seed and propagation in the nursery, the plant may not be ready for outplanting until the following fall/winter. This is often the most important phase of planning a successful restoration project. If you are not in a position to grow the plants yourself, it is a good idea to order plants from a local native plants nursery as soon as you have selected a restoration site.

Bare-root stock can also be used instead of container stock. However, bare-root stock is often difficult to locate because few nurseries produce it. Spacing of plants depends on the species, the goals of the project, desired densities, and many other factors. General spacing recommendations are included in Table XI-1, page XI-26.

Nurseries specializing in California native plants do things differently than typical landscape nurseries. California native plant nurseries usually custom collect site specific material for particular restoration projects, or at minimum, they track where the plant material was collected. This ensures that you can purchase plant material suitable for your project site.

The California Native Plant Society website, *http://www.cnps.org/links/grow links.htm* includes a variety of resources about California flora, including a list of native plant nurseries.

Common container sizes found in native plants nurseries are listed below:

Container Name	Size	Uses
6” and 8” supercell	1 1/8” x 6” 1 1/8” x 8”	Best for plants with fibrous root systems
deepots	2 1/2” x 10”	Good for trees and shrubs
treepot	4” x 14”	Generally used for trees
treebands	2 1/2” x 5”	Good for trees and shrubs

Native plants nurseries also use unique containers like treepots, deepots or supercells (shown to the left) to develop an optimum root-to-shoot ratio (see example photo, above right). This approach provides plants with a well established root system prior to outplanting at the revegetation site.

Revegetation Techniques

Emergent Transplant Installation

Plants such as rushes, sedges and tules are commonly called emergent plants, because they are often associated with creeks, wetlands and lakes, where they emerge from the water. They may reproduce from seed or from the spreading of underground rhizomes. This vegetative form of reproduction makes emergent species ideal candidates for transplantation into revegetation sites. These species are widely adapted to a range of environments, including high velocity bankfull channels, slow moving backwaters, seeps on hillslopes, and stable, relatively dry floodplains. It is important to identify the species to use and transplant them in an appropriate location. There are also some non-native species of emergents that should not be transplanted into riparian zones. Care should be taken to sensitively harvest these plants so the existing population is not seriously degraded. It is a good idea to take several small clumps from a variety of larger clumps, leaving the majority of each population intact to ensure genetic diversity.


Collecting emergent vegetation


Emergent vegetation, rhizomes exposed


Installation of emergent vegetation

Steps required to transplant emergent species:

- In the winter or early spring, carefully harvest rhizomes and the above-ground portions of the plant with a mattox, sharp trowel or shovel. Make sure one to several intact rhizomes remain for each transplant.
- Store the collected plant in a cool moist location until time for transplanting. Ideally, plants should be stored in moist soil, and should be transplanted as soon as feasible after collection.
- Dig a hole for the transplant that is large enough to accommodate the extended rhizome without bending or breaking it. Place dirt around the rhizome, pack it down, and water it in thoroughly to close any air holes around the rhizome.
- Trim back the above ground portions of the plant in order to stimulate rhizome growth.

Dormant Willow or Cottonwood Sprig Installation

Willows and cottonwoods are in the willow family (*Salicaceae*) and are generally adapted to bankfull channel environments. Species in this family form specialized roots along their stems, allowing for vegetative reproduction in riparian corridors. This feature makes them good candidates for installation as sprigs or dormant cuttings. In general, willows need significant amounts of light and a year-round source of moisture. They are good candidates for revegetation as long as their root zone remains moist during the summer. Because of their ability to withstand flood flows, they are often a good choice for bank stabilization projects in bankfull channel areas. There are many varieties of willow and cottonwood in California. Some (such as the curly willow and Lombardy poplar) are not native and should never be planted in riparian areas. They may not supply the same habitat values as the native plants, and may hybridize with them. Cuttings should be harvested from a variety of parent plants in order to avoid out-planting genetically identical material. These techniques result in a more successful project, will ensure genetic diversity, and do the least damage to the collection site.

Sharp, clean loppers produce high quality sprigs and cuttings

Typical dimensions for willow and cottonwood sprigs

Steps required to install dormant willow and cottonwood cuttings:

- Harvest cuttings during the winter months when plants are dormant (usually December-January). Although willows and cottonwoods will grow from cuttings at other times of the year, dormant cuttings are more resistant to disease, have higher survival rates, and do not require irrigation if planted in the appropriate location. Sprigs may be harvested using sharp, clean loppers, hand shears, or a chainsaw. The cuttings

Store cuttings in a moist environment

may be collected at a range of sizes (i.e., ½ inch to 4 inches diameter and up to 8 feet long). It is important to select material that has not become too woody, and that has several viable buds along the stem.

- Cuttings may be used immediately, stored on-site in the stream, or stored off-site in a bucket of cool water. Ideally, material should be harvested and installed the same day.

- Sprigs should be installed with buds pointing up, with approximately ¾ of the cutting in the soil, and ¼ exposed. Holes may be dug with a pick, with a piece of rebar, with an auger, or a backhoe (for large material). In areas with soft soil, you may avoid digging a hole by cutting the bottom at an angle and pounding it into the ground with a small sledge hammer. If the top is damaged by the hammer, cut off the top of the sprig to allow for clean healing or place a driving shield over the top to drive in the sprig.

Auger used for planting holes

Small sledge hammer for installing sprig

Clean, sharp loppers cut off damaged top of sprig

Container Plant Installation with Shelters
Container plants need to be ordered or propagated months in advance and may be grown by a native plants nursery or an individual practitioner (see page XI-16). Although the installation of container plant material requires more up-front planning than sprigging, emergent transplants and direct seeding, it also allows for the installation of a more diverse plant palette. Some projects use a two-phased approach, with cuttings, emergents and direct seeded species installed the first year, followed by installation of container plants the second year.

Steps required for installing container plants with shelters:

- Plants should be installed during the winter. Plants that will not be irrigated should be planted from December through February, after rains have thoroughly saturated the ground. Plants that will be drip irrigated can be installed at other times during the year. Because of the dangers of planting on the bank of a stream during high flow periods, when stream banks are slippery and the current swift, it may be best to delay some projects until conditions are safe.

- When installing plants, dig holes to twice the depth of the root-ball of the plant to be installed, crumbling any large soil clumps. Partially refill the hole, firmly tamping the soil to create a firm base for the new plant. Place the plant so the top of the root-ball is slightly above finish grade, to allow for future settling. Fill the hole and tamp firmly to remove any air pockets. Irrigate immediately, ensuring the water soaks deeply, unless the ground is already saturated.

Remove weeds from the planting area

Dig the planting hole twice the depth of the root ball

Water the plant immediately, ensuring that the water soaks deeply. If planting in low moisture conditions, plants should be watered during the planting process and therafter until rains begin.

- Where damage from domestic animals and wildlife is a concern, consider protecting plants with shelters (except those that will be in flood-scoured areas). Shelters should be firmly staked and tied so they will remain upright. There are a variety of shelters available, ranging from chicken wire enclosures (screen and collar, shown in photo at bottom) to plastic tubes (a.k.a., *supertubes,* shown in photo at right). All of these methods have proven successful, if they are maintained and weeds are controlled. Shelters should be removed as soon as the plants begin to outgrow them (3-5 years is typical for riparian plants).

- Weeds should be carefully controlled in revegetation areas before and after installation. Plants can become lost in the weeds, increasing maintenance costs and reducing project success. Mow tall weeds before installation, and consider using weed mats (3-foot-diameter sheets of specially designed woven or perforated plastic) around each new plant.

Installation of supertube on newly planted native seedling

Installation of weed mat

Installation of screen and collar protective hardware

Direct Seed Installation

Several riparian species are good candidates for direct seeding. These include large seeded species such as buckeye, native California black walnut, California bay laurel and the native oaks. Large seeds provide these species with a reserve of nutrients that can sustain them during the early phases of seedling development. Although some other seed producing species can be direct seeded under ideal conditions (including weed free environments with good soil moisture), it is generally not a successful technique. Additionally, many seeds are adapted to very specific conditions prior to germination, and may require treatment such as cold stratification or seed coat scarification. In order to ensure genetic diversity and maximize project success, seeds should be collected from several source plants.

Buckeye seed with developing root

Steps required for direct seeding:

- Collect the buckeye, bay, walnut or oak seeds when ripe (fall or winter, depending on the species). Ideally, seeds should be collected from the trees, rather than the ground in order to reduce damage from insects and bacteria. Seeds should come off easily. Check each seed for large numbers of insect holes or mechanical damage, and discard those that appear diseased or feel lighter than the others.

Careful placement of buckeye seed

- Store seeds in a cool place until ready for out-planting. If seeds will be stored for more than a few days, they should be placed in plastic bags with perlite and refrigerated.

- Plant seeds in the winter, when soil moisture has reached a depth of 10 inches or more. Dig a shallow hole at each planting location, and cover seeds with one to two inches of soil. If seeds have begun to germinate, care should be taken to protect the tender new root. For buckeye, only one seed should be required, whereas for the other species you will want to install three to five seeds per planting spot. Once they have germinated, you can select the strongest seedling and clip the others with shears.

- If you choose to protect seedlings from deer browse, the techniques described on the following pages may be used.

Cover seed with 1-2 inches of soil

Project Maintenance
Maintenance of native plant revegetation projects is critical to project success, and often requires an equal or greater expenditure of labor and resources than the installation phase. Maintenance usually includes weeding, watering and general monitoring.

Important maintenance tasks include:

- Regular hand weeding around individual plants during the height of growing season in spring and early summer, as well as one final weeding in the fall. In some cases, where tall weedy species like mustard, hemlock or fennel are present, the whole site may require mowing or mechanical weeding in order to ensure site access and reduce excess shading.

- Soil moisture should be checked on a regular basis during the first two to three growing seasons and plants evaluated for drought stress. The watering regime (whether hand irrigation or a drip system) should be scheduled according to plant needs, rather than an arbitrary schedule. Irrigation should include the minimum amount necessary to keep the plants healthy so they do not become dependent upon additional water. If the plants are appropriate to the location, and installed correctly at the right time of year, they should not require irrigation past year three. Watering should taper off as the plants mature.

- General monitoring should take place at each maintenance visit. Each plant should be checked for signs of disease, rodent or insect browse, and drought stress. Damaged plants should be replaced when possible. Encroachment by invasive species should also be monitored, and these species controlled before they take over the revegetation site.

Mechanical weeding of project site

Hand watering of individual plant

REGULATORY AGENCIES AND REQUIREMENTS

(excerpted from The Pierce's Disease/Riparian Habitat Workgroup, 2000
Riparian Vegetation Management for Pierce's Disease in North Coast California Vineyards)

Several federal, state, and local agencies have regulatory authority over work done in the riparian corridor and may need to be contacted for a revegetation project. It is the landowner's responsibility to be familiar with these agencies and notify them when a project is planned.

Different agencies may have jurisdiction over a project, depending on the character or extent of the project. Most revegetation projects will involve only the removal of specific non-native plants, and replanting of native plants. Such simple revegetation projects will require the least regulatory agency input. The one agency that will certainly require notification, even for a simple revegetation project, is the California Department of Fish and Game. In addition, the Regional Water Quality Control Board may need notification if the project would result in soil erosion, and/or runoff of pesticides into the stream (due to removal of a vegetative buffer).

Some revegetation projects may have a streambank stabilization component. If the stabilization involves re-contouring of the streambed and banks, the United States Army Corps of Engineers and NOAA Fisheries may need notification, in addition to the two agencies mentioned above. Streambank stabilization projects that use bio-technical approaches, such as live vegetation baffles and revetments, will have fewer negative impacts to natural resources and may need less regulatory agency involvement than projects with standard engineering and riprap. The use of standard engineering and riprap is generally discouraged in areas that contain threatened and endangered species, such as salmon and steelhead, because of the negative effects on habitat.

Formal agency notification typically involves completing a form that describes the project, often with a project design map and written description, and paying a fee. Talking to agency representatives about the project before this formal notification can save a significant amount of time. Most agencies encourage informal consultation in the early stages of project planning. The concerns of each party can be addressed, and potential roadblocks eliminated or reduced. In some cases, one agency may pass your project on for review by other agencies, but do not assume this will happen. The landowner and project manager is always responsible for informing all agencies. Many of these agencies charge fees to process the applications and permits. Call each agency for information and a current fee schedule.

Riparian revegetation project, Russian River watershed

Become familiar with the regulatory agencies described below. Even better, get to know the agency staff that work in your area and find out what their interests are, before designing your project (refer to Part VI, Project Planning and Organization).

Activity	Agency to Contact
Native plant revegetation	California Department of Fish and Game
Native plant bio-engineering	California Department of Fish and Game
Streambank stabilization (riprap, other structures)	United States Army Corps of Engineers California Department of Fish and Game
Earth moving & placement of fill	United State Army Corps of Engineers California Department of Fish and Game Regional Water Quality Control Board County Permit and Resource Management Dept. County Planning Department Natural Resources Conservation Service
Herbicide application	Agricultural Commissioners Office Regional Water Quality Control Board
Vegetation removal (native or non-native)	California Department of Fish and Game

Riparian corridor expansion project

Herbicide application

Table XI-1. Native Plants for Revegetation: Planting Location, Container Type and Spacing

The following plants are common in central and north coast watersheds and are recommended for use in riparian revegetation projects. Before choosing plants for a revegetation project, survey your area to determine the appropriate species, or consult with a native plant specialist. This table provides information about the typical location of riparian species, the revegetation approach (e.g., container, direct seed, dormant sprig or transplant) and general spacing suggestions.

COMMON NAME	LATIN NAME	PLANTING LOCATION	REVEGETATION APPROACH	SPACING feet-on-center	PAGE
BROADLEAF TREES					
Big Leaf Maple	*Acer macrophyllum*	floodplain	container	8 – 10’	A-1
Black Cottonwood	*Populus balsamifera* ssp. *trichocarpa*	channel	container, sprig	8 – 10’ 2 – 6’	A-2
Box Elder	*Acer negundo* var. *californicum*	floodplain	container	8 – 10’	A-3
California Bay Laurel	*Umbellularia californica*	floodplain	container	8 – 10’	A-4
California Buckeye	*Aesculus californica*	floodplain	container, direct seed	8 – 10’	A-5
Coast Live Oak	*Quercus agrifolia*	floodplain	container, direct seed	8 – 10’	A-6
Fremont Cottonwood	*Populus fremontii* ssp. *fremontii*	floodplain, channel	container, sprig	8 – 10’ 2 – 6’	A-7
Mountain Dogwood	*Cornus nuttallii*	channel	container	8 – 10’	A-8
No. CA Black Walnut	*Juglans californica* var. *hindsii*	floodplain	container	8 – 10’	A-9
Oregon Ash	*Fraxinus latifolia*	floodplain, channel	container	8 – 10’	A-10
Oregon Oak	*Quercus garryana* var. *garryana*	floodplain	container, direct seed	8 – 10’	A-11
Red Alder	*Alnus rubra*	floodplain, channel	container	8 – 10’	A-12
Sycamore	*Platanus racemosa*	floodplain	container	8 – 10’	A-13
Valley Oak	*Quercus lobata*	floodplain	container, direct seed	8 – 10’	A-14
Water Birch	*Betula occidentalis*	channel	container	8 – 10’	A-15
White Alder	*Alnus rhombifolia*	channel	container	8 – 10’	A-16
Willow	*Salix* spp.	channel, floodplain	container, sprig	8 – 10’ 2 – 6’	A-17
CONIFEROUS TREES					
California Nutmeg	*Torreya californica*	floodplain	container	8 – 10’	A-18
Coast Redwood	*Sequoia sempervirens*	floodplain	container	8 – 10’	A-19
Douglas Fir	*Pseudotsuga menzieii*	floodplain	container	8 – 10’	A-20
Pacific Yew	*Taxus brevifolia*	floodplain	container	8 – 10’	A-21
Western Hemlock	*Tsuga heterophylla*	floodplain	container	8 – 10’	A-22
SHRUBS AND SMALL TREES					
Blue Elderberry	*Sambucus mexicana*	floodplain	container	8 – 10’	A-23
California Blackberry	*Rubus ursinus*	floodplain	container	4 – 6’	A-24
California Hazelnut	*Corylus cornuta* var. *californica*	floodplain	container	4 – 6’	A-25
California Wild Rose	*Rosa californica*	floodplain	container	4 – 6’	A-26
Cascara	*Rhamnus purshiana*	floodplain	container	4 – 6’	A-27
Coffeeberry	*Rhamnus californica*	floodplain	container	4 – 6’	A-28

COMMON NAME	LATIN NAME	PLANTING LOCATION	REVEGETATION APPROACH	SPACING feet-on-center	PAGE
SHRUBS AND SMALL TREES					
Coltsfoot	*Petasites frigidus*	floodplain	container	4 – 6’	A-29
Creambush	*Holodiscus discolor*	floodplain	container	4 – 6’	A-30
Elk Clover	*Aralia californica*	floodplain	container	4 – 6’	A-31
Hawthorn	*Crataegus douglasii*	floodplain	container	4 – 6’	A-32
Mulefat	*Baccharis salicifolia*	floodplain	container	4 – 6’	A-33
Ninebark	*Physocarpus capitatus*	floodplain	container	4 – 6’	A-34
Osoberry	*Oemleria cerasiformis*	channel	container	4 – 6’	A-35
Pacific Wax Myrtle	*Myrica californica*	floodplain	container	4 – 6’	A-36
Red Elderberry	*Sambucus racemosa*	floodplain	container	8 – 10’	A-37
Red Flowering Currant	*Ribes sanguineum*	floodplain	container	4 – 6’	A-38
Red Twig Dogwood	*Cornus glabrata*	floodplain	container	4 – 6’	A-39
Salmonberry	*Rubus spectabilis*	floodplain	container	4 – 6’	A-40
Snowberry	*Symphoricarpos albus*	floodplain	container	4 – 6’	A-41
Spiraea	*Spiraea douglasii*	floodplain	container	4 – 6’	A-42
Stink Currant	*Ribes bracteosum*	floodplain	container	4 – 6’	A-43
Stream Dogwood	*Cornus sericea*	channel	container	4 – 6’	A-44
Thimbleberry	*Rubus parviflorus*	channel	container	4 – 6’	A-45
Toyon	*Heteromeles arbutifolia*	floodplain	container	4 – 6’	A-46
Twinberry	*Lonicera involucrata*	floodplain	container	4 – 6’	A-47
Vine Maple	*Acer circinatum*	floodplain	container	4 – 6’	A-48
Western Azalea	*Rhododendron occidentale*	floodplain	container	4 – 6’	A-49
Western Spicebush	*Calycanthus occidentalis*	floodplain	container	4 – 6’	A-50
Wild Mock Orange	*Philadelphus lewisii*	floodplain	container	4 – 6’	A-51
VINES					
California Wild Grape	*Vitis californica*	floodplain	container	4 – 6’	A-52
Dutchman's Pipevine	*Aristolochia californica*	floodplain	container	4 – 6’	A-53
Honeysuckle	*Lonicera hispidula* var. *vacillans*	floodplain	container	4 – 6’	A-54
Manroot	*Marah fabaceus*	floodplain	container	4 – 6’	A-55
Poison Oak	*Toxicodendron diversilobum*	floodplain	container	4 – 6’	A-56
Virgin’s Bower	*Clematis lasiantha*	floodplain	container	4 – 6’	A-57
EMERGENT AND HERBACEOUS PLANTS					
Bulrush	*Scirpus acutus* var. *occidentalis*	channel	container, transplant	1 – 2’	A-58
Cattail	*Typha latifolia*	channel	container, transplant	1 – 2’	A-59
Creeping Wild Rye	*Leymus triticoides*	floodplain	container, transplant	1 – 2’	A-60
Horsetail	*Equisetum* spp.	floodplain, channel	container, transplant	1 – 2’	A-61
Indian Rhubarb	*Darmera peltata*	channel	container, transplant	1 – 2’	A-62
Mugwort	*Artemesia douglasii*	floodplain, channel	container, transplant	1 – 2’	A-63
Rush	*Juncus* spp.	floodplain, channel	container, transplant	1 – 2’	A-64
Sedge	*Carex* spp.	floodplain, channel	container, transplant	1 – 2’	A-65
Spike rush	*Eleocharis* spp.	channel	container, transplant	1 – 2’	A-66
Stinging Nettle	*Urtica dioica*	floodplain, channel	container, transplant	1 – 2’	A-67

GLOSSARY

Achene: Dry, one-seeded fruit that often looks like a seed. Produced in a one-chambered ovary. Does not open to release the seed.

Allelopathic: Plant produces and releases a toxic substance that results in suppressed growth in other plant species.

Alternate: Describes growth pattern in which new structures develop singularly along axis. For leaves, only one leaf is produced per node so leaves appear to have "alternated" the side of the stem from which they grew (see opposite).

Annual: Plant completes entire life cycle, from germination to seed production and death, in one year or growing cycle (see biannual, perennial).

Asexual: Reproduction by a single individual using a process that is not sexual and does not involve the union of individual cells and the reassortment of genetic characteristics.

Biennial: Plant completes entire life cycle, from germination to seed production and death, in two years or growing cycles. Usually flowers are produced only during the second cycle (see annual, perennial).

Bisexual: Flowers have both female and male fertile reproductive structures (see unisexual, dioecious, monoecious).

Bract: A leaf-like or scale-like structure associated with and usually directly under a flower or cone.

Capsule: Dry, pod-like fruit with fused or partially fused chambers. When ripe, the fruit splits to release multiple seeds.

Catkin: An unbranched inflorescence of closely attached flowers. Flower petals and sepals are inconspicuous or absent but bracts can be showy. Flowers are all the same sex on each catkin.

Compound: Composed of two or more parts or repeating a structural pattern.

Deciduous: Leaves fall off naturally at the end of each growing season and re-grow after a period of leaf-less dormancy (see evergreen).

Dioecious: Male and female flowers produced on separate plants. Each plant produces either male or female unisexual flowers (see monoecious and bisexual).

Elliptic (al): Shaped like a flattened circle, widest at center and tapering almost equally at both ends.

Evergreen: Leaves remain green and on the plant throughout the year, and do not shed en-mass at the end of the growing season (see deciduous).

Gall: An abnormal outgrowth in plant tissue caused by certain parasitic insects, fungi, bacteria, or mechanical injury.

Inflorescence: A cluster of flowers and associated structures such as bracts, petioles and stems (does not include full sized foliage leaves).

Lanceolate: Lance shaped, width widest along lower half and tapers to a point at the tip.

Monoecious: Plant produces both male and female unisexual flowers (see dioecious and bisexual).

Oblong: Longer than wide, with almost parallel sides and rounded corners at each end.

Opposite: Describes a growth pattern in which new structures develop directly across from one another. In leaves, two leaves will grow per node on opposite sides of the stem (see alternate).

Ovate: Egg shaped, widest below middle, tip round or pointed.

Palmate: Radiating from a common point, similar to fingers from the palm of a hand.

Perennial: Plants live more than two years or growing cycles. For this text, description applies to plants that are non-woody above ground and also describes species that lose all above ground structures during dormancy and re-grow from roots (see annual, biannual).

Petiole: Slender stem that supports the leaf, i.e. the leaf stalk.

Pistil: Female reproductive structure of the flower. At the base is the ovary with one or more ascending stalk-like structures (styles) supporting the pollen receiving structure, the stigma (see stamen).

Sepal: Outer most structure of the flower. Similar to petals but usually green.

Stamen: Male reproductive structure of the flower. A stalk like structure (filament) with a pollen-producing anther at the tip (see pistil).

Stigma: Pollen receiving structure of the pistil. Usually located near the flower center, elevated above the ovary. The stigma is often sticky or hairy and sometimes lobed.

Terminal: At the end or tip of a structure.

Unisexual: Flowers that have either male or female fertile reproductive structures but not both (see bisexual, dioecious, monoecious).

BIBLIOGRAPHY

Recommended publications for further information on riparian habitat and restoration:

Best, Catherine, J.T. Howell, Walter and Irja Knight, and Mary Wells. 1996. *A Flora of Sonoma County*. California Native Plant Society Press, Sacramento, California.

Burridge, Betty. 1995. *Sonoma County Breeding Bird Atlas - Detailed maps and accounts for our nesting birds*.

Circuit Rider Productions, Inc. 1989. *Acorn to Oak: A Guide to Planting and Establishing Native Oaks,* Circuit Rider Productions, Inc., 9619 Old Redwood Highway, Windsor, California 95492.

Circuit Rider Productions, Inc. 1999. *The Cavity Nesting Bird Education and Enhancement Project.* Circuit Rider Productions, Inc., 9619 Old Redwood Highway, Windsor, California 95492.

Chestnut, V.K. 1974. *Plants Used by the Indians of Mendocino County, California.* Mendocino County Historical Society, Publication Headquarters, 243 West Bush Street, Fort Bragg, California, 95437.

Faber, Phyllis M. and Robert F. Holland. 1982. *Common Riparian Plants of California: A Field Guide for the Layman*. Pickleweed Press, 212 Del Casa, Mill Valley, California, 94941.

Goodrich, Jennie, Claudia Lawson, Vana Lawson and Parrish Lawson. 1980. *Kashaya Pomo Plants.* Heyday Books, Berkeley, California.

Hickman, James C., ed. 1993. *The Jepson Manual: Higher Plants of California*. University of California Press, Berkeley and Los Angeles, California.

Marcus, Laurel and Dennis Jackson. 1998. *Watershed Stewardship - Creating a Watershed Atlas and Monitoring Program.* Sotoyome Resource Conservation District, Santa Rosa, California.

Martin, Alexander C., Herbert S. Zim and L. Nelson Arnold. 1961. *American Wildlife & Plants: A Guide to Wildlife Food Habits.* Dover Publications, Inc., 180 Varick Street, New York, New York, 10014.

McMinn, Howard E. 1974. *An Illustrated Manual of California Shrubs.* University of California Press, Berkeley and Los Angeles, California.

Ornduff, Robert. 1974. *Introduction to California Plant Life.* University of California Plant Life. University of California Press, Berkeley and Los Angeles, California.

Schmidt, Marjorie G. 1980. *Growing California Native Plants.* University of California Press, Berkeley, California 94720.

Smith, Gladys L. and Clare R. Wheeler. 1992. *A Flora of the Vascular Plants of Mendocino County, California.* The University of San Francisco, San Francisco, California.

The Pierce's Disease/Riparian Habitat Workgroup, 2000. *Riparian Vegetation Management for Pierce's Disease in North Coast California Vineyards.* Circuit Rider Productions, Inc., 9619 Old Redwood Highway, Windsor, California 95492.

Warner, Richard E. and Kathleen M. Hendrix. 1984. *California Riparian Systems - Ecology, Conservation, and Productive Management*. University of California Press, Berkeley and Los Angeles, California.

NORTH COAST INTEGRATED REGIONAL WATER MANAGEMENT PLAN

North Coast Integrated Regional Water Management Plan Proposition 84 Round 1 Implementation Grant

Priority Project Technical Documents: Plans and Specifications

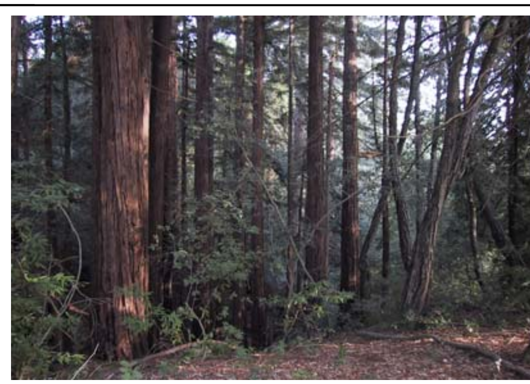
345 - Bodega Bay HU Water Resources Management Project, Gold Ridge RCD

- Save Our Salmon: Salmon Creek Instream Habitat Enhancement Plan, Tannery Creek Large Wood Structures, Conceptual Plan
- Save Our Salmon: Salmon Creek Habitat Rehabilitation Program, Phase 1, Residential Garden and Small Agricultural Rainwater Collection System
- Gold Ridge RCD, Salmon Creek Integrated Watershed Management Plan, 2010
- Prunuske Chatham, Inc, Salmon Creek Water Conservation Plan, Occidental Arts & Ecology Center, 2010

THE SALMON CREEK WATERSHED ASSESSMENT AND RESTORATION PLAN

Grant Agreement P0230439



A Project of the Gold Ridge Resource Conservation District with grant funding from the California Department of Fish and Game Fisheries Restoration Grant Program

The Salmon Creek Watershed Assessment and Restoration Plan

Version 1, March 31 2007
Revised April 16, 2007

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TABLE OF CONTENTS

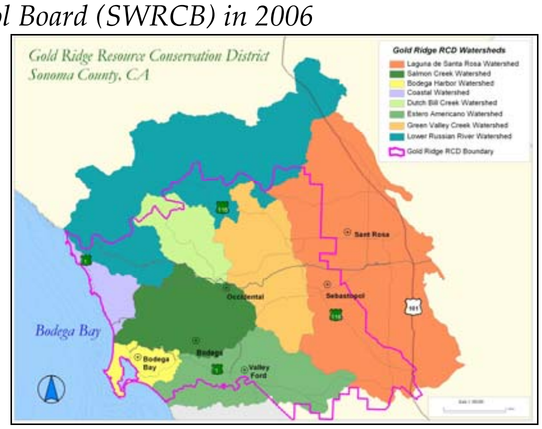
EXECUTIVE SUMMARY

The Gold Ridge Resource Conservation District (GRRCD), established in 1941, has been a principal contributor in preserving natural resources in western Sonoma County over the past 64 years. Many changes have occurred with regards to land use in the district. What used to be primarily agricultural land is now industry and rural development. Consumer food preferences have also changed over the course of time. For instance, the production of cherries, apples, and berries has given way to the production grapes, placing additional pressures on landowners to develop marginal lands for premium grapes. This similarly places additional pressures on our resources, both natural and technical, to prevent soil erosion and to maintain water quality in local streams and water supplies. Changes in endangered species designations throughout the state have also impacted landowners and land use management practices within the district.

This report was prepared to fulfill the requirements of Agreement Number P0230439 with the California Department of Fish and Game (DFG). This report and related documents, provides the basis for completion of this grant. The purpose of this grant was to provide landowners in the Salmon Creek Watershed with the ability to have erosion sites on their property assessed by qualified professionals, to develop a citizen based water quality monitoring program, to identify keystone limiting factors of anadromous salmonids, to build watershed capacity among stakeholders, and to conduct a broad landowner outreach and community education program in the watershed.

Through this funding, an assessment needs analysis was conducted through public meetings and focused steering committee meetings. This DFG grant provided a spring-board from which other watershed needs were determined and subsequently funded. These grant programs include the following:

- Salmon Creek Estuary and Enhancement Study – *funded by the State Coastal Conservancy(SCC) in 2004*
- Salmon Creek Roads Assessment – *funded by DFG and SCC in 2005*
- Salmon Creek Oral History Project – *funded by DFG in 2004*
- Salmon Creek Integrated Watershed Assessment Plan – *funded by the State Water Resources Control Board (SWRCB) in 2006*



Map of the Watersheds within the Boundaries of the Gold Ridge RCD

GRANT REPORT SUMMARY
Agreement #: P0230439

Dates of Work: May 1, 2003 through March 31, 2007
RCD Person Hours Expended: 1086.75 (District Manager, Project Director, and Watershed Coordinator)
Total of Each Fund Source Expended:

- California Department of Fish and Game - $142,162.00
- State Coastal Conservancy - $27,500.00
- GRRCD In-Kind Services - $20,000.00
- Salmon Creek Residents Cost-Share (Volunteer WQ Monitoring) - $45,000 (This number is an approximation based on the volunteers expending about 1125 documented hours @ $40.00/hour)
- **Total Project Cost: $234,662.00**

Summary of Outreach Activities:

- **Watershed Activities Attended:** Quarterly Salmon Creek Watershed Assessment Plan steering committee meetings; Two Sonoma County Watershed Day events; Monthly Salmon Creek Watershed Council meetings; and Four public meetings (to update the community on the progress of this and other grant opportunities)
- **Newsletters:** Attached with this report

Accomplishments (based on approved DFG Scope of Work):

- Successfully compiled existing and historic salmonid related data available for Salmon Creek for inclusion into the Salmon Creek Assessment and Restoration Plan (Chapter 3, Chapter 4 & Chapter 5);
- Successfully developed a citizen based water quality monitoring program that followed DFG protocols (Chapter 4).
- Successfully completed an erosion source inventory on over 40 different properties in the Salmon Creek watershed (Chapter 5).
- Successfully built watershed capacity among stakeholders by holding quarterly steering committee meetings which included members of the Gold Ridge RCD staff and Board of Directors, the Salmon Creek Watershed Council, the Department of Fish and Game, Prunuske Chatham Inc., and other interested parties.
- GRRCD staff attended and participated in Salmon Creek Watershed Council meetings, West County (Sonoma County) Watershed Day events, and other public meetings. The GRRCD also actively engaged the agricultural community to build a consensus on management strategies that would work for preserving traditional agriculture in west Sonoma County.

Task not Completed:
The geomorphic analysis that was an important part of this funding agreement was not completed due to constraints of time and budget. However, with the assistance of the DFG contract manager, the GRRCD secured funding from State Water Resources Control Board for this assessment and continued water quality monitoring. These assessments will augment this Assessment and Restoration Plan no later than December 31, 2008.

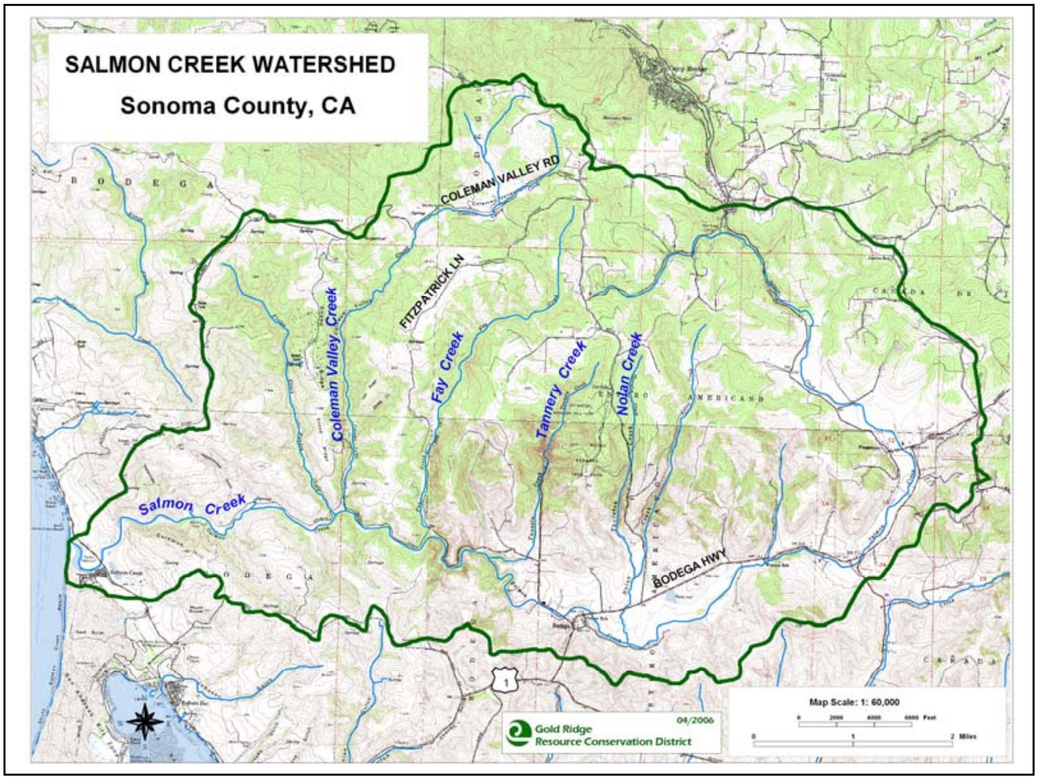
Successes & Lessons Learned: The philosophy of the Gold Ridge Resource Conservation District (RCD) is that a citizen-driven planning process is the optimal method to achieve resource management in its District watersheds. Although a conservation planning process that provides for extensive community involvement has many benefits, an important cost of such an approach is often a failure to meet scientific or uniform standards in data collection and analysis. The failure to meet such standards can undermine the value and efficacy of volunteer monitoring programs, as well as all subsequent planning documents. This was one of the dilemmas we faced early on in the Salmon Creek Assessment Plan planning process. To address this issue, it was agreed upon by both the Salmon Creek Watershed Council (SCWC) and the RCD that a high caliber sub-contractor (Prunuske Chatham, Inc. [PCI]) would be needed to train volunteer monitors, to oversee data collection as well as to analyze data in keeping with key professional standards.

It was also decided early in the organization of this plan that we would utilize a watershed management approach for the development of this program. The principles of the watershed approach (Environmental Protection Agency) focus on partnerships, a focused geographic area, and sound management techniques based on strong science and data. All stakeholder groups in the Salmon Creek Watershed were encouraged to share relevant information and to participate in the decision-making processes, which entailed goal setting and prioritization of issues and concerns. The RCD, SCWC, and PCI were initially successful in this process. However, because of some inherent mistrust between residents of the watershed, the issue of water quality data and resultant "finger-pointing" became a point of contention. The RCD has a strong mandate to protect the rights and privacy of individual landowners, and did not feel it prudent that raw, unanalyzed data be distributed prior to the conclusion of this project. This decision by the RCD, in consultation with the SCWC and PCI, led to some stakeholders dropping out of the program, leaving less than the full watershed represented at steering committee and public meetings. The RCD tried in good faith to bridge this gap by providing relevant updates and information in its newsletters and through public events. However, some stakeholders continued to feel their concerns were not being addressed and did not rejoin the planning process.

Outside of some perceived marginalization of certain watershed residents, the RCD deems this project a tremendous success. Toward the end of the program, at the last public meeting, representatives from both the environmental and the agricultural community were present and no negative feedback from either group was received. In essence, the project successfully coordinated stakeholders to ensure that compatible conservation practices and water quality monitoring data were included in a plan to address key limiting factors in Salmon Creek. In addition, this grant funded program enabled the RCD to provide many opportunities for citizen involvement, particularly through the volunteer water quality monitoring component. It was very important to have as much local participation as possible to facilitate cooperative learning about conservation needs and the development of long-term watershed planning goals. Having a volunteer water quality monitoring program brought together an interesting and diverse group of residents in the watershed.

In summary, the primary goal of the Salmon Creek Watershed planning process was to include and synthesize a broad range of stakeholder views, interests and information. Through the collaborative efforts of resource agencies and watershed groups, including but not limited to the California Department of Fish and Game, the North Coast Regional Water Quality Control Board, the State Coastal Conservancy, the Salmon Creek Watershed Council, Prunuske Chatham, Inc., and the Gold Ridge RCD, this goal was achieved.

Chapter 1: Introduction



The Salmon Creek Watershed is located within the Bodega Bay Hydrologic Unit (HU). The Bodega Bay HU consists of Americano Creek, the Estero Americano, Cheney Gulch, Scotty Creek, Salmon Creek, and associated tributaries. All drain into the Bodega Bay and the Gulf of the Farallones National Marine Sanctuary. The California Unified Watershed Assessment identified the Bodega Bay HU as a Category 1 Priority Watershed due to excessive loading of sediment and nutrients. The Regional Water Quality Control Board's (RWQCB) Watershed Management Initiative (WMI) also identified confined animal facilities and throughout the Bodega Bay HU as sources of nitrogen, phosphorous, organic matter and sediment into the bay itself. The Bodega Bay HU is typified by cooler temperatures and relatively high rainfall due to coastal influences. The terrain is relatively steep, with streams carving through the Coast Range and entering the Pacific Ocean south of the Russian River. These streams are located in erosive topography and extremely sensitive to land disturbance. The 1987 Sonoma County Coastal Wetlands Enhancement Plan (Enhancement Plan) identified Salmon Creek and stated that "bank erosion on tributary streams which are freely accessed by livestock is common. Loss of woody plants on channel banks of most of the tributaries is a major problem contributing to the destabilization of the streambanks (Circuit Rider Productions, Inc., 1987)." The Enhancement Plan further states that "several tributary streams and reaches of Salmon Creek will continually provide higher rates of sediment delivery than would naturally occur. This will continue to degrade the marshes and open water areas of the estuary as well as continue to degrade steelhead and salmon spawning habitat. Salmon Creek is an important anadromous fish stream and restoration of its fisheries habitat through erosion control should be considered a priority (ibid.)." The RWQCB Board has similarly identified riparian vegetation, channel protection, and increased riparian zones along Salmon Creek as targeted non-point source (NPS) pollution projects. Through a cooperative effort between several agencies, the goal of this project has been to promote the implementation of needed NPS pollution controls and to assist landowners with best management practices (BMPs) that will restore water quality. The main goal of this project is to improve and protect water quality by helping landowners achieve Tier 1 voluntary compliance with current and future NPS regulations.

Salmon Creek Watershed covers approximately 35.3 square miles; Salmon Creek is the mainstem and includes a series of six major parallel tributaries (Finley, Fay, Tannery, Nolan, Thursten and Coleman Valley Creeks) (DFG Salmon Creek Stream Inventory Report 2003, p.2). The watershed also contains 17 unnamed, smaller tributaries. From its highest point at 797 feet, the mainstem of Salmon Creek runs south through Occidental and makes a westerly curve near Freestone before reaching the Pacific Ocean 3 miles north of Bodega Bay. The watershed's terrain is characterized by steep topography and soils that are highly erosive and sensitive to disturbance. Vegetation occurring in the watershed is a combination of deciduous and mixed coniferous forests and grasslands.

The Salmon Creek Watershed is almost completely privately owned (95%). Primary land uses include rangeland, viticulture, timber, rural residential and urban. Current and historic land use activities have degraded the natural environment, impaired water quality and aquatic habitat, and increased the rate and amount of sedimentation. Salmon Creek Watershed once had a thriving anadromous fish population, vibrant stands of vegetation, and exceptional water quality.

Historic farming practices and current intensive grazing have reduced riparian vegetation, causing stream and bank erosion. Livestock in streams generally inhibit growth of new trees, exacerbate erosion and reduce summertime survival of juvenile fish by defecating in the water (DFG, 2004). Erosion leads to increased sedimentation and water temperatures, degrading the quality of marshes and open water area in the estuary.

Although the Salmon Creek Watershed is not on the federal Clean Water Act 303 (d) list, it is an important coho salmon and steelhead trout tributary to the Pacific Ocean. The WMI states that in Salmon Creek, "concerns have been raised by the public regarding increased sedimentation, water temperature, nutrients, and salmonid habitat." In 2002, the California Department of Fish and Game (DFG) did a habitat typing study in the watershed and found high sediment yield to be a significant problem in both the mainstem and the tributaries in the watershed. Although the last coho sighting was in 1996 (Michael Banks, Bodega Marine Lab, and Bill Cox, DFG), DFG has stated that Salmon Creek is a fully restorable salmonid stream. Recognizing the importance of Salmon Creek, Gold Ridge RCD is working with landowners to develop riparian and streambank stability projects, as well as projects that will restrict the access that livestock have to the creek.

The beneficial uses for Salmon Creek include Municipal (MUN), Agriculture (AGR), Industrial (IND), Groundwater Recharge (GWR), Navigation (NAV), Contact Recreation (REC1), Non-Contact Recreation (REC2), Commercial (COMM), Coldwater Fisheries (COLD), Wildlife Habitat (WILD), Rare, Threatened, or Endangered Species (RARE), Migration of Aquatic Organisms (MIGR), Spawning, Reproduction and/or Early Development (SPAWN), Shellfish Harvesting (SHELL) (potential) , Estuarine Habitat (EST), and, Aquaculture (AQUA) (potential).

How this document is organized:
Chapter 2 of this document presents a general description of the Salmon Creek Watershed, its associated land uses, and watershed soils. Chapter 3 summarizes the habitat typing inventory done by DFG in 2002 – 2004. Chapter 4 presents baseline water quality data and the volunteer water quality monitoring program pioneered by the Salmon Creek Watershed Council Chapter 5 presents not only an overview of sediment sources and impacts in the watershed, but also presents the results of field inventories done by staff at Prunuske Chatham, Inc (PCI) on various properties throughout the watershed. Chapters 6 provides a discussion of some typical management practices recommended during the planning process, and by other agencies in similar watershed locations, to enhance the overall health of Salmon Creek and the productivity of its natural capital.

The Salmon Creek Watershed Restoration Plan should be viewed as a "living document." The goals and management strategies outlined in this watershed management plan are based on our current level of understanding of the ecological processes and health of the watershed. It is expected that management issues and priorities in the watershed will change through time as will the goals and objectives of this document. In order to monitor and document the implementation of this plan, as well as to foster an adaptive management approach to implementation, the RCD will create and maintain a program implementation matrix that will be posted on our website: http://www.goldridgercd.org.

Chapter 2: Watershed Description and Land Use

Prior to European settlement, the Salmon Creek Watershed was inhabited for at least 8,000 years by Native Americans. Most recently, the Coast Miwok tribe had several small villages and seasonal encampments along the valleys between Freestone and Bodega, as well as at the estuary. Although the Indians did not practice formal agricultural they did manage the land through fire, selective gathering and propagating, and hunting. Oral stories passed through the generations speak to the incredible richness and diversity of the Salmon Creek watershed (Prunuske Chatham, Inc 2006).

Salmon Creek Watershed marks the southern boundary of the extensive mixed evergreen forests of northern Sonoma County and Mendocino County. The five main tributaries and the headwaters of Salmon Creek drain high, steep, forested ridges and canyons (Figure 2-2). They flow into the open, rolling grasslands that typify the countryside to the south through which the upper and middle portions of Salmon Creek traverses. The low ridges that form the southern boundary of the watershed are mixed grassland and coastal scrub communities. Riparian hardwood, coastal terrace grassland, shore dune, estuarine, wetland, and vernal pool plant communities are also found in the watershed. This diverse ecology supports the broad range of animal species associated with each habitat type, and includes threatened and endangered species such as anadromous fish, freshwater shrimp, tidewater gobi, northern spotted owl, red tree voles, and southern red-legged frog.

Europeans, starting with the Russians in 1811, brought large-scale, intensive land use practices to the watershed – establishing small ranches in the Freestone and Bodega area to support their fur-trading forts. By 1850 the small agricultural community of Smith's Ranch had been established (now known as Bodega) with a population of at least 300. Agriculture and logging took off from this point, and over the next hundred years the watershed saw heavy use that drastically altered its forests, streams, and grasslands.

Today the land cover of the Salmon Creek Watershed is still mostly forest, grassland, and shrub communities (Figure 2-1). Forests make up a little over 50 percent of land cover (11,474 acres); while grasslands make up 37 percent of land cover (8,303 acres). There are 1,996 acres of shrubs; 424 acres of vineyards; 110 acres of paved surfaces; and 90 acres of orchards in the watershed. The distribution and composition is significantly changed from what was present prior to European settlement. As land use pressures change, the plant communities shift. Adjustments to all natural systems, especially the stream channels, continue as a response to historic land use practices.

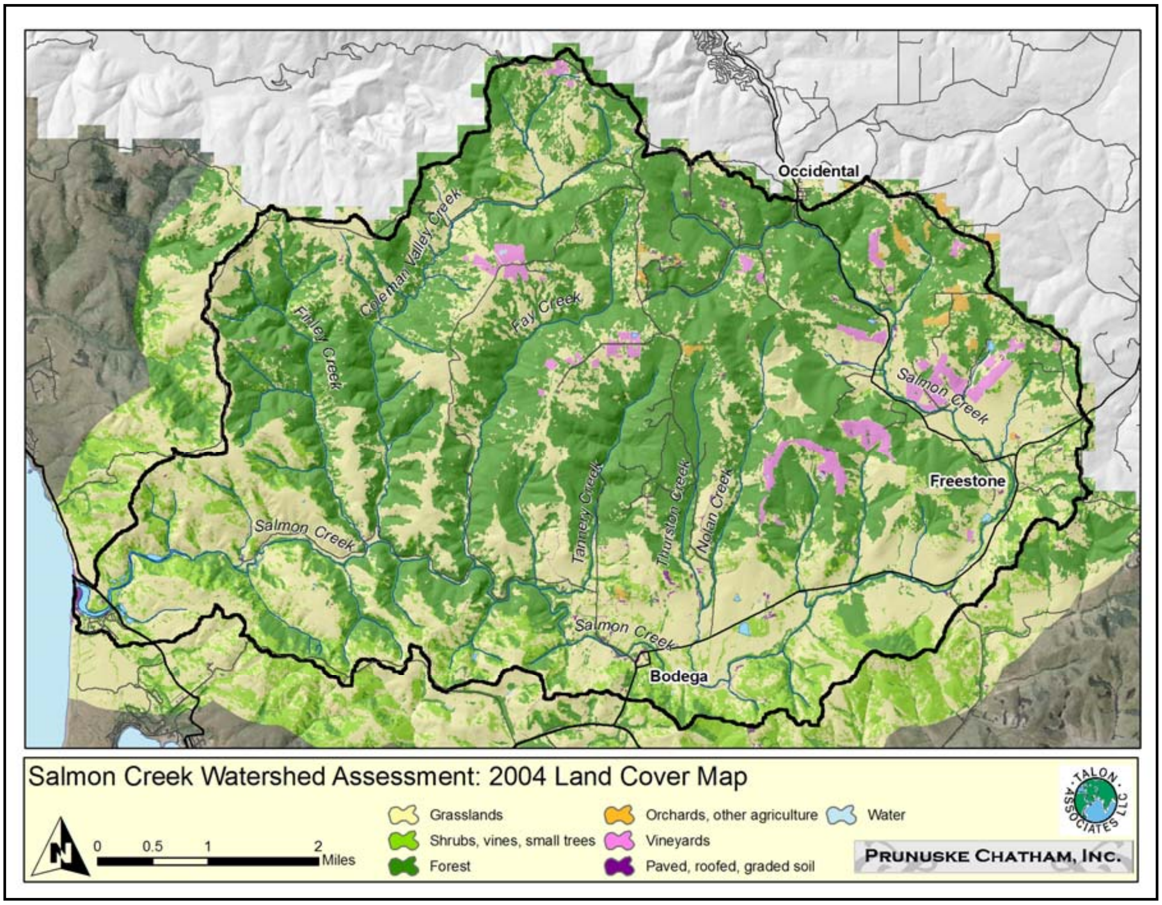
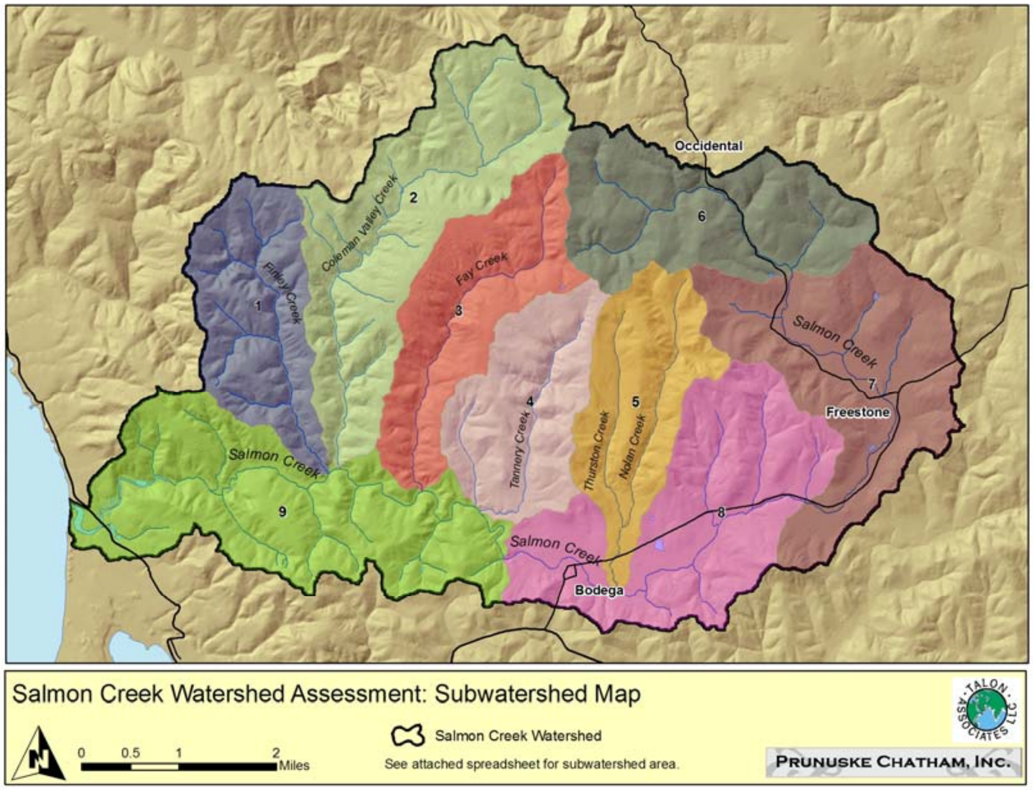


Figure 2-1. *Land cover in the Salmon Creek watershed. Total watershed acreage is 22,448. Forests make up 11,474 acres; grasslands 8,303 acres; shrubs 1,996 acres; vineyards 424 acres; paved surfaces 110 acres; orchards 90 acres; and water 49 acres.*

The Salmon Creek Watershed still maintains healthy stands of redwoods along ridgelines. Close to 50 percent of the forested land in the watershed is comprised of redwood forests, approximately 5, 457 acres. Other unique habitat types in the watershed include coastal oak woodland (824 acres) and coastal scrub (870 acres) interspersed with grasslands in the western sub-watersheds. Healthy montane riparian vegetation occurs along most reaches of the mainstem and tributaries. Although most of the grassland is dominated by annual European species, populations of native coastal prairie grasses can still be found throughout the western side of the watershed.

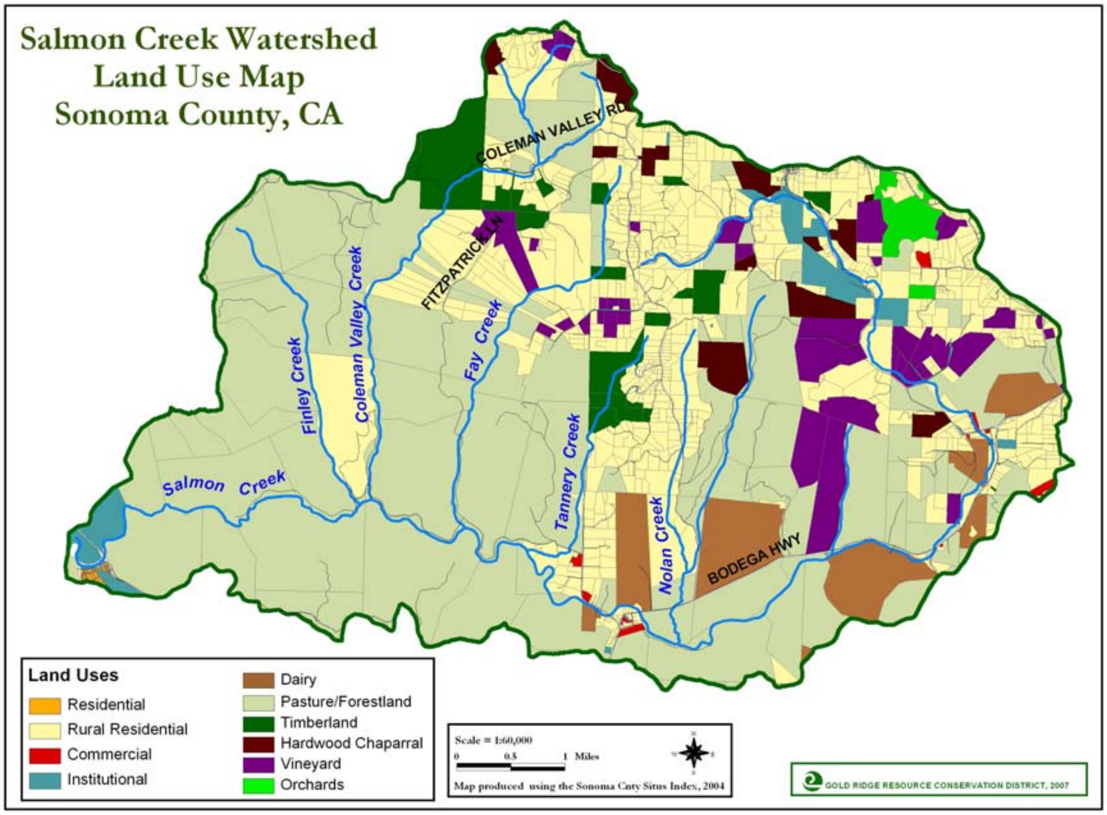
Figure 2-2. *Map showing the sub-watersheds of Salmon Creek. In addition to the main tributaries, the mainstem is divided into four sub-sections. The mainstem sections are the headwaters (#6), the upper reach (#7), the middle reach (#8), and lower Salmon Creek (#9).*



Land Use in the Salmon Creek Watershed is predominantly agricultural and low-density, rural residential development (Figure 2-3; Table 2-1). There are concentrations of homes along roads and ridgelines and in the towns of Occidental, Freestone, Bodega, and Salmon Creek. Forests cover much of the northern ridges and logging is minimal. Several small vineyards have been developed along the ridgelines and in the town of Freestone. Most of the lower watershed is still largely undeveloped and remains as grazing land for beef cattle, sheep, and horses. A few orchards remain in the eastern watershed. Family dairies continue to in the Bodega valley. Table 2-2 provides land use data by sub-watershed.

Land Use	Acres
Residential (higher density)	16
Rural Residential	6,023
Commercial	55
Institutional	430
Dairy	1,104
Pasture/Forestland	12,016
Orchard	179
Vineyard	1,187
Hardwood Chaparral	493
Timberland	791

Figure 2-3. Land use in the Salmon Creek Watershed (Sonoma County Situs Index, 2004).



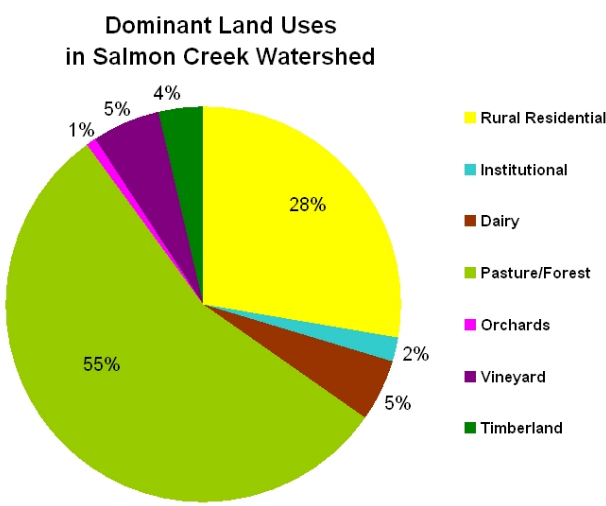


Figure 2-4. *Dominant Land Uses in the Watershed.*

Throughout the watershed many of the historic large ranches have been subdivided and sold, transitioning the land to lightly managed rural residential

The dominant land use in the Salmon Creek Watershed is still livestock grazing; pasture is mixed with forestland, particularly at higher elevations (Figure 2-3). Land uses vary by sub-watershed. Land use in the lower Salmon Creek and Finely Creek sub-watersheds are still predominantly pastureland, 95% and 89% respectively (Table 2-2). The upper Salmon Creek, Thurston and Nolan Creek, and Freestone Valley sub-watersheds are the most heavily developed with a mix of land uses. Most of this development is located around the towns of Occidental, Freestone and Bodega.

Table 2-2. *Land uses by the nine sub-watersheds.*

Subwatershed	Land Use	Acres	% of Land Use
Coleman Valley Creek	Hardwood Chaparral	99.1	3%
Coleman Valley Creek	Institutional	3.0	<1%
Coleman Valley Creek	Pasture/Forest	1587.9	**49%**
Coleman Valley Creek	Rural Residential	1055.9	**33%**
Coleman Valley Creek	Timberland	406.3	13%
Coleman Valley Creek	Vineyard	73.4	2%
Fay Creek	Hardwood Chaparral	2.1	<1%
Fay Creek	Institutional	2.2	<1%
Fay Creek	Pasture/Forest	1021.3	**51%**
Fay Creek	Rural Residential	790.3	**40%**
Fay Creek	Timberland	59.6	3%
Fay Creek	Vineyard	113.5	6%
Finley Creek	Pasture/Forest	1613.0	**89%**
Finley Creek	Rural Residential	194.9	11%
Freestone Valley	Commercial	19.8	1%
Freestone Valley	Dairy	388.5	13%
Freestone Valley	Hardwood Chaparral	121.8	4%
Freestone Valley	Institutional	63.0	2%
Freestone Valley	Orchards	4.9	<1%
Freestone Valley	Pasture/Forest	806.7	**28%**
Freestone Valley	Rural Residential	1031.3	**36%**
Freestone Valley	Timberland	2.5	<1%
Freestone Valley	Vineyard	454.5	16%
Lower Salmon Creek	Institutional	138.7	4%
Lower Salmon Creek	Pasture/Forest	3242.4	**95%**
Lower Salmon Creek	Residential	15.6	<1%
Lower Salmon Creek	Rural Residential	32.7	1%

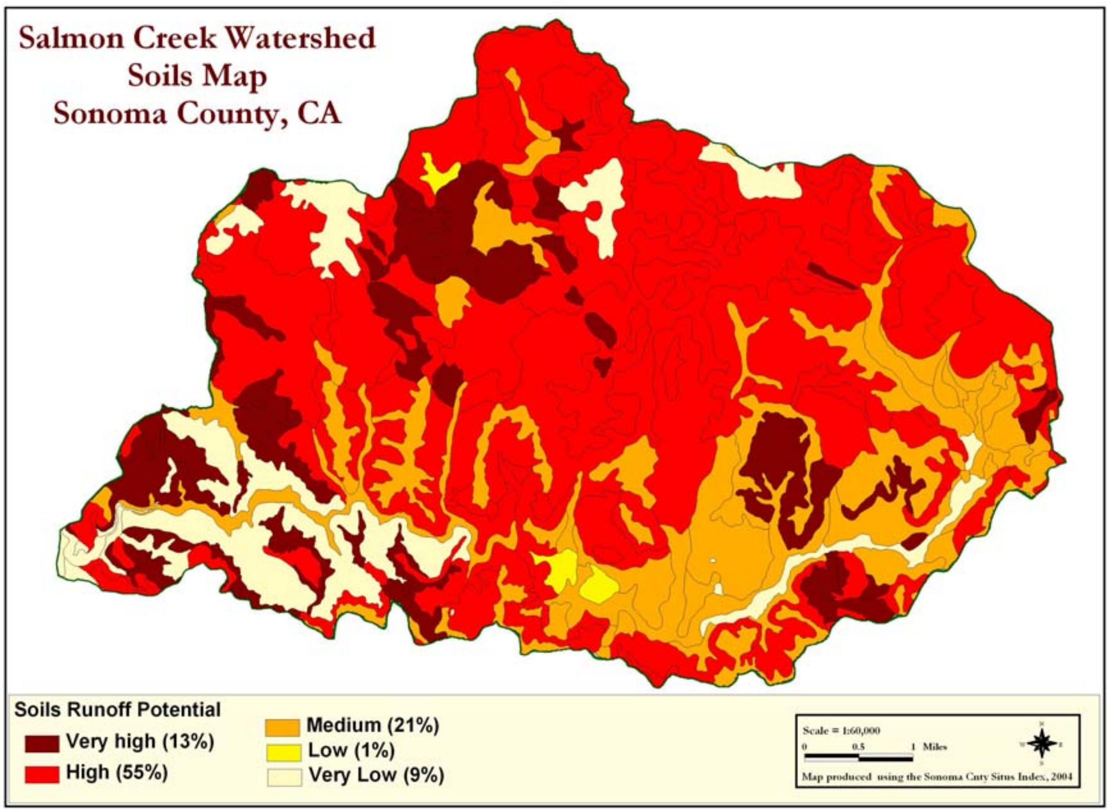
Table 2-2. *Conti.*

Subwatershed	Land Use	Acres	% of Land Use
Middle Salmon Creek	Commercial	19.5	1%
Middle Salmon Creek	Dairy	529.9	17%
Middle Salmon Creek	Institutional	4.2	<1%
Middle Salmon Creek	Pasture/Forest	1883.7	**62%**
Middle Salmon Creek	Rural Residential	263.7	9%
Middle Salmon Creek	Vineyard	357.8	12%
Tannery Creek	Commercial	2.7	<1%
Tannery Creek	Dairy	49.6	3%
Tannery Creek	Institutional	4.4	<1%
Tannery Creek	Pasture/Forest	872.8	**51%**
Tannery Creek	Rural Residential	537.0	**31%**
Tannery Creek	Timberland	211.9	12%
Tannery Creek	Vineyard	42.2	2%
Thurston and Nolan Creek	Dairy	134.7	8%
Thurston and Nolan Creek	Hardwood Chaparral	113.2	6%
Thurston and Nolan Creek	Institutional	0.3	<1%
Thurston and Nolan Creek	Pasture/Forest	783.1	**45%**
Thurston and Nolan Creek	Rural Residential	680.0	**39%**
Thurston and Nolan Creek	Timberland	32.0	2%
Thurston and Nolan Creek	Vineyard	1.1	<1%
Upper Salmon Creek	Commercial	11.3	<1%
Upper Salmon Creek	Hardwood Chaparral	151.9	7%
Upper Salmon Creek	Institutional	201.7	9%
Upper Salmon Creek	Orchards	171.9	7%
Upper Salmon Creek	Pasture/Forest	156.3	7%
Upper Salmon Creek	Rural Residential	1384.7	**60%**
Upper Salmon Creek	Timberland	76.6	3%
Upper Salmon Creek	Vineyard	143.8	6%

Watershed Soils

Due to the steep topography of the watershed, close to 70 percent of soils are considered highly prone to runoff (Figure 5-6). Refer to Appendix B for a list of watershed soils, runoff potential, drainage classification and acres. The two dominant soil types in the watershed are Gold Ridge, Fine Sandy Loam (26%) and Steinbeck Loam (16%).

Figure 5-6. *Salmon Creek Watershed Soils Runoff Classification.*



As is evident in Figure 5-7, most of the high erosion hazard soils in the watershed are located in the Finley Creek and lower Salmon Creek sub-watersheds.

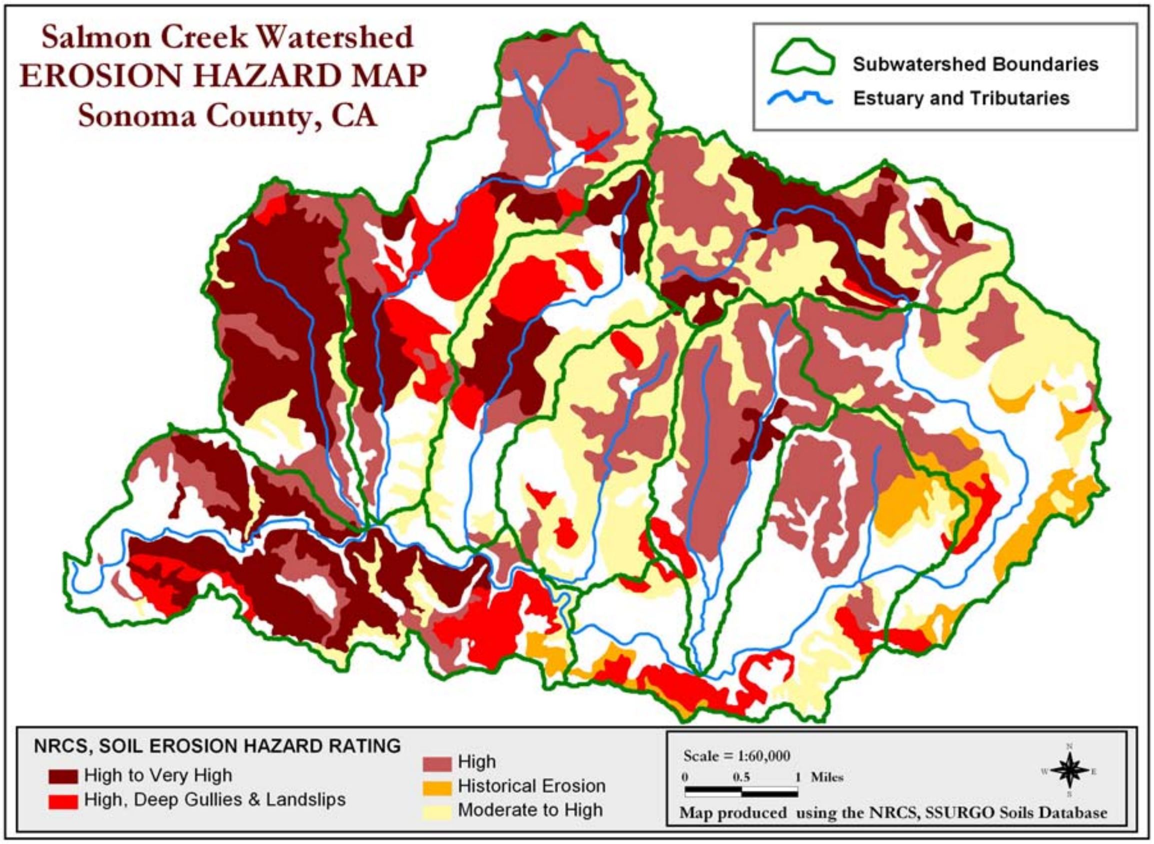


Figure 5-7. *Salmon Creek Watershed Erosion Hazard Map.*

Chapter 3 Salmon Creek Watershed Stream Inventory Report Synopsis

Photo Courtesy of Steve Killey

To best manage fisheries it is essential to know how much habitat is available and how it is utilized by fish. California Department of Fish and Game (DFG) stream and biological inventory reports are done in order to provide assessment of fish present and habitat available. Stream habitat surveys were conducted on the mainstem of Salmon Creek and its tributaries: Coleman Valley Creek, Finely Creek, Nolan Creek, Tannery Creek and Thurston Creek following the methodology presented in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al., 1998). Fisheries scientists walked and measured creeks and assigned habitat types to specific reaches. There are nine components to an inventory form: flow, channel type, temperatures, habitat type, embeddedness, shelter rating, substrate composition, and canopy and bank composition. For a more detailed version of the information presented below please reference appropriate *Stream Inventory Report,* per Salmon Creek Watershed Stream (DFG 2004). These reports are posted on the Gold Ridge RCD website at http://www.goldridgercd.org.

Table 3.1. Habitat Inventory for Salmon Creek and its Tributaries

Stream Survey	Date of Survey	Water Temp. in ˚F *1	% Pools	% Pools with max. depth > 2 ft *2	% Stream length with pools max. depth > 2 ft *3	Mean Shelter Rating *4	# of low gradient riffles with either gravel or small cobble as dominant substrate *5	% Gravel/Cobble Embedded-ness in fine sediment with rating of 3 or 4 *6	# of pool tail-outs with cobble embedded-ness < 25%	% Canopy *7
Salmon Creek Mainstem	7/24/03 - 8/21/03	54˚F to 76˚F	38%	53%	28%	35	52 of 66	29%	3%	65%
Coleman Valley Creek	6/29/02 - 9/22/02	50˚F to 68˚F	22%	74%	16%	14	3 of 4	17%	6%	65%
Fay Creek	9/19/02 - 9/21/02	52˚F to 59˚F	16%	74%	13%	17	1 of 1	13%	4%	92%
Finley Creek	6/28/02 - 7/22/03	54˚F to 63˚F	19%	28%	5%	25	5 of 5	34%	16%	78%
Nolan Creek	7/15/03 - 7/17/03	54˚F to 60˚F	23%	53%	13%	26	11 of 13	45%	0%	54%
Tannery Creek	9/23/02 - 9/29/02	48˚F to 52˚F	9%	73%	7%	42	no data	17%	35%	90%
Thurston Creek	7/18/03 - 7/21/03	50˚F to 60˚F	18%	56%	11%	24	8 of 9	29%	0%	83%

*1 Temperatures at or above 65˚F are considered above the stress threshold for salmonids.

*2 Primary pools are defined to have a max. depth of at least two feet, occupy at least half of the width of the low flow channel and be as long as the low flow channel width.

*3 In coastal coho and steelhead streams it is generally desirable to have primary pools comprise 50% of total habitat length.

*4 A pool rating of approximately 80 is desired. Log and root wad cover in the pool and flatwater habitats would improve both summer and winter habitat.

*5 High percentages are generally considered good for spawning salmonids.

*6 Cobble embeddedness measured to be 25% or less (rating 1) is considered best for the needs of salmon and steelhead.

*7 80% canopy coverage is considered desirable for salmonid habitat.

Salmon Creek Stream Inventory Report (DFG, 2003)

The mainstem of Salmon Creek was surveyed on the days 7/24/2003 – 8/21/2003. Almost 16 stream miles were surveyed during this time, beginning at the wetlands above the mouth and ending 15.9 miles upstream. Given the data collected during the survey and presented in Table 3.1, the following limiting factors were identified and enhancement opportunities were prescribed. Table 3.2. below summarizes the presence of species found in the mainstem of Salmon Creek.

Limiting Factors:

1. High water temperatures
2. Low number of deep pools
3. Low instream shelter value
4. Gravel/Cobble Embeddedness in Fine Sediment
5. Low canopy cover (shade)

Fisheries Enhancement Opportunities:

1. Improving and monitoring access for migrating salmon particularly in the upper reaches.
2. There appear to be 16 log debris accumulations that have the potential to cause bank erosion. Modification of these log debris accumulations is not recommended but they should be monitored.
3. There are sections of the stream being impacted by livestock in the riparian zone. Alternatives to limit cattle access, control erosion and increase canopy should be explored by landowners.
4. Map and prioritize sources of upslope and in-channel erosion. Near-stream riparian planting is encouraged.
5. Active and potential sediment sources related to roads near Salmon Creek should be mapped and treated according to their potential for sediment yield to the stream and its tributaries.
6. Increase canopy for Salmon Creek with tree plantings (willow, alder, redwood and Douglas fir) where cover is low. Plantings may need to be paired with bank stabilization or upslope erosion control projects.
7. Sites throughout the entire surveyed stream would benefit from bio-technical vegetative techniques to re-establish floodplain benches and a defined low flow channel. This would discourage lateral migration of the base flow channel and decrease bank erosion.
8. Where feasible, increase woody cover in pool and flatwater habitat along the entire stream.
9. Conduct gravel sampling. Results may indicate the need for structures that decrease channel incision recruit and sort spawning gravel, and expand redd distribution in the stream. Where existing dams are retaining gravel sites downstream should be resurveyed for spawning gravel quality and quantity.

10. Where feasible, design and engineer pool enhancement structures to increase number or pools in the upper reaches.

Table 3.2. Species Observed in Historical and Recent Surveys in Salmon Creek

Years	Species	Source	Native/Introduced
2001 **2003**	Steelhead Trout *(Oncorhynchus mykiss)*	CDFG	Native
2003	Pacific Lamprey *(Lampetra tridentatus)*	CDFG	Native
2001 **2003**	Sculpin or Cottoids *(Cottus sp.)*	CDFG	Native
2001 **2003**	California or Venus Roach *(Hesperoleucus symmetricus)*	CDFG	Native
2003	California Freshwater Shrimp *(Syncaris pacifica)*	CDFG	Native
2001 **2003**	Threespine Stickleback *(Gasterosteus aculeatus williamsoni)*	CDFG	Native

Coleman Valley Creek Stream Inventory Report (DFG, 2002)

Coleman Valley Creek was surveyed on the days 6/29/2002 – 9/22/2002. The Coleman Valley Creek survey began at the confluence with the mainstem of Salmon Creek and extended 2.9 miles upstream. Given the data collected during the survey and presented in Table 3.1., the following limiting factors were identified and enhancement opportunities were prescribed. Table 3.3. below summarizes the presence of species found in Coleman Valley Creek.

Limiting Factors:

1. High water temperatures
2. Low number of deep pools
3. Low instream shelter value
11. Gravel/Cobble Embeddedness in Fine Sediment
1. Low canopy cover (shade)
2. Low flow

Fisheries Enhancement Opportunities:

1. Rearing conditions throughout the creek appear inadequate this time due to low flow. Pools were disconnected due to low flow. Low instream flow should be addressed by increasing riparian protection and restoration, sediment control, and employing best management practices that encourage permeability and infiltration.
2. There are sections of the stream being impacted by livestock in the riparian zone. Alternatives to limit cattle access, control erosion and increase canopy should be explored by landowners.
3. Map and prioritize sources of upslope and in-channel erosion. Near-stream riparian planting is encouraged.
4. Active and potential sediment sources related to roads in the Coleman Valley Creek should be mapped and treated according to their potential for sediment yield to the stream and its tributaries.
5. Increase canopy for Coleman Valley Creek with tree plantings (willow, alder, redwood and Douglas fir) where cover is low. Plantings may need to be paired with bank stabilization or upslope erosion control projects.
6. Reach 1 would benefit from bio-technical vegetative techniques to re-establish floodplain benches and a defined low flow channel. This would discourage lateral migration of the base flow channel and decrease bank erosion.
7. Where feasible, increase woody cover in pool and flatwater habitat along the entire stream.
8. Conduct gravel sampling. Results may indicate the need for structures that decrease channel incision recruit and sort spawning gravel, and expand redd distribution in the stream.
9. Where feasible, design and engineer pool enhancement structures to increase number or pools in the upper reaches.

Table 3.3. Species Observed in Historical and Recent Surveys, Coleman Valley Creek

Years	Species	Source	Native/Introduced
2001	Steelhead Trout *(Oncorhynchus mykiss)*	CDFG	Native
2001	Sculpin or Cottoids *(Cottus sp.)*	CDFG	Native
2001	California or Venus Roach *(Hesperoleucus symmetricus)*	CDFG	Native
2001	Threespine Stickleback *(Gasterosteus aculeatus williamsoni)*	CDFG	Native

Fay Creek Stream Inventory Report (DFG, 2003)

Fay Creek was surveyed on the days 6/28/2002 – 7/22/2003. The Fay Creek survey began at the confluence with the mainstem of Salmon Creek and extended up the creek to the end of anadramous fish passage at a rock falls. Given the data collected during the survey and presented in Table 3.1, the following limiting factors were identified and enhancement opportunities were prescribed. Table 3.4. below summarizes the presence of species found in Fay Creek.

Limiting Factors:

1. Low number of deep pools
2. Low instream shelter value
3. Gravel/Cobble Embeddedness in Fine Sediment

Fisheries Enhancement Opportunities:

1. Where feasible, design and engineer pool enhancement structures to increase number or pools in the upper reaches.
2. Where feasible, increase woody cover in pool and flatwater habitat along the entire stream.
3. Fay Creek would benefit from bio-technical vegetative techniques to re-establish floodplain benches and a defined low flow channel. This would discourage lateral migration of the base flow channel and decrease bank erosion.
4. Map and prioritize sources of upslope and in-channel erosion. Near stream riparian planting is encouraged.
5. Increase canopy and bank stability for Fay Creek with tree plantings (willow, alder, redwood and Douglas fir) where canopy is not at acceptable levels. Plantings may need to be paired with bank stabilization or upslope erosion control projects.
6. Active and potential sediment sources related to roads near Fay Creek should be mapped and treated according to their potential for sediment yield to the stream and its tributaries.
7. Conduct gravel sampling. Results may indicate the need for structures that decrease channel incision recruit and sort spawning gravel, and expand redd distribution in the stream. Where existing dams are retaining gravel sites downstream should be resurveyed for spawning gravel quality and quantity.

Table 3.4. Species Observed in Historical and Recent Surveys in Fay Creek

Years	Species	Source	Native/Introduced
2001	Steelhead Trout *(Oncorhynchus mykiss)*	CDFG	Native
2001	Sculpin or Cottoids *(Cottus sp.)*	CDFG	Native
2001	Threespine Stickleback *(Gasterosteus aculeatus williamsoni)*	CDFG	Native

Finley Creek Stream Inventory Report (DFG, 2003)

Finley Creek was surveyed on the days 7/24/2003 – 8/21/2003. The Finley Creek survey began at the confluence with the mainstem of Salmon Creek and extended upstream to the end of anadramous fish passage at a rock falls. Given the data collected during the survey and presented in Table 3.1, the following limiting factors were identified and enhancement opportunities were prescribed. Table 3.5. below summarizes the presence of species found in Finley Creek.

Limiting Factors:

1. Low number of deep pools
2. Low instream shelter value
3. Gravel/Cobble Embeddedness in Fine Sediment

Fisheries Enhancement Opportunities:

1. Rearing conditions throughout the creek appear inadequate this time due to low flow. Pools were disconnected due to low flow. Low instream flow should be addressed by increasing riparian protection and restoration, sediment control, and employing best management practices that encourage permeability and infiltration.
2. There are sections of the stream being impacted by livestock in the riparian zone. Alternatives to limit cattle access, control erosion and increase canopy should be explored by landowners.
3. Where feasible, design and engineer pool enhancement structures to increase number or pools in the upper reaches.
4. Where feasible, increase woody cover in pool and flatwater habitat along the entire stream.
5. Map and prioritize sources of upslope and in-channel erosion. Near-stream riparian planting is encouraged.
6. Active and potential sediment sources related to roads near Finley Creek should be mapped and treated according to their potential for sediment yield to the stream and its tributaries.
7. Increase canopy and bank stability for Finely Creek with tree plantings (willow, alder, redwood and Douglas fir) where canopy is not at acceptable levels. Plantings may need to be paired with bank stabilization or upslope erosion control projects.
8. Reaches 1 and 2 would benefit from bio-technical vegetative techniques to re-establish floodplain benches and a defined low flow channel. This would discourage lateral migration of the base flow channel and decrease bank erosion.
9. Conduct gravel sampling. Results may indicate the need for structures that decrease channel incision recruit and sort spawning gravel, and expand redd distribution in the stream.

Table 3.5 Species Observed in Historical and Recent Surveys in Finley Creek

Years	Species	Source	Native/Introduced
2001	Steelhead Trout *(Oncorhynchus mykiss)*	CDFG	Native
2001	Sculpin or Cottoids *(Cottus sp.)*	CDFG	Native
2001	California or Venus Roach *(Hesperoleucus symmetricus)*	CDFG	Native
2001	Threespine Stickleback *(Gasterosteus aculeatus williamsoni)*	CDFG	Native

Nolan Creek Stream Inventory Report (DFG, 2003)

Nolan Creek was surveyed on the days 7/15/2003 – 7/17/2003. The Nolan Creek survey began at the confluence with the mainstem of Salmon Creek and extended upstream to the end of anadramous fish passage at 33' rock falls. Given the data collected during the survey and presented in Table 3.1, the following limiting factors were identified and enhancement opportunities were prescribed. Table 3.6. below summarizes the presence of species found in Nolan Creek.

Limiting Factors:

1. Low number of deep pools
2. Low instream shelter value
3. Gravel/Cobble Embeddedness in Fine Sediment

Fisheries Enhancement Opportunities:

1. Rearing conditions throughout the creek appear inadequate this time due to low flow. Pools were disconnected due to low flow. Low instream flow should be addressed by increasing riparian protection and restoration, sediment control, and employing best management practices that encourage permeability and infiltration.
2. There are sections of the stream being impacted by livestock in the riparian zone. Alternatives to limit cattle access, control erosion and increase canopy should be explored by landowners.
3. Where feasible, design and engineer pool enhancement structures to increase number or pools in the upper reaches.
4. Where feasible, increase woody cover in pool and flatwater habitat along the entire stream.
5. Map and prioritize sources of upslope and in-channel erosion. Near-stream riparian planting is encouraged.
6. Active and potential sediment sources related to roads in Nolan Creek should be mapped and treated according to their potential for sediment yield to the stream and its tributaries.
7. Increase canopy and bank stability for Nolan Creek with tree plantings (willow, alder, redwood and Douglas fir) where canopy is not at acceptable levels. Plantings may need to be paired with bank stabilization or upslope erosion control projects.
8. Reaches 1 and 2 would benefit from bio-technical vegetative techniques to re-establish floodplain benches and a defined low flow channel. This would discourage lateral migration of the base flow channel and decrease bank erosion.
9. Conduct gravel sampling. Results may indicate the need for structures that decrease channel incision recruit and sort spawning gravel, and expand redd distribution in the stream.

Table 3.6 Species Observed in Historical and Recent Surveys in Nolan Creek

Years	Species	Source	Native/Introduced
2003	Steelhead Trout *(Oncorhynchus mykiss)*	CDFG	Native
2003	Pacific Lamprey *(Lampetra tridentatus)*	CDFG	Native
2003	Sculpin or Cottoids *(Cottus sp.)*	CDFG	Native
2003	California or Venus Roach *(Hesperoleucus symmetricus)*	CDFG	Native
2003	California Freshwater Shrimp *(Syncaris pacifica)*	CDFG	Native
2003	Threespine Stickleback *(Gasterosteus aculeatus williamsoni)*	CDFG	Native

Tannery Creek Stream Inventory Report (DFG, 2002)

Tannery Creek was surveyed on the days 9/23/2002 – 9/29/2002. The Tannery Creek survey began at the confluence with the mainstem of Salmon Creek and extended upstream to the end of anadramous fish passage at rock falls. Given the data collected during the survey and presented in Table 3.1 the following limiting factors were identified and enhancement opportunities were prescribed. Table3.7 below summarizes the presence of species found in Tannery Creek.

Limiting Factors:

1. Low number of deep pools
2. Low instream shelter value
3. Gravel/Cobble Embeddedness in Fine Sediment

Fisheries Enhancement Opportunities:

1. Where feasible, design and engineer pool enhancement structures to increase number or pools in the upper reaches.
2. Where feasible, increase woody cover in pool and flatwater habitat along the entire stream.
3. There are several log debris accumulations currently on Tannery Creek that have the potential for causing bank erosion. They should be monitored for fish passage and erosion.
4. Map and prioritize sources of upslope and in-channel erosion. Near-stream riparian planting is encouraged.
5. Active and potential sediment sources related to roads in Tannery Creek should be mapped and treated according to their potential for sediment yield to the stream and its tributaries.
6. Reach 1 would benefit from bio-technical vegetative techniques to re-establish floodplain benches and a defined low flow channel. This would discourage lateral migration of the base flow channel and decrease bank erosion.
7. Conduct gravel sampling. Results may indicate the need for structures that decrease channel incision recruit and sort spawning gravel, and expand redd distribution in the stream.

Table 3.7 Species Observed in Historical and Recent Surveys in Tannery Creek

Years	Species	Source	Native/Introduced
2001	Steelhead Trout *(Oncorhynchus mykiss)*	CDFG	Native
2001	Threespine Stickleback *(Gasterosteus aculeatus williamsoni)*	CDFG	Native

Thurston Creek Stream Inventory Report (DFG, 2003)

Thurston Creek was surveyed on the days 7/18/2003 – 7/21/2003. The Thurston Creek survey began at the confluence with the mainstem of Salmon Creek and extended upstream to the end of anadramous fish passage at 42' bedrock sheet. Given the data collected during the survey and presented in Table 3.1, the following limiting factors were identified and enhancement opportunities were prescribed. No species presence table available for the Thurston Creek Stream Inventory Report.

Limiting Factors:

1. Low number of deep pools
2. Low instream shelter value
3. Gravel/Cobble Embeddedness in Fine Sediment

Fisheries Enhancement Opportunities:

1. There is at least one section where stream is being impacted from livestock in the riparian zone. Livestock in streams generally inhibit the growth of new trees, exacerbate erosion, and reduce summertime survival of juvenile fish by defecating in the water. Alternatives to limit cattle access, control erosion and increase canopy, should be explored with the landowner.
2. Map and prioritize sources of upslope and in-channel erosion. Near stream riparian planting is encouraged.
3. Increase canopy on Thurston Creek by planting with (willow, alder, redwood and Douglas fir) where canopy is not at acceptable levels. Plantings may need to be paired with bank stabilization or upslope erosion control projects.
4. Where feasible, design and engineer pool enhancement structures to increase number or pools in the upper reaches.
5. Where feasible, increase woody cover in pool and flatwater habitat along the entire stream.
6. There are several log debris accumulations currently on Thurston Creek that have the potential for causing bank erosion. They should be monitored for fish passage and erosion.
7. Active and potential sediment sources related to roads in Thurston Creek should be mapped and treated according to their potential for sediment yield to the stream and its tributaries.
8. Reaches 1 would benefit from bio-technical vegetative techniques to re-establish floodplain benches and a defined low flow channel. This would discourage lateral migration of the base flow channel and decrease bank erosion.
9. Conduct gravel sampling. Results may indicate the need for structures that decrease channel incision recruit and sort spawning gravel, and expand redd distribution in the stream.

Chapter 4: Water Quality Monitoring

The California Department of Fish and Game (DFG) funding established a volunteer monitor program to collect water quality data for Salmon Creek and its tributaries. Volunteer water quality monitoring fills a void in data for the watershed and provides an opportunity for community involvement in watershed issues. The program sought to collect baseline data that could be used to determine how water quality issues might contribute to the decline of the salmonid populations in the watershed. Salmonid health and habitat restoration were at the heart of the watershed level planning. With the last known coho documented in 1996 by DFG, a concern among residents drove the effort for this project. The baseline monitoring efforts were collected with salmonid standards in mind. Results presented in the water quality monitoring section used coho and steelhead habitat, breeding, and spawning standards to determine suitable water quality.

Water quality tests were limited to temperature, pH, dissolved oxygen, phosphate, nitrates, chlorine, conductivity, salinity, and turbidity. These parameters were selected to give baseline information related to salmonid health and the best data for the effort and experience levels of the volunteers. Volunteer efforts continue today, long after the grant funds were exhausted. The program has expanded to collect additional data for the watershed.

Water quality can be highly variable in natural environments. The idea of "good" and "bad" water quality can be contentious and difficult to pinpoint without spending some time monitoring the creek and understanding the many contributing factors in a watershed. Temperatures, soil and plant conditions, our input of chemicals and wastes, animal distribution, and naturally occurring concentrations of "pollutants" are the complex variables that must be understood to gain an understanding of the monitoring results. Often misunderstood, chemical monitoring of the creek does not identify what is wrong in the creek and where it is coming from. It only provides a snapshot view of a continuously flowing cycle of water. Where the water has traveled, or what reactions may have occurred while it moved through the system are hard to identify, especially without point-source pollution.

Fortunately, there is a natural balance to the watershed and the creek can carry some of the waste and beneficially use it to improve conditions for the inhabitants of the watershed. Species living in a watershed are adapted to live within a particular range of parameters, from water quality to weather conditions and geology. Understanding Salmon Creek's baseline conditions will allow us to better identify the changes and monitor the effects of our actions in the watershed.

Methods
Where possible, the program aimed for compliance with the State Water Resources Control Board's (SWRCB) Surface Water Ambient Monitoring Program (SWAMP) protocol. Without access to a lab or the funds to continue monitoring if a lab were required, we chose to use tests that would produce results in the field. The tests and equipment were purchased with this goal in mind. Another issue for a volunteer monitoring effort was to keep maintenance and lab costs to a minimum. Equipment and reagents for tests were purchased with grant funds and the reagents were cheap enough to be replenished with minimal fundraising efforts. The Hach Company was selected as the supplier for most of the equipment because of their reputation for easy-to-use, high quality equipment. The funding itself restricted purchases to a $500 limit for a single piece of equipment. This limitation resulted in the purchase of Hach color wheel tests for the nutrients as opposed to a portable colorimeter, increasing the subjectivity and margin of error for those tests. Testing procedure, cleaning, and calibration methods were standardized in order to produce as little variance as possible. Volunteers were provided with laminated instructions for each test to limit user error.

Equipment

The North Coast Water Regional Water Quality Control Board (RWQCB) generously loaned the volunteer program a portable YSI 600XL multi-parameter sonde and YSI 650 data collector. The YSI 600 probe and 650XL data collector were configured to collect temperature, pH, conductivity, salinity, and dissolved oxygen. SWAMP training for calibration, cleaning, and use of the equipment were provided to Prunuske Chatham, Inc. (PCI) staff by Peter Otis of the RWQCB. Calibration and cleaning records are attached as Appendix B. The YSI remained with volunteers for several months until the RWQCB staff began low flow monitoring. After this change, a PCI-owned YSI 55 was used instead. The YSI 55 measured all the same parameters as the YSI 600 except for pH, which was measured with the Hach PocketPal™ pH tester instead. The YSI 55 also required user calibration for altitude adjustments to measure dissolved oxygen. This calibration procedure was followed by each volunteer prior to each use.

Turbidity was measured using a Hach 2100P portable turbidimeter. Suspended sediment samples were not considered due to the high costs associated with lab fees and a lack of volunteer monitor involvement. The turbidimeter is designed to produce immediate results for turbidity in the field. Turbidity only measures how cloudy the water appears using a beam of light projected through the sample in a glass vial. The glassware is cleaned by volunteers prior to each reading to limit fouling from fingerprints or dirt. Each vial is marked with an arrow to align the vial with the meter and labeled to ensure repeated use of the same vial. The glassware and the turbidimeter were cleaned and checked weekly by PCI staff. The turbidimeter was calibrated using a Hach's StablCal Formazin standard every 3 months and with a monthly check against Hach's Gelex calibration product. The monthly measurement checked for drift greater than 5%.

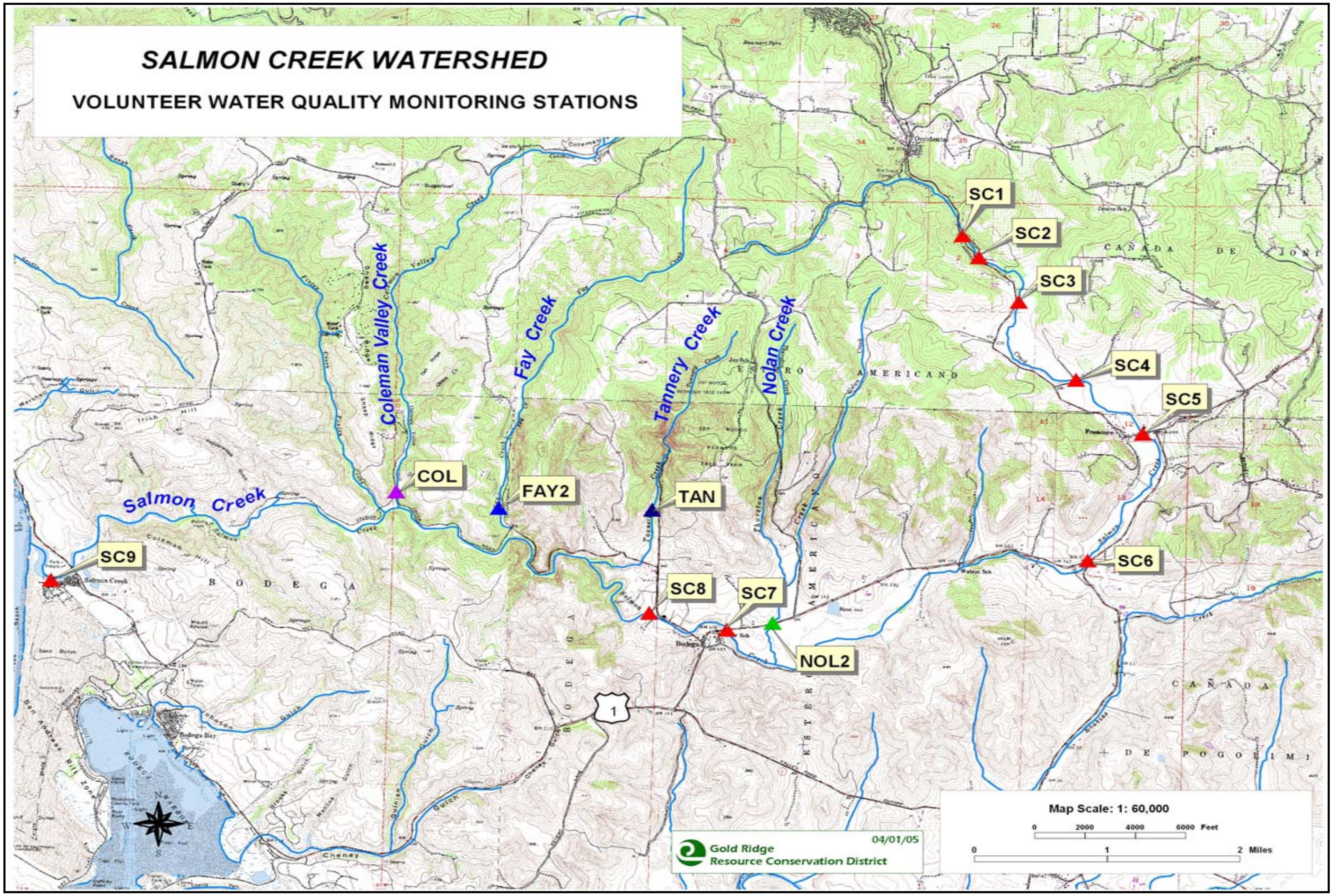
The nutrient tests were measured using the Hach color wheel tests. The nutrients tested by volunteers included tests for phosphates (0-1 mg/L) and nitrates (0-30 mg/L). These tests utilize a gradient color wheel and require the volunteer to match the color of their treated sample with the color on the wheel. The tests have a built-in compensation for any background color in the water sample, but leave a bit of wiggle room for interpreting the results. The volunteers were usually monitoring their sites in pairs, so the protocol required the volunteers to each come to their results separately and confidentially before disclosing the results to each other. If the results were different, the volunteers could then re-check their results and come to an agreement about the result. Since the end of the DFG grant, the Salmon Creek Watershed Council has received additional funds to purchase a portable colorimeter to replace the color wheels. In addition to the nutrients, total chlorine was measured using the color wheel.

Hach PocketPal™ testers were used to measure pH and conductivity. These small handheld sticks are dipped into the water to get a measurement. The testers were calibrated weekly to ensure that they remained reliable. These meters were purchased prior to borrowing the YSI. The results from the meters seemed comparable to the YSI.

Temperature monitoring included measuring air and water temperatures at the time of the data collection. Volunteers were equipped with a thermometer in addition to the internal thermometer on the YSI probe.

Volunteer Recruitment
The volunteer monitoring program was advertised though the Salmon Creek Watershed Council (SCWC) and at public meetings held by the GRRCD. Watershed e-mail groups were forwarded information and several local papers announced the Salmon Creek projects. The first volunteer training was held in the old Pastorale building after several months of requests for volunteers. The group was introduced to the program, its goals, the equipment, and the concepts behind water quality monitoring. Volunteers met each other, partnered, and selected locations to perform their monthly monitoring. The commitment by volunteers involved monitoring their site once a month at a regular time to limit fluctuations in their data. After the initial training, volunteers were met onsite by PCI staff to be trained to select the exact location of each monitoring site, use of equipment, and to troubleshoot any problems while testing. Most groups had two visits with PCI staff, though others required additional instruction.

To address issues of privacy, public bridges were used for access to a majority of the test sites. Several volunteers requested to test on their own property and these requests were granted. Limited efforts were made to locate additional sites along mainstem Salmon Creek in the reach between Freestone and Bodega, and between Bodega and the Estuary. These efforts were unsuccessful. The program had approximately 20 different volunteers monitoring 9 sites along mainstem Salmon Creek and 5 tributaries (Fay, Tannery, Thurston, Nolan, and Coleman). The volunteer and site numbers fluctuated slightly throughout the course of the program. When possible, we recruited new volunteers to continue monitoring critical sites along the watershed.



SALMON CREEK WATERSHED
VOLUNTEER WATER QUALITY MONITORING STATIONS
Coleman Valley Creek
Fay Creek
Tannery Creek
Nolan Creek
Salmon Creek
SC1
SC2
SC3
SC4
SC5
SC6
SC7
SC8
SC9
COL
FAY2
TAN
NOL2
Gold Ridge
Resource Conservation District
04/01/05
Map Scale: 1: 60,000
0 2000 4000 6000 Feet
0 1 2 Miles

Monitoring Results

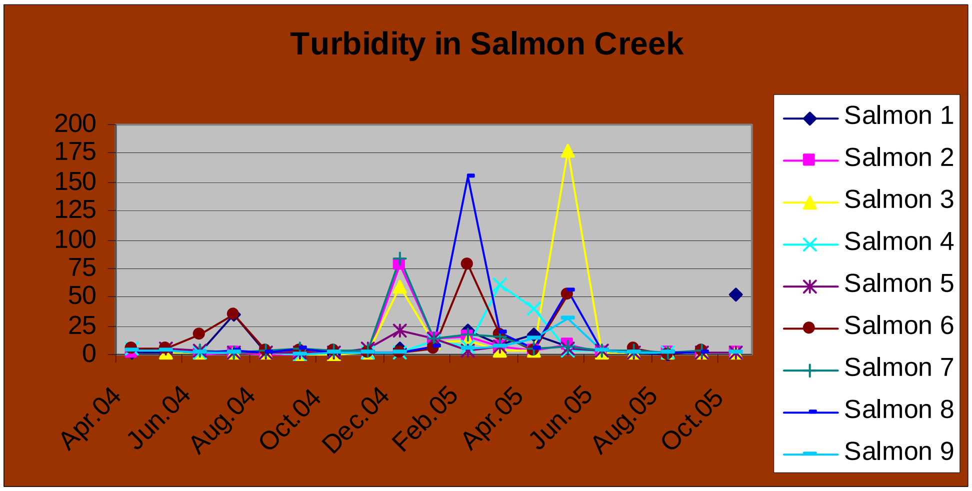
The results have been sorted by reach for comparability and better analysis of the data. The upper watershed includes the Occidental sites from just downstream of town to Salmon Creek School. Freestone includes Freestone Flat Road and the Freestone Bridge. The Freestone Valley Ford Cutoff Road was kept alone due to its isolated location. The Bodega sites included the Bodega Bridge and another site just downstream on Salmon Creek Road. The Estuary was also kept separate. The tributaries were clustered together for comparison.

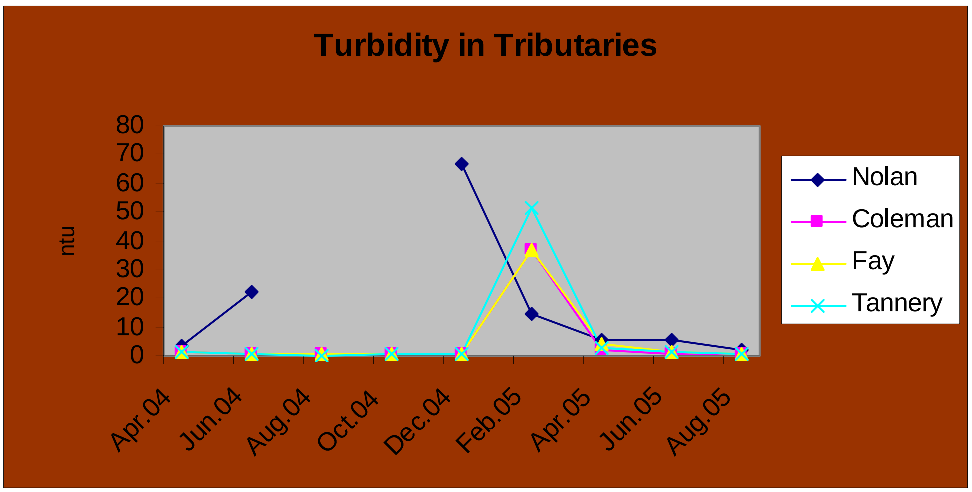
The data, by and large, showed that water quality in Salmon Creek is good. This, of course, is not to say that it couldn't be improved. Conditions in Salmon Creek were surprisingly better than expected. Overall, conditions were favorable for salmonids, though improvements could be made. Suitable habitat is critical for the salmonid population in the watershed. Like humans, fish need areas for food, shelter and need suitable means to transport themselves from one location to another. The entire stretch of creek may not provide prime habitat, but areas must allow fish passage and survival nearby. During storm flows, fish need refuge in slower moving waters and in the summer months, they need deep pools with cool, clean water. They need nurseries in the clean gravels at the creek bottom and woody debris to hide from predators. Competition is often fierce, and the more habitat, the greater the numbers of fish making their way to the ocean. Throughout the year, fish need access to food, often found in the faster moving riffles.

Turbidity

Water quality data indicates turbidity may be the single biggest water quality issue in the watershed. Turbidity is a measurement of clarity in the water sample. It does not distinguish size or type of particle in the water, the turbidimeter simply measures how much light passes through the sample. Of course for salmonids, some turbidity at the right time can be beneficial. Adult fish return to the same streams where they were born after storm events to take advantage of higher flows. In our creeks, these are also periods of higher turbidity associated with storm events. The adults gather downstream and wait for the right opportunity of flow and turbidity to move upstream. Females locate an area suitable for the eggs. The location needs to have cool, clean waters and provide enough flow for the eggs to hatch. Once the fertilized eggs are hidden among rocks in the streambed, fine sediment can settle out of the water and block the flow of oxygenated water to the eggs. At this stage the fine sediments are deadly since the eggs can not move to a better location. When the young fish emerge form the rocks, low levels of turbidity can be beneficial for feeding and hiding. At this stage the fish are large enough to move up and downstream, allowing them to escape turbid waters for a calm area, if it is available. Deep pools serve this purpose well and creeks with faster moving riffles and deep, slow pools provide the necessary habitat for fish populations. Sediment in Salmon Creek has been one of the primary concerns for salmonid health. Turbidity data was gathered by the volunteers show results consistent with winter storm flows and summer algal blooms.

Graph 4.1 and 4.2 Turbidity Results for Salmon Creek and Tributaries 2004 -2005





The results from the volunteer monitoring effort reflects only monthly data. Storm related peaks and periods of turbidity are not captured in the results. In the monitoring by volunteers, storm events were often missed altogether or recorded long after the peak turbidity event. Volunteers committed to testing at the same time of day each month, resulting in extraordinarily lucky rain-free days for most. In an attempt to gain additional information about the watershed, PCI staff collected storm-related turbidity readings during the rainy season in 2004-5. The image below shows the relationship of turbidity on salmonids health over time. The column on the left shows the turbidity levels in nephelometric turbidity units (NTUs), the numbers across the bottom shows time in hours, days, weeks, and months. The green area is suitable for salmonids, the yellow begins to impact health, the orange is detrimental, and the red is fatal. Based on this research, PCI staff collected additional turbidity information at 10 sites on the mainstem and 4 tributary locations. This data would be collected in one trip, beginning at Occidental and ending at the estuary. The results analyzed turbidity data from both sources alongside rain and stage data. Turbidity levels should be studied further, especially during storm events. The data from the few storm-related turbidity runs show turbidity levels remaining above the detrimental level for salmonids for an extended period of time.

Impact Assessment Model for Clear Water Fishes
Exposed to Conditions of Reduced Water Clarity

Visual clarity of water (yBD) and related variables: alternate		preferred		Duration of exposure to conditions of reduced VISUAL CLARITY ($\log_e$ hours)											Fish reactive distance: calibrated for trout		
				0	1	2	3	4	5	6	7	8	9	10			
NTU ($\Delta ntu_{\Sigma,\Lambda}$)	zSD (m)	BA (m^{-1})	yBD (m)	Severity-of-ill-effect Scores (SEV) -- Potential. SEV = - 4.49 + 0.92($\log_e$ h) - 2.59($\log_e$ yBD)											ψ_{BD} (cm)	xRD (cm)	
1100	0.01	500	0.010	7	8	9	10	11	12	13	14				1		O
			0.014	7	7	8	9	10	11	12	13	14			1		N
400	0.03	225	0.02	P6π	7	7	8	9	10	11	12	13	14		2		M
			0.03	4	5	6	7	8	9	10	11	12	13	14	3		L
150	0.07	100	0.05	3	P4π	P5π	6	7	8	9	10	11	12	13	5		K
			0.07	2	3	4	5	6	7	8	9	10	11	11	7		J
55	0.15	45	0.11	P1π	2	3	4	5	6	7	8	9	10	10	11	6	I
			0.16	0	1	2	3	4	5	6	7	8	9	9	16	17	H
20	0.34	20	0.24	0	P0π	P1π	2	3	4	5	6	7	8	8	24	30	G
			0.36	0	0	0	1	2	3	4	5	6	6	7	36	42	F
7	0.77	9	0.55	0	P0π	0	0	1	2	3	4	4	5	6	55	55	E
			0.77	0	P0π	P0π	0	0	1	2	3	4	4	5	77	66	D
3	1.53	4	1.09	0	P0π	0	0	0	0	1	2	3	4	5	109	77	C
			1.69	0	0	0	0	0	0	0	1	2	2	3	169	90	B
1	3.68	2	2.63	P0π	P0π	P0π	0	0	0	0	0	0	1	2	263	104	A
				1	3	7	1	2	6	2	7	4	11	30			
				Hours			Days			Weeks		Months					
				a	b	c	d	e	f	g	h	i	j	k			

The data collected shows periods of extended turbidity after each rain event. The image below combines rainfall totals and turbidity measurements by the volunteers and PCI staff with the severity of impacts to salmonids shown in the dashed yellow (low impact) and orange (detrimental) lines. The turbidity measurements collected by PCI are clearly above the detrimental level on several occasions.

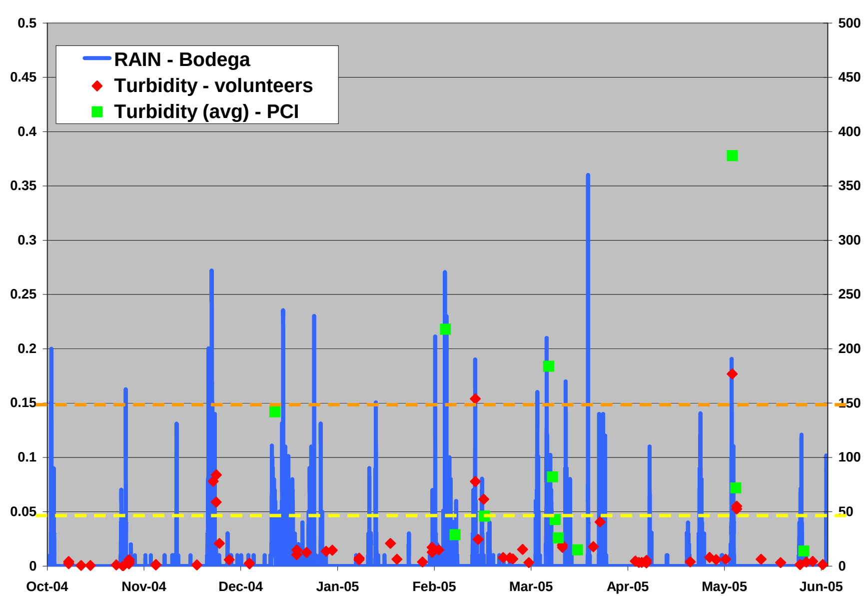


Table 4.3 Turbidity Data vs. Rainfall- 2004 - 2006

Individual storm event data details the trend for turbidity in the watershed. Turbidity levels remain high, above the detrimental levels even several hours after the heaviest rainfall. (See Appendix A for additional images.)

Dissolved Oxygen and Temperature

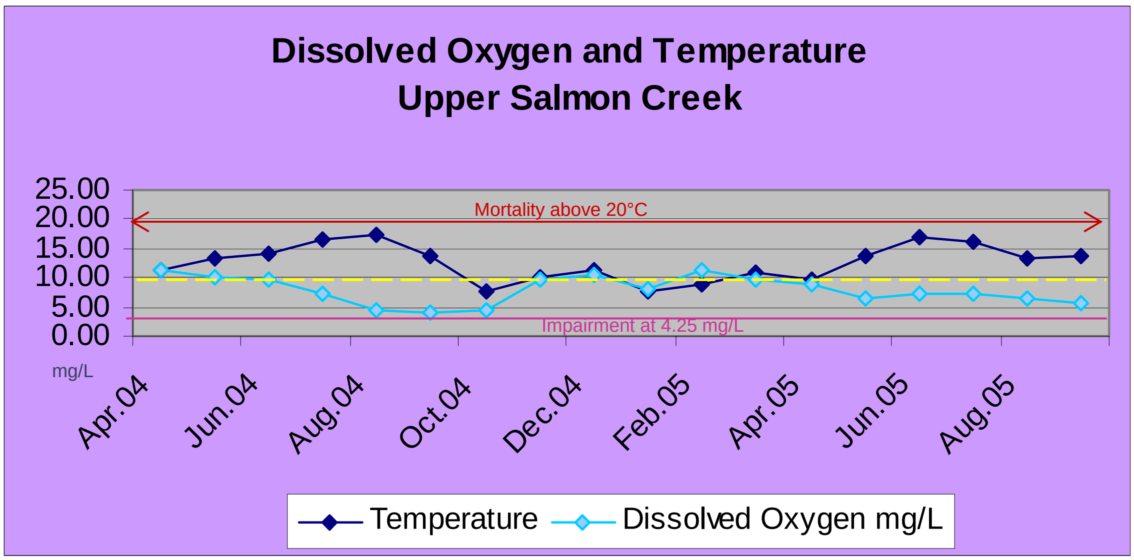
The dissolved oxygen and temperature data were compared side-by-side. Dissolved oxygen refers to the oxygen in the water that is made available for fish and aquatic insects. Dissolved oxygen enters the waterway from plant roots, agitation (including waterfalls and faster moving, tumbled water) and is critical for a healthy fish population. Water temperature must stay relatively constant within a limited range to support fish. Our native salmonid species are more sensitive than many of the non-native fish (like bass and pike). Temperature has a direct relationship with dissolved oxygen in the water supply. The higher the water temperature becomes, the lower the dissolved oxygen levels become.

If fish have suitable habitat conditions accessible nearby, they can move to cooler waters. During the warmer months the data often shows a spike in dissolved oxygen with levels above 100%. Supersaturation of oxygen is present in the waters due to the rapid growth of algae. Often these waters are typically nutrient-rich, slow moving or stagnant and are warmer than acceptable for salmonids. The supersaturated waters quickly change as the algae dies off. The decomposition of the organic plant matter requires the use of oxygen resulting in critically low levels of oxygen. Many reaches along Salmon Creek become quite shallow or stagnant during the summer months as water levels drop. Again, the critical issue is the availability of suitable habitat. Fish need suitable habitat year-round and for all age groups of fish living in the creek. The data shows good conditions in the winter breeding months and scattered areas of good habitat during the summer months. Graphs 4.3 – 4.10 below show dissolved oxygen and temperature for all the reaches of mainstem and the tributaries.

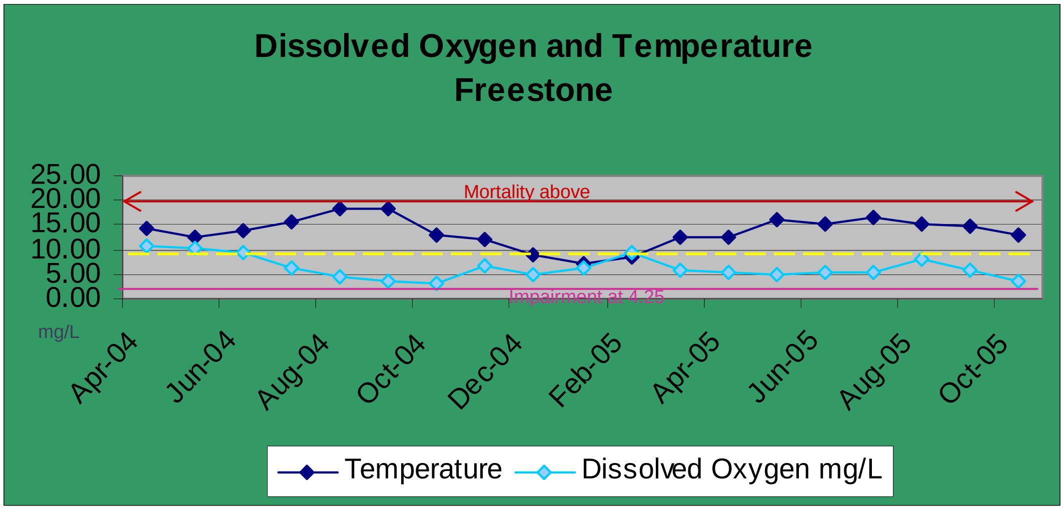
Salmonids and Temperature[4]

Wet Months						Dry Months					
N	D	J	F	M	A	M	J	J	A	S	O
	Spawning Spawning water temperature between 3.9-9.4°C (8); incubation temperature between 0-24°C (10); embryo mortality at 15°C DO 7.2 mg/L										
Juveniles spend 1-4 years in stream (average 2 years)											
Temperature should not go above 20°C (10°C optimum) for salmonids											
Dissolved Oxygen no lower than 5 mg/L. Normal function at 7.75 mg/L, distress at 6.0 mg/L, impairment at 4.25 mg/L.											

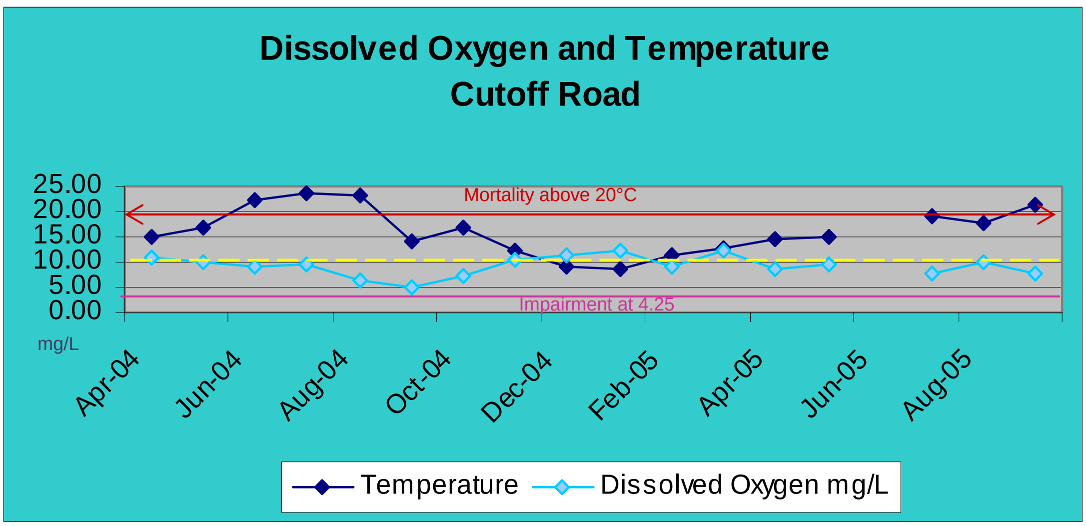
Table 4.4 Temperature Requirements for Salmonids (Barnhart 1986)



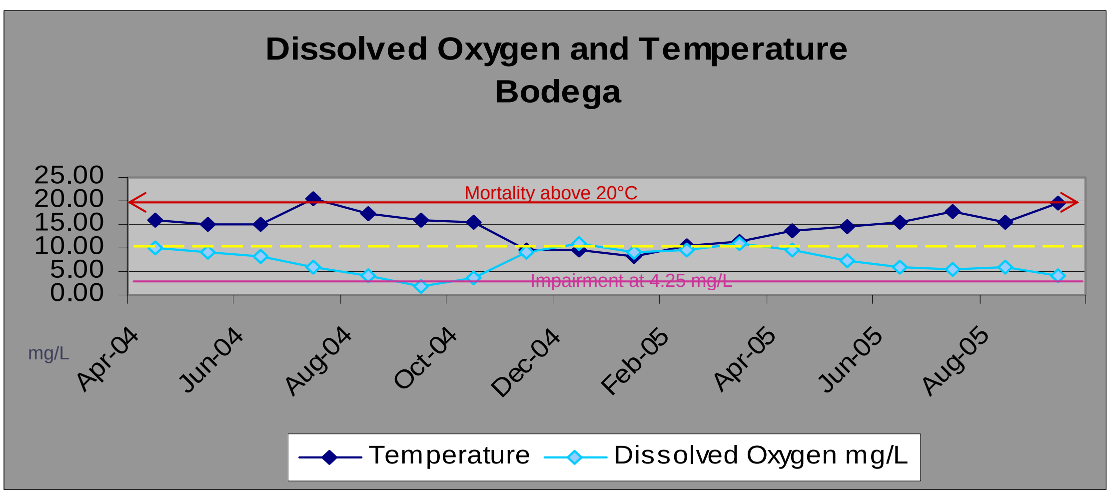
Graph 4.3 Dissolved Oxygen and Temperature in Salmon Creek 2004-2005



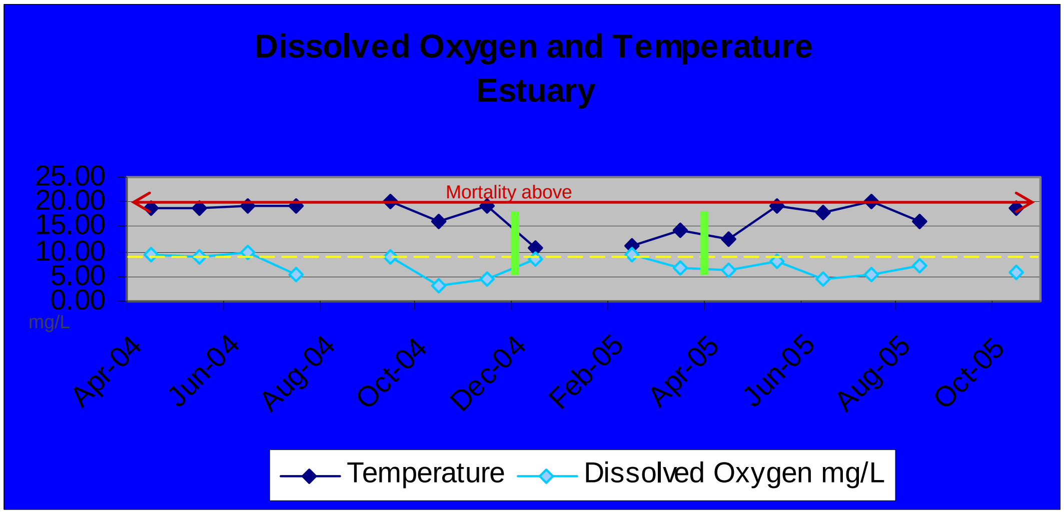
Graph 4.4 Dissolved Oxygen and Temperature at the Freestone Site 2004-2005



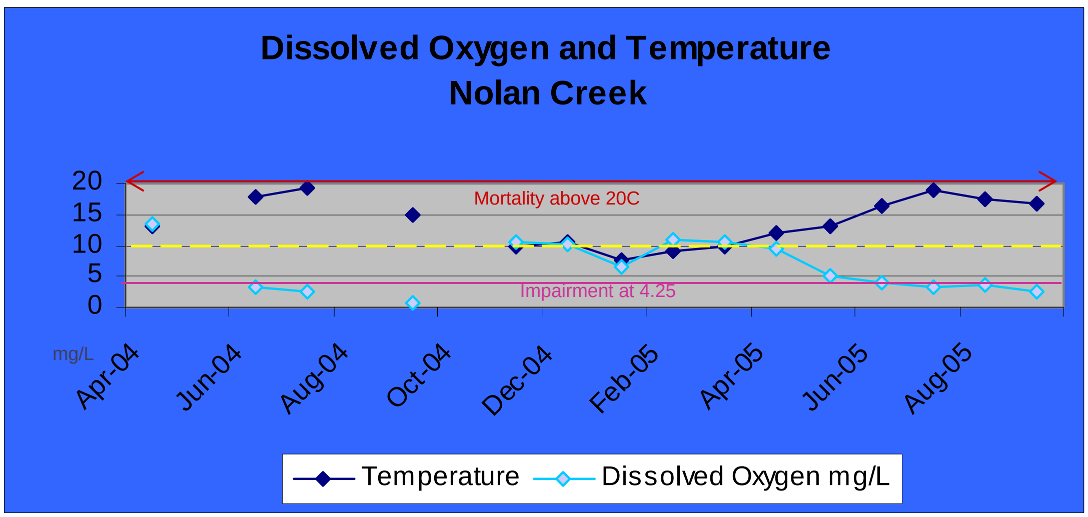
Graph 4.5 Dissolved Oxygen and Temperature at the Cutoff Road Site 2004-2005



Graph 4.6 Dissolved Oxygen and Temperature at the Bodega Bay Site 2004-2005

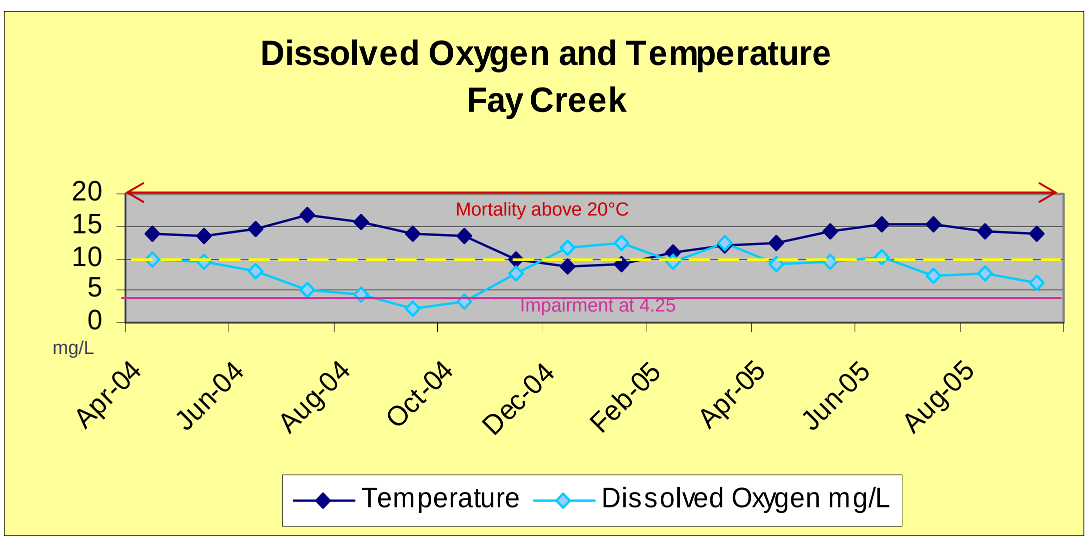


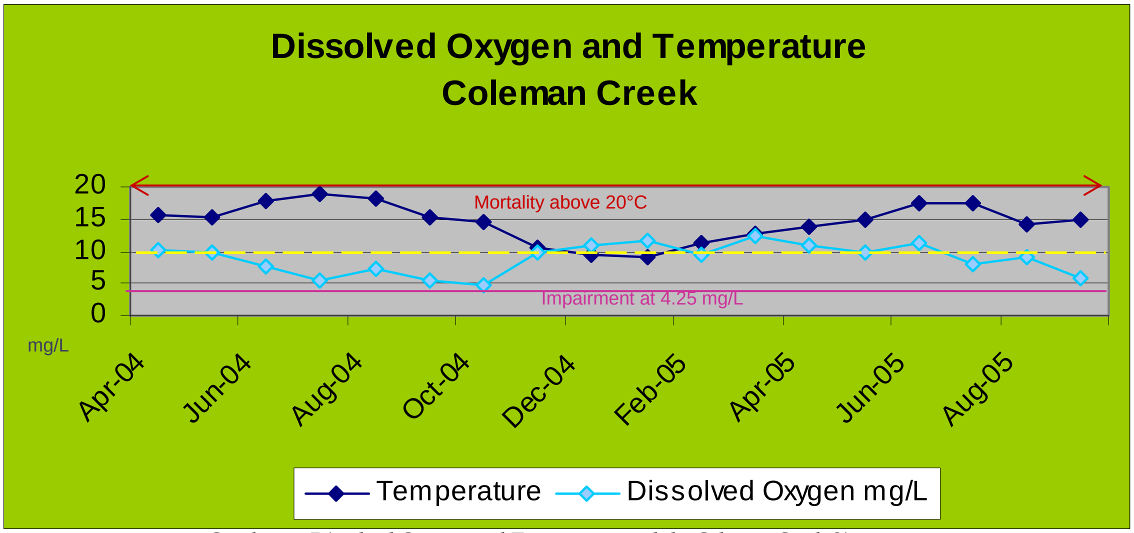
Graph 4.7 Dissolved Oxygen and Temperature at the Estuary Site



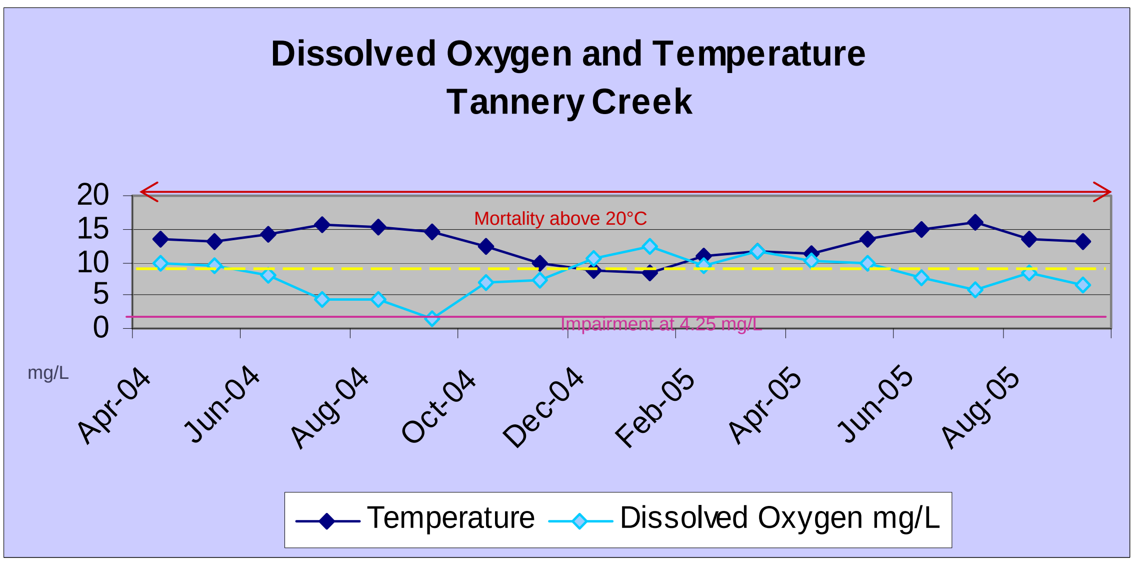
Graph 4.8 Dissolved Oxygen and Temperature at the Nolan Creek Site

Graph 4.9 Dissolved Oxygen and Temperature and the Fay Creek Site





Graph 4.10 Dissolved Oxygen and Temperature and the Coleman Creek Site



Graph 4.10 Dissolved Oxygen and Temperature and the Tannery Creek Site

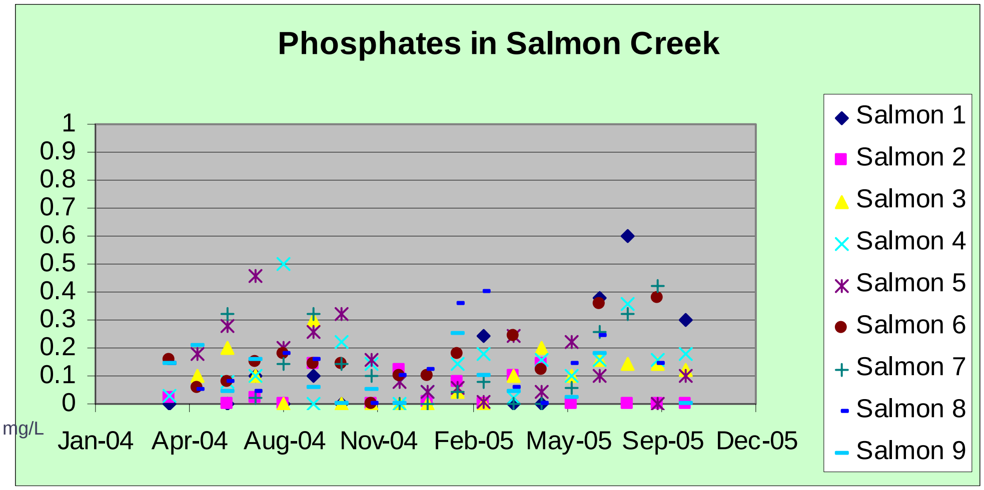
Mortality occurs above 20°C. Distress begins at 6.0 mg/L, impairment occurs at 4.25 mg/L. The ideal temperature for salmonids is 10°C with dissolved oxygen at 7.75 mg/L.

Nutrients: Phosphates and Nitrates

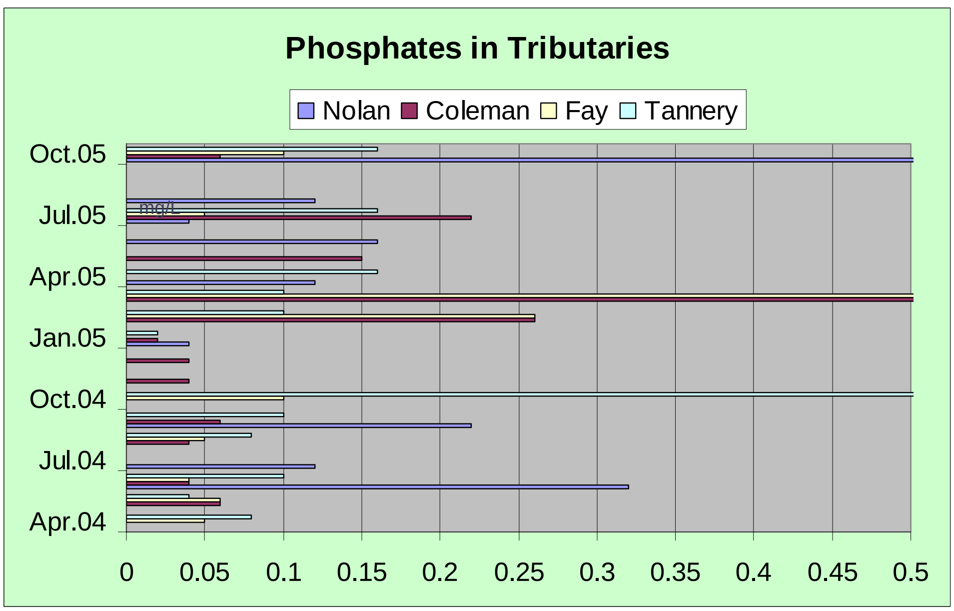
Phosphates and nitrates were monitored at all sites to detect levels of pollution in the watershed. The tests were designed to test for the lowest possible quantities detectable by our equipment. Tests showed very few incidents of spikes above critical levels. Each parameter is discussed in further detail below.

Phosphates and nitrates are part of the natural composition of a stream. They are common to all animal and human waste and important to the growth of plants (fertilizers). Since animals, fish, and birds live in and around the creeks, some level of phosphates and nitrates are perfectly natural. They enable plant growth and provide food for fish and insects. Problems arise when the phosphates and nitrates are found in excess quantities. Pollution from leaking septic tanks, livestock, the application of too much fertilizer, or other human activities can create an imbalance in the creek. Algal blooms use the excess nutrients, but in the decomposition process, they take dissolved oxygen from the water as they die off.

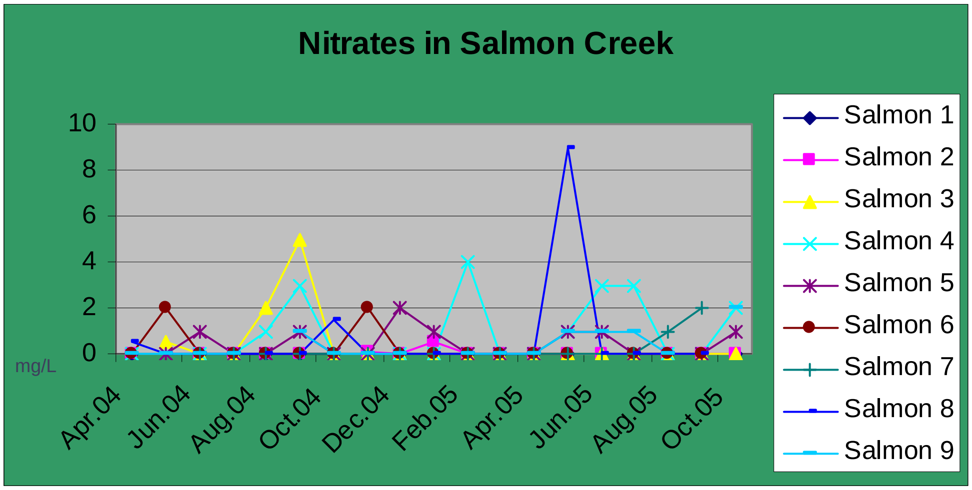
In aquariums, phosphate levels above 1 mg/L are considered problematic for fish. Our results show phosphates generally well below 1 mg/L. More troubling are the two spikes not shown on the graphs. On October 24th, 2004, the phosphate level at the Estuary was 5 mg/L with 0.4 inches of rain the day before. On March 26th, 2005, a phosphate reading of 10 mg/L was noted at the Cutoff Road. Phosphates at such high levels are indicative of pollution and are deadly for fish. It is important to note that the type of water quality monitoring performed by volunteers does not necessarily implicate the location where the sample is collected. In order to locate a source of pollution, or point source, testing would occur at a known source of pollution. The tests would then be repeated up and down stream of that source. In some cases, educated guesses might be made, but without the testing to back up the results, it is difficult to lay blame when testing at only one location.



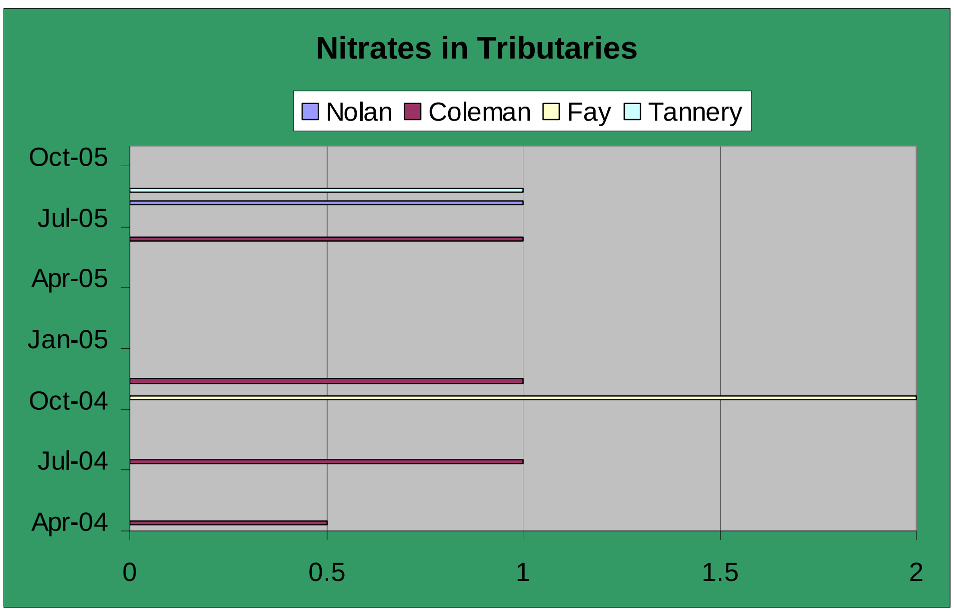
Graph 4.11 Phosphate in Salmon Creek – 2004- 2005 (Measured in mg/L)



Graph 4.12 Phosphates in Tributaries – 2004 – 2005 (Measured in mg/L)



Graph 4.13 Nitrates in Salmon Creek – 2004 - 2005



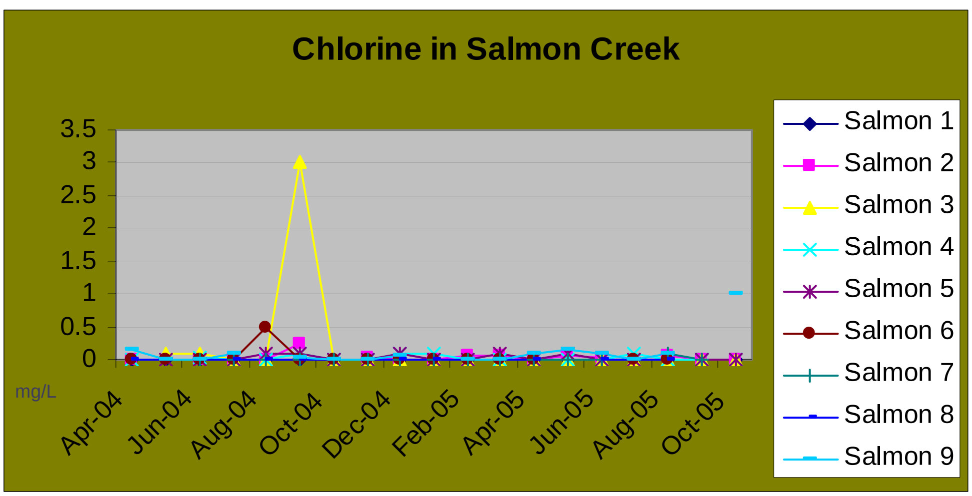
Graph 4.14 Nitrates in Tributaries – 2004 - 2005(Measured in mg/L)

The EPA limit for nitrates in drinking water is 10 mg/L. (Hach website) No data was available for salmonid limits.

Chlorine

Chlorine is a highly toxic gas often used as a disinfectant in household sanitation and in municipal drinking water supplies. Commonly found in most homes as bleach, chlorine is highly reactive and quickly forms bonds with compounds in the water. Once bonded, some of the risks associated with the chlorine are greatly reduced. Risks are further reduced as chlorine dissipates into the air. The "free" or available chlorine poses the greatest threat to aquatic life. Only 0.01 mg/L of free chlorine kills coho. One milligram in a liter of water is a quantity equivalent to a drop of water into a full bathtub (Alaska DEC 2004). This would be one hundredth of that drop.

Salmon Creek volunteers monitored for total chlorine due to the equipment's lack of accuracy. Free chlorine tests could not be performed with confidence given the limitations of the equipment. Mainstem Salmon Creek typically had total chlorine values between 0 and 0.1 mg/L. There were two spikes in the mainstem, one at Salmon Creek School (3 mg/L) and the other at the Estuary (1 mg/L). The tributaries were not tested for chlorine due to the low likelihood of finding measurable levels of chlorine in the waterways. The overall chlorine results appear to show a healthy system with very little total chlorine in the creek. The spikes (3mg/L at Salmon Creek School and 0.5 mg/L at Freestone Bridge) might be understood as errors in the testing methods or as positive hits for chlorine as it passed through the system.



Graph 4.15 – Chlorine in Salmon Creek 2004-2005

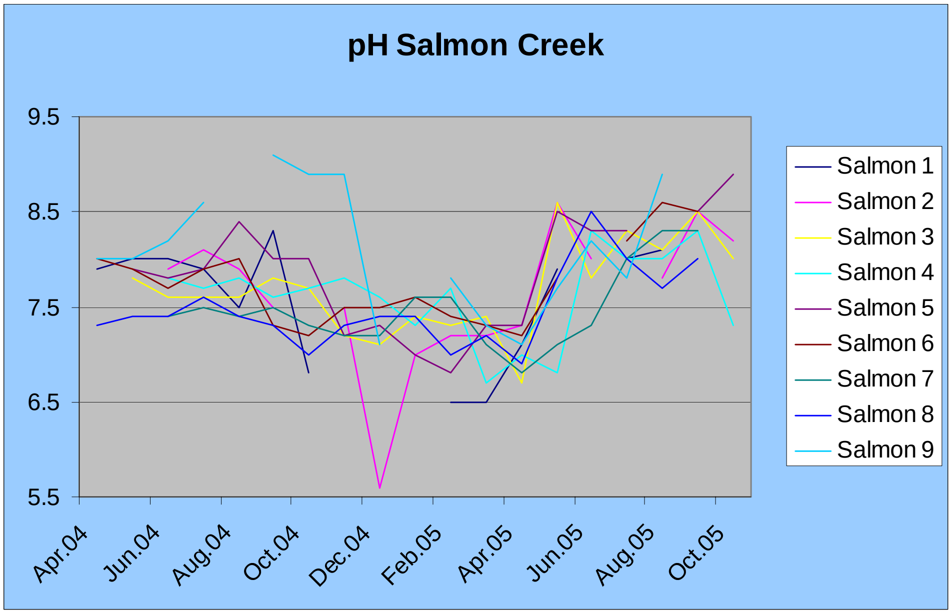
pH

pH is a measure of acidity or alkalinity of water. The pH is a range from 0 to 14 with highly acidic waters at 0 and highly alkaline waters at 14. Pure water is neutral and in the middle of the range at 7. Acids are commonly known and it is easy to understand why they may be dangerous for creeks. Soda, battery acid, citric acid, coffee, and urine are all common acids. Alkaline (or basic) liquids include seawater, ammonia, baking soda, soaps, and bleaches. It is easy to understand why neutral water is desirable, but it isn't always naturally occurring in a creek.

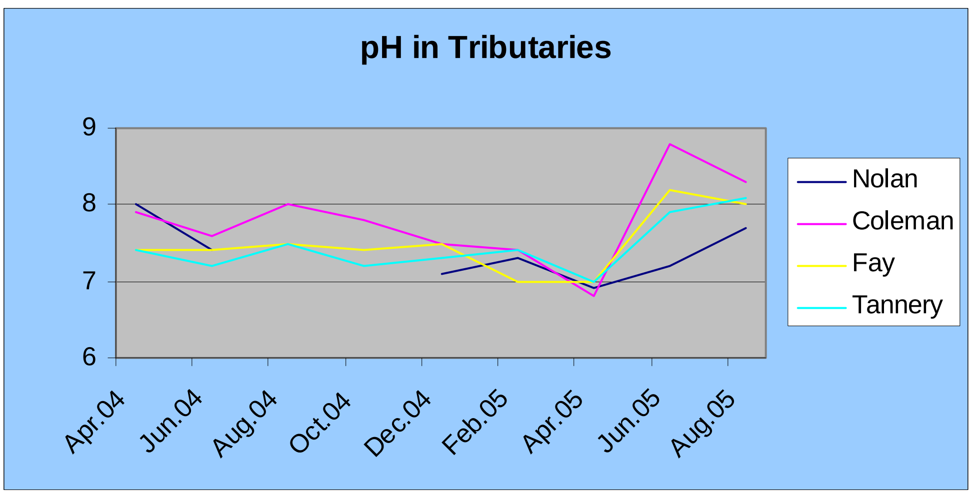
Many natural factors contribute to pH. Our redwoods and pine trees are acidic, though our maples are alkaline. Soils can be either, depending on the composition of rocks and minerals. Our local soils are a little acidic. Oddly enough, our watershed appears to have slightly alkaline waters. As water levels drop, the waters become increasingly alkaline in Salmon Creek and its tributaries. The reasons are unknown, though without rainfall to contribute to runoff, it seems that perhaps this could be a natural phenomenon. Further testing, especially groundwater testing may help identify the issues with pH. Table 4.3 below indicates that alkaline conditions in the range found for our watershed are within the tolerable range for trout.

Table 4.3 pH Effects (SWRCB 1963)

Minimum	Maximum	Effects observed
3.8	10.0	Fish eggs could be hatched but deformed young were often produced.
4.1	9.5	Range tolerated by trout
4.5	9.0	Trout eggs and larvae develop normally
5.0		Limit for stickleback
	8.7	Upper limit for good fishing waters
5.4	11.4	Fish avoided waters beyond these limits
6.0	7.2	Optimum range for fish eggs



Graph 4.16 pH in Salmon Creek 2004-2005



Graph 4.17 pH in Tributaries 2004-2005

Conclusion

Water quality monitoring requires long-term data collection to better understand the trends and responses of the watershed to the many demands placed on our water supply. It can be used to better understand what is happening in the water itself, but it has its limitations. Water quality monitoring is a snapshot view of a continuous flow of water. What occurs in the days or minutes before a sample is collected can be missed in a chemical analysis. Baseline monitoring is essential to the understanding of how our water is impacted by population growth, agriculture, climate changes, and restoration efforts. Salmonids depend on very clean, cool water for their survival and water quality monitoring will determine whether this is a limiting factor for the fish. The monitoring program is a low-cost, highly interactive effort to collect data to better understand watershed health. Volunteers contribute usable data and better understand the conditions of their watershed. With the equipment and protocols in place, every effort should be made to support the program and use the data to study the watershed conditions.

A volunteer monitor coordinator should be identified for the monitoring efforts. Even with committed volunteers, the overall scheduling, data management and maintenance of the equipment requires several hours of effort each month. Ideally, funding would be written into other grants and fundraising efforts to ensure calibration standards, reagents, and other supplies could be ordered when needed.

Storm-related turbidity monitoring shows turbidity events as the creeks quickly rise and fall during our flashy flood events. The data is unlike anything collected on a monthly basis by water quality monitors. A team of volunteers should be trained and ready to monitor storm events for turbidity. It would be ideal to have at least 2 turbidimeters available for this effort. Other water quality data is less important during these events, especially since the high flows dilute the pollutants.

Restoration efforts should consider habitat for salmonids of all age classes. Habitat should be available especially during the dry summer months in areas with suitable cover and a food source.

Further testing should be done to try and locate the source of the high pH levels for Salmon Creek. Groundwater testing of wells may provide some additional insight.

Macroinvertebrate monitoring will provide additional information about water quality. DFG has a SWAMP approved protocol for bioassessment that would provide water quality data for longer periods of time based on the insects living in the creeks.

Chapter 5: Sediment Source Inventory

High rates of sediment delivery to Salmon Creek and its tributaries have been targeted as a priority issue by local residents and regulatory agencies concerned with improving salmonid habitat and riparian corridor health. Low pool frequencies and depths coupled with relatively high embeddedness values throughout the stream system indicate that fine sediment is impacting crucial salmonid spawning and rearing habitat.

Erosion processes and relative sediment source activity is affected by land use practices, climate patterns, and changes in channel conditions. Most erosion processes occur naturally. Weathered bedrock is slowly transported downslope, accumulating on hillsides and in hollows. Upslope material is carried to the drainage system through slow, episodic hillslope erosion processes. Channels themselves are dynamic, constantly adjusting systems that go through cycles of erosion and deposition. Land use practices can amplify erosion processes, causing increased rates of erosion and sediment yields. Sediment sources in the watershed include sheetwash, gully development and expansion, channel incision through headcut migration, bank erosion, landslides, rotational slumps, subsurface tunneling, animal burrowing, trampling, and rainsplash.

Hillslope sources contribute sediment primarily to colluvial storage. Sheetwash and landsliding may contribute directly to channel sediment, depending on land use and proximity of the source to the channel. Disconnected gullies and tunneling (collapse pits) in upland swales temporarily store their sediment in colluvial hollows until they become incorporated into the 1st order tributary gully system through headcutting and bank erosion.

Production of in-channel sediment in Salmon Creek is from four primary sources. The first is enlargement of the drainage network through downcutting and bank erosion in the 1st order tributaries and new gully development. The second source is 2nd and 3rd order channel bank erosion and bed mobilization. Landslides in the steep, forested tributary headwaters are the third significant source. The fourth source, contributing primarily fine sand and silt to the system, is upland sheetwash. Exposed surfaces from grazing pressure, livestock trails, agricultural activities, residential disturbance, and rural roads deliver fine sediment directly to perennial channels and indirectly across pastureland to gully and drainage networks. This source was not addressed in this study.

An inventory of erosion sites was completed on 26 properties within the Salmon Creek Watershed in the spring of 2004. The properties assessed included large agricultural holdings, small rural-residential acreages, and urban stream-side lots. The focus of the project was to document sediment sources that have the potential to deliver material directly to the stream network and provide a prioritized repair list for future funding and implementation projects.

As this project was the first large-scale assessment in Salmon Creek several factors constrained widespread participation in the erosion inventory program. General community awareness of erosion management and cumulative sediment impacts is limited. Many landowners, especially the large agricultural operations, are hesitant to allow right of entry to their land and to sign long-term access agreements. Concern over regulatory actions and potential findings that might result in onerous land management requirements or fines often limits participation in this type of program. On-going education and observation of positive outcomes for other landowners from this project will, over time, reduce the apprehension and provide additional opportunities for erosion surveys and sediment management activities throughout the watershed.

Assessment Methods

Landowners were contacted to participate in the erosion assessment through public meetings, private mailings, and informational flyers placed around the watershed. Fifty five landowners signed access agreements for the erosion inventory. Limited project funds, site visit scheduling problems, and a focus on large properties or those located adjacent to perennial streams narrowed that list down to twenty six properties.

A standardized erosion inventory form was developed and used to record erosion sites. A copy of the site form is in Appendix B.

The inventory form is composed of multiple erosion assessment descriptors, and includes:

- **Site Location.**
- **Topography and Land Use.**

- **Erosion Description**: A brief visual description of the erosion site, including category (i.e. headcut, bank failure, gully, knickpoint, road, or landslide).
- **Erosion Dimensions**: Measurements of length, width, and height of erosion site.
- **Erosion Style (type)**: Notation of whether the erosion is *chronic, episodic,* or *natural*. Chronic erosion is constant and occurs during significant rainfall. Common types are sloughing, sheet erosion, rilling, and headcutting. Episodic erosion occurs occasionally, often in a big pulse. Landslides are a common example. Natural erosion is what would be expected to occur over time in an undisturbed environment, and is not caused or accelerated by human activities. Erosion can be both chronic and episodic, such as a landslide that continues to erode.
- **Erosion Activity**: Highly active sites are characterized by fresh, bare soil, no vegetation, vertical slopes, or fresh, loose sediment deposited at the base of the site.
- **Erosion Potential:** This is a ranking of how much soil could potentially be mobilized from a site in the future. Upslope stability (soil stability, presence of bedrock or dense vegetation, grade control) is the key factor, along with erosion type, in determining whether a site has high, medium, or low erosion potential.
- **Future Potential Sediment Volume**: Calculated cubic yards of sediment likely to enter the stream system over time as erosion continues at the site.
- **Access Rating**: *High*ly accessible sites can be reached with a vehicle by road. *Medium* accessibility can be reached with equipment, although there may not be existing road access. *Low* accessibility cannot be reached by vehicles, equipment and materials must be hand carried or obtained on site.
- **Repair Priority**: Considers erosion potential, activity, percent of impairing sediment, accessibility, and cost. For example, a small headcut that can be quickly repaired at low cost might have a higher priority than a more active site in a remote location.
- **Repair or Enhancement Value**: Ranking of the value of repairing the site for five factors: property enhancement, educational opportunities, community value, instream habitat improvement, and upland habitat improvement.
- **Description of Repair Types and Methods**: A brief discussion and listing of possible repair methods for future project guidance and cost estimation. Repair types include common methods used for grade control, stream bank stabilization, biotechnical solutions, and storm water management. The methods chosen are based on erosion category, severity, stability, and location with respect to infrastructure.
- **Sketch/Calculations**: A quick site sketch showing a planview and/or cross section of the erosion feature. Also includes useful landmarks for later visits.

- **Estimated Repair Cost**: General price range for construction costs based on most likely repair method and permit requirements. This estimate is based on the site characteristics and costs at the time of the inventory. This is to be considered a rough estimate. Physical changes to the site, increases in labor and equipment costs, and updated permit requirements and fees will affect the actual cost to design and construct.

At the start of each property assessment an interview with the landowner was conducted to get a general history of the property, quickly locate known erosion sites, and address questions and concerns. Drainages on each property were then walked to locate and document erosion sites. Each erosion site was photographed and details recorded on an inventory sheet. The information collected was then transferred to an electronic database.

The sites were mapped and ArcGIS was used to statistically analyze several descriptive categories (erosion form/type, potential, activity, and yield) and physical parameters (elevation, slope, land cover, and soil k-factor).

Results Summary

The 26 properties assessed cover less than a quarter of the watershed area. However, they depict a range of lot sizes, land use, land cover, and topographic features. Thus the 139 sites documented are representative of the types and severity of erosion occurring in the watershed (Table 5-1). Copies of the field inventory sheets are located in Appendix B. Figure 5-1 shows the overall distribution of sites and their ranking by repair priority. Sites with high future sediment yields, in combination with high activity rates and erosion potential are typically ranked high priority. A lower ranking on any of two of these three parameters results in a lower priority. Access and beneficial natural process considerations are also taken into account in the ranking.

Table 5-1. *List of sediment source inventory sites, location, type, and descriptors used to analyze erosion in the Salmon Creek watershed. Sediment production for each category are: Low yields = 0-100 yds^3 , Medium yields = 100-1,000 yds^3, and High yields = >1,000 yds^3. Unusual climatic conditions or changes to a site could lead to accelerated erosion processes and increase the estimated yield.*

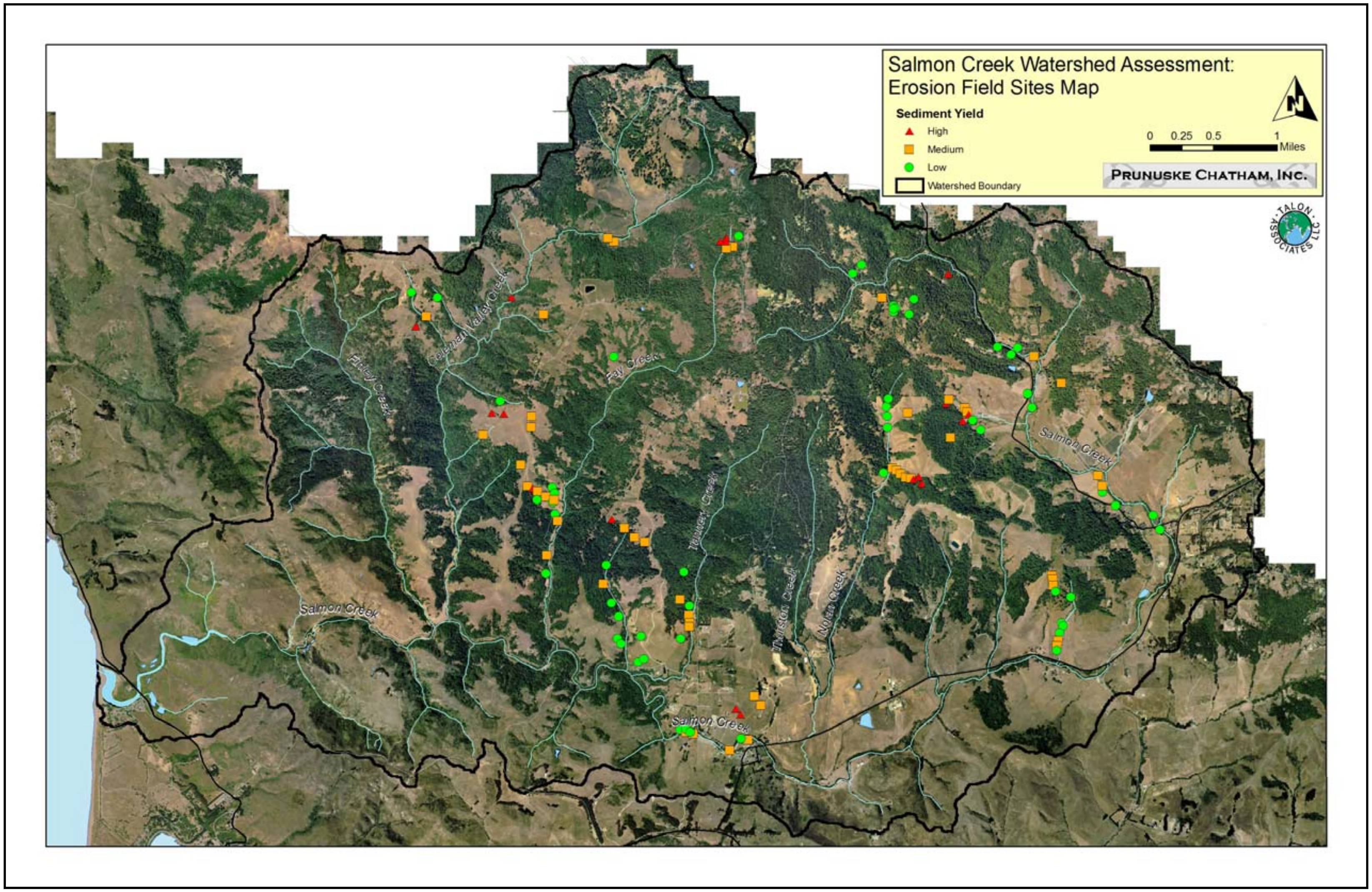
Inventory #	ID	Sub-watershed	Type	Eros Potential	Eros Activity	Potential Sed Yield	Priority (revised)
1	DM-1	Salmon/Marmar	gully/headcut	High	High	High	High
2	DM-2	Salmon/Marmar	gully/headcut	High	Med	High	High
3	DM-3	Salmon/Marmar	headcut	Med	Low	Medium	Med
4	DM-4	Salmon/Marmar	headcut	High	High	Medium	Med
5	DM-5	Salmon/Marmar	gully/headcut	High	High	High	High
6	DM-6	Salmon/Marmar	knickpoint	High	High	Low	Med
7	DM-7	Salmon/Marmar	knickpoint	Med	Med	Medium	High
8	DM-8	Salmon/Marra	headcut	Low-Med	Low	Low	Low
9	DM-9	Salmon/Marmar	headcut	Med	High	Medium	High
10	DM-10	Nolan	knickpoint	High	Med	Medium	High
11	DM-11	Nolan	knickpoint	Low-Med	Med	Low	Low
12	DM-12	Nolan	knickpoint	Med	High	Low	Low
13	DM-13	Nolan	headcut	Med	Med	Low	Low
14	DM-14	Nolan	headcut	Low	Med	Low	Low
15	DM-15	Nolan	knickpoint	High	High-Med	Low	Med
16	DM-16	Nolan	headcut	High	High-Med	Medium	High
17	DM-17	Nolan	knickpoint	High-Med	High-Med	Medium	Med
18	DM-18	Nolan	knickpoint	High	High	Medium	High
19	DM-19	Nolan	headcut	High	Med	Medium	Med
20	DM-20	Nolan	knickpoint	High-Med	Med	Medium	Med
21	DM-21	Nolan	gully/headcut	Med	Med	High	Med
22	DM-22	Nolan	gully/headcut	Med	Med	High	Med
23	DM-23	Nolan	gully/headcut	High	High	High	High
24	DM-24	Nolan	road	Med	Med	Low	Med
25	SCS-1	Salmon -upper	bank failure	High	High	Low	Med
26	PKG-1	Salmon -mid	bank failure	Med	Med	Medium	Med
27	MO -22	Tannery	headcut	Med	Low	Low	Low
28	WK-1	Coleman Valley	headcut	High	Med-High	Medium	High
29	WK-2	Coleman Valley	gully/headcut	High	Med-Low	Medium	Med
30	AH-1	Salmon -upper	gully/headcut	High	High	Low	Med
31	SCS-2	Salmon -mid	headcut	Med	Med	Low	Low
32	SCS-3	Salmon -mid	headcut	Low-Med	Med-Low	Medium	Low
33	MJ-1	Coleman Valley	slide	High	High	High	High
34	MJ-2	Coleman Valley	slide	High	High-Med	Medium	Med
35	AB-1	Salmon -mid	bank failure	High	Med	Low	Med
36	AB-2	Salmon -mid	headcut	Med	Low	Low	Low
37	AB-3	Salmon -mid	bank failure	High-Med	Med	Medium	Med
38	AB-4	Salmon -mid	headcut	High-Med	High-Med	Low	Med
39	AB-5	Salmon -mid	bank failure	High-Med	Med	Low	Med
40	AB-6	Salmon -mid	bank failure	Med	Med	Medium	Med

Inventory #	ID	Sub-watershed	Type	Eros Potential	Eros Activity	Potential Sed Yield	Priority (revised)
41	RP-1	Salmon -mid	bank failure	High	High-Med	Medium	Med
42	JB-1	Salmon -upper	headcut	Med	Med	Low	Med
43	O-1	Salmon -upper	bank failure	Low	Med	Low	Low
44	RH-1	Salmon -upper	bank failure	Med-High	High-Med	Low	Med
45	RH-2	Salmon -upper	headcut	Med-Low	Med-Low	Low	Low
46	JS-1	Salmon -upper	bank failure	Low	Low	Medium	Low
47	DS-1	Salmon -upper	headcut	Med	Low	Low	Low
48	DS-2	Salmon -upper	headcut	Med	Med	Low	Low
49	DS-3	Salmon -upper	headcut	Med	High-Med	Low	Med
50	DS-4	Salmon -upper	headcut	High	Med	Low	Low
51	DS-5	Salmon -upper	headcut	Med	High-Med	Low	Med
52	DS-6	Salmon -upper	headcut	Med	Med	Low	Med
53	DS-7	Salmon -upper	knickpoint	High	High	Medium	Med
54	Mo-1	Tannery	headcut	Low	Low	Low	Low
55	Mo-2	Tannery	gully/headcut	Low	Med-Low	Medium	Low
56	Mo-3	Tannery	headcut	Med-High	Med	Low	Med
57	Mo-4	Tannery/Moon	road	High	Med	Medium	Med
58	Mo-5	Tannery/Moon	headcut	High	Med	Low	Med
59	Mo-6	Tannery/Moon	headcut	Med	Low	Low	Low
60	Mo-7	Tannery/Moon	headcut	Med	Med	Low	Med
61	Mo-8	Tannery/Moon	headcut	Low	Low	Low	Low
62	Mo-9	Tannery/Moon	road	Med	Med	Medium	Med
63	Mo-10	Tannery/Moon	road	High	High	Medium	Med
64	Mo-11	Tannery/Moon	gully/headcut	High	High	High	High
65	Mo-12	Tannery/Moon	road	Med	Med	Low	Low
66	Mo-13	Tannery/Moon	road	High	High	Low	Med
67	Mo-14	Tannery/Moon	road	High	High-Med	Low	Med
68	Mo-15	Tannery/Moon	bank failure	Med	Med	Medium	Med
69	Mo-16	Tannery/Moon	road	Med	Med-Low	Low	Med
70	Mo-17	Fay Cr.	bank failure	High	High	Low	Med
71	Mo-18	Fay Cr.	bank failure	High	High	Medium	Med
72	Mo-19	Tannery	bank failure	High	High	Medium	Med
73	Mo-20	Tannery	bank failure	Med-High	Med	Medium	Med
74	Mo-21	Tannery	headcut	Med	Med	Medium	Med
75	Mo-23	Tannery/Moon	road	Med	Med	Medium	Med
76	RB-1	Fay Cr.	headcut	Med	Med	Low	Low
77	WR-1	Coleman Valley	road	High	Med	Low	Med
78	WR-2	Coleman Valley	gully/headcut	High	High-Med	High	High
79	WR-3	Coleman Valley	gully/headcut	High	Med	High	High
80	WR-4	Coleman Valley	gully/headcut	Med	High-Med	Medium	Med
81	WR-5	Fay Cr.	gully/headcut	High	Med	Medium	High
82	WR-6	Fay Cr.	gully/headcut	High	High	Medium	High
83	WR-7	Coleman Valley	slide	High	High	Medium	High
84	WR-8	Fay Cr.	road	High	High	Medium	Med
85	WR-9	Fay	gully/headcut	High	High	High	High
86	WR-10	Fay	gully/headcut	High	High	Medium	High

Inventory #	ID	Sub-watershed	Type	Eros Potential	Eros Activity	Potential Sed Yield	Priority (revised)
87	WR-11	Fay	headcut	High	Med	Medium	Med
88	WR-12	Fay	road	Med	Med-Low	Low	Med
89	WR-13	Fay	road	Med	Med-Low	Low	Med
90	WR-14	Fay	road	Low	Low	Low	Low
91	WR-15	Fay	bank failure	High	High	Medium	Med
92	WR-16	Fay	road	Med	High-Med	Low	Med
93	WR-17	Fay	road	Med	Med	Low	Low
94	WR-18	Fay	bank failure	High	High	Medium	Med
95	WR-19	Fay	road	High-Med	High-Med	Low	Med
96	GW-1	Salmon -mid	bank failure	High	High	Low	Med
97	GW-2	Salmon -mid	gully/headcut	High	High	High	High
98	GW-3	Salmon -mid	gully/headcut	High	High	High	High
99	GW-4	Salmon -mid	gully/headcut	High	High	Medium	Med
100	GW-5	Salmon -mid	headcut	High	High-Med	Medium	High
101	RA-1	Salmon -upper	slide	High	High	High	High
102	PM-1	Coleman Valley	road	Med-High	High-Med	Low	Med
103	DUS-1	Fay Creek	headcut	Med	Med	Low	Med
104	DUS-2	Fay	headcut	Med-High	High-Med	High	High
105	DUS-3	Fay	gully/headcut	Med-High	Med	High	High
106	DUS-4	Fay	gully/headcut	High	High	High	High
107	DUS-5	Fay	gully/headcut	High	High	Medium	High
108	DUS-6	Fay	gully/headcut	High	High	Medium	High
109	TP-1	Salmon -mid	gully/headcut	Med	Med	Medium	Med
110	TP-2	Salmon -mid	gully/headcut	Med-High	High-Med	Medium	Med
111	TP-3	Salmon -mid	gully/headcut	High	High	Medium	High
112	TP-4	Salmon -mid	gully/headcut	High	High	Low	Med
113	TP-5	Salmon -mid	road	Low	Low	Low	Low
114	TP-6	Salmon -mid	bank failure	Med	Med	Low	Med
115	TP-7	Salmon -mid	knickpoint	Low-Med	Med-Low	Low	Low
116	TP-8	Salmon -mid	bank failure	Med-Low	Low-Med	Low	Low
117	TP-9	Salmon -mid	bank failure	Low-Med	Med-Low	Medium	Med
118	TP-10	Salmon -mid	headcut	Med	Med	Medium	Med
119	TP-11	Salmon -mid	headcut	Med-Low	Med-Low	Low	Low
120	CR -1	Salmon -low	gully/headcut	Med	Med-Low	Low	Low
121	CR-2	Salmon -low	gully/headcut	Med	Med-Low	Low	Med
122	CR-3	Salmon -low	gully/headcut	Med	Med-Low	Medium	Med
123	RHO-1	Salmon -upper	road	Low	Low	Low	Low
124	RHO-2	Salmon -mid	bank failure	Med-Low	Low-Med	Low	Low
125	OS-1	Coleman Valley	gully/headcut	Med	Med	Medium	Med
126	OS-2	Coleman Valley	road	Med-High	Med	Low	Low
127	OS-3	Coleman Valley	gully/headcut	Med-Low	Med-Low	High	Med
128	JM-1	Salmon -upper	bank failure	Med-High	High-Med	Medium	Med
129	JM-2	Salmon -upper	bank failure	High-Med	High-Med	Medium	Low
130	JM-3	Salmon -upper	bank failure	Med	Med	Low	Med
131	DG-1	Salmon -upper	bank failure	Med-Low	Low	Low	Low
132	O-2	Salmon -upper	bank failure	High	Med	Low	Med

Inventory #	ID	Sub-watershed	Type	Eros Potential	Eros Activity	Potential Sed Yield	Priority (revised)
133	JG-1	Salmon -upper	headcut	Med	Med	Low	Med
134	JG-2	Salmon -upper	gully/headcut	High-Med	Med	Low	Med
135	JG-3	Salmon -upper	gully/headcut	High-Med	High-Med	Low	Med
136	JG-4	Salmon -upper	gully/headcut	High	High-Med	Low	Med
137	JG-5	Salmon -upper	gully/headcut	High-Med	High-Med	Medium	High
138	JG-6	Salmon -upper	headcut	Med	Med	Low	Low
139	AH-2	Salmon -upper	bank failure	High	High-Med	Medium	Med

Figure 5-1. *Location of erosion sites documented in the Salmon Creek watershed on 26 assessed properties. The relative sediment yield of each site is represented by the colored dots*



Sediment sources contributing directly to the stream system fall into five types: gullies and headcuts, bank failure, knickpoints, road related erosion, and landslides (Table 5-2). The gully/headcut type is the most common, with 75 of 139 total sites falling into this category. It includes both well established gullies that are growing by both extension and widening, as well as small headcuts that have the potential to enlarge into gullies. Bank failures on the 1st and 2nd order perennial streams are the second most frequently occurring type of sediment source. Erosion caused by improperly constructed and maintained roads is also common and not wholly assessed in this project. It is likely that road related erosion accounts for a large percentage of fine sediment in the streams. Erosion features associated with roads include channel scour at culvert outlets, road slumps from culvert failures, and severely eroding inboard ditches. In-channel knickpoints are small waterfalls of up to 3' in height that move upstream. They indicate channel incision processes are occurring and often initiate additional erosion from bank failures and landslides. Landslides, and slumped hillsides are less common, though may produce large amounts of sediment.

Table 5-2. *Number of sites in each erosion type documented during this project.*

EROSION TYPE					**TOTAL # OF SITES**
Gully/ Headcut	Bank Failure	Knickpoint	Road Erosion	Landslide	
75	28	11	21	4	**139**

The distribution of sediment source types within each sub-watershed varies slightly between watersheds and compared to the overall distribution (Table 5-3). Gullies and headcuts are the most widespread sediment source throughout the watershed. Bank erosion appears to occur more frequently on the mainstem than the tributaries, although this may be a function of the inventory locations. The high percentage of knickpoints in Nolan Creek is due to the fact that the assessment was limited to the headwaters and was focused on several large, rapidly expanding gully complexes with multiple knickpoints moving up them. The percentage of road related erosion is higher in the tributaries because the topography is steeper (more prone to failure), construction methods are often not robust enough, and the roads tend to parallel the channels.

Table 5-3. *Percentage of occurrence of erosion types in the sub-watersheds of Salmon Creek based on the erosion inventories. Inventory spatial coverage was scattered and incomplete, thus these numbers can only be considered representative. These numbers do not reflect the relative yields produced by each sediment source. Gullies, headcuts, and road-related erosion typically have a higher yield potential than bank erosion. Sediment delivery from landslides and slumping is episodic, yet can produce large amounts of sediment.*

Sediment Source	Sub-watersheds						Total Percentage by Source Type
	Salmon Creek (upper)	Salmon Creek (mid/lower)	Nolan Creek	Tannery Creek	Fay Creek	Coleman Valley	
Gully/ Headcut	59	57	47	48	55	50	**54**
Bank Failure	27	37	NA*	14	18	NA*	**20**
Knickpoint	8	3	47				**8**
Road Erosion	3	3	6	38	27	29	**15**
Landslide/ Slump	3					21	**3**

*(*Not Assessed – inventory did not include perennial stream sections.)*

Statistical and spatial analyses of the sediment source data produced inconclusive results. The number of sites (139) is too few for a statistically valid data set. Two slight trends showed up in the data. Grassland erosion sites appear to have a marginally greater mean potential yield than forested sites, and sites at higher elevations in the watershed tend to have higher mean yields. Neither slope nor soil K-factor (erodibility) showed up as a distinguishing factor in location, frequency, or sediment yield. Due to the inconclusive results a predictive spatial analysis model could not be run.

Conclusion

Two important considerations in determining the severity of erosion sites are the potential sediment yield (Figure 5-2) and the erosion activity (Figure 5-3). Potential sediment yields were ranked into three categories (high, medium, and low) based on the volume of sediment they are likely to mobilize and transport to the stream system. Erosion activity was also ranked similarly, and is based on evidence of recent soil loss and feature movement (e.g. headcut moving upstream, bank sloughing).

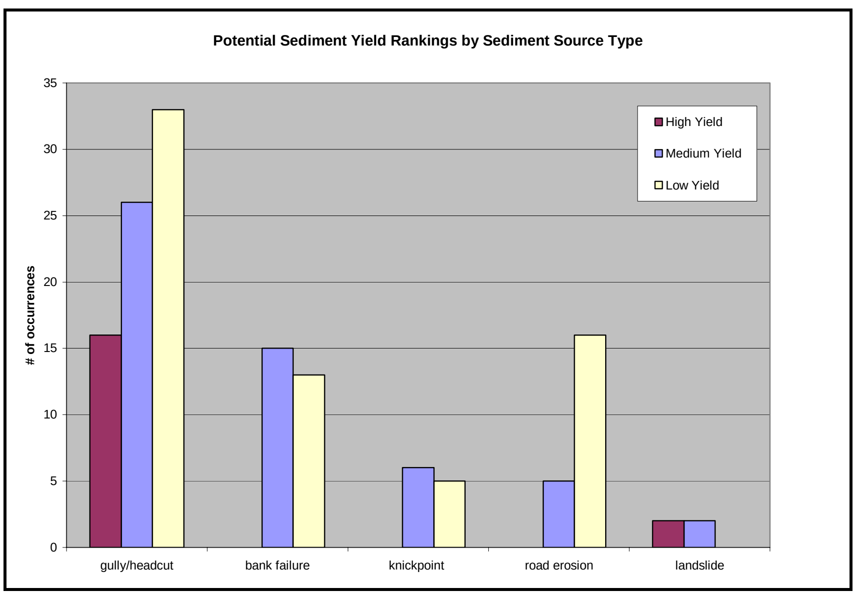


Figure 5-2. *Number of sites inventoried in each category by potential sediment yield. Sediment production for each category are: Low yields = 0-100 yds^3 , Medium yields = 100-1,000 yds^3, and High yields = >1,000 yds^3. Unusual climatic conditions or changes to a site could lead to accelerated erosion processes and increase the estimated yield.*

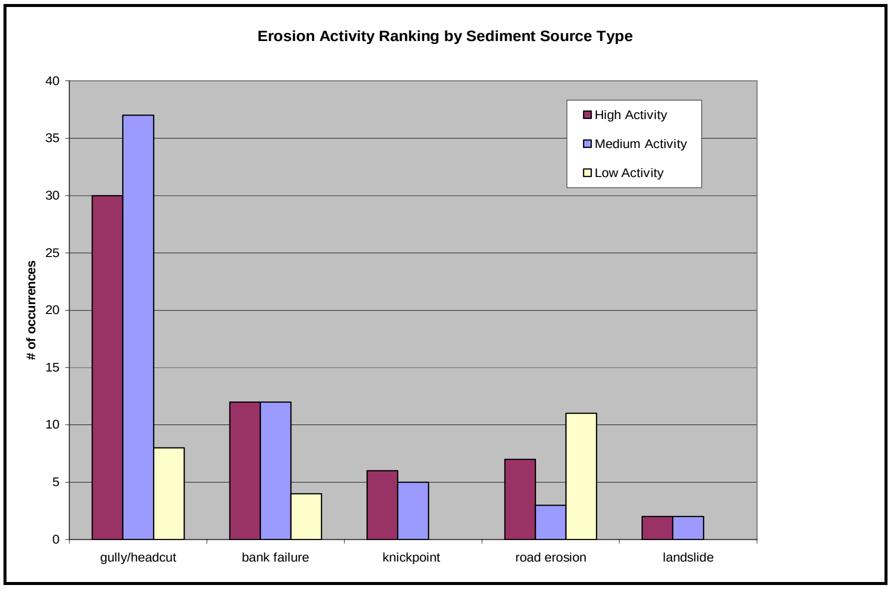
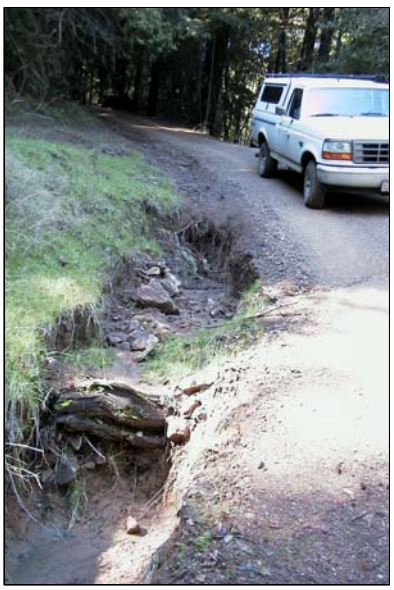


__Figure 5-3__. Number of sediment sources ranked by erosion activity and type. Highly active sites appear to have recently lost material, are devoid of vegetation, and are unstable. At the other end, low activity sites do not show signs of recent movement and are stabilizing through vegetation establishment or changes in erosive forces.

The highest potential sediment yielding sites are gully/headcut systems and landslides. They also tend to exhibit recent activity. These two source types tend to exhibit both episodic and chronic sediment delivery behavior. Of the two types, gullies tend to develop from human land use activities. Landslides, especially in the steep areas underlain by Franciscan Formation are naturally occurring, and, as would be expected, the four landslides documented during the study are in the forested canyons of the upper watershed areas. Another crucial difference between these two high yield sources is that landslides deliver coarse material and large woody debris; two components necessary for a healthy stream system that are often undersupplied. Gullies, on the other hand, produce primarily fine grained material, contributing to degraded instream habitat conditions. Gullies and headcuts mobilize upland soils that, under natural undisturbed conditions, would remain in place and contribute to grassland productivity and nutrient retention.

Many gully/headcut sites have a low potential yield. These sites are primarily small, grassland headcuts that have some activity, but appear to be moving slowly or are

limited in the amount of material available. Larger gullies in forested areas or with well established vegetation are also placed in the low yield category if they appear to be stabilized. Knickpoints, or small steps in the bed, in stream or gully systems do not produce high amounts of sediment; however they may destabilize banks and cause additional headcuts or gully development to occur as they move upstream. They can also destabilize gully repairs if not taken into account during the design phase.



Road erosion was examined superficially in this inventory as it was beyond the scope. A detailed road assessment will be performed in 2007 by Gold Ridge RCD, and the results will augment the data presented in this report. Large road-associated erosion sites, such as culvert failures and eroding in-board ditches, were documented at several locations.

Overall the erosion activity of each source type is ranked higher than the yield or repair priority (Figure 5-4). This is especially true of streambank failures. Eroding banks often

look raw, are highly visible, and introduce sediment directly to the stream, which is why they are commonly targeted as a high priority repair projects for sediment reduction. Bank erosion is a dynamic, natural process necessary for stream health and in-stream habitat development. This is especially true in incised channels such as those found throughout Salmon Creek. Channel widening often occurs after channels have incised due to landuse or climatic changes. Evidence of the widening process is areas of bank sloughing or scalloping. The end result of this erosion is a stable, inset floodplain that provides riparian habitat, high flow refugia, and increased flood water storage.

Bank erosion is a finite, self-managing process. It is also normal, and desirable from a habitat standpoint, for incised streams to go through a period of widening after incision. The volume of sediment derived from a single bank failure site is usually between 50 and 300 cubic yards, as compared to gullies that produce 500-5000 cubic yards. Thus gullies and headcuts were chosen as high priority repairs over the active bank erosion sites (Figure 5-5, Table 5-4).

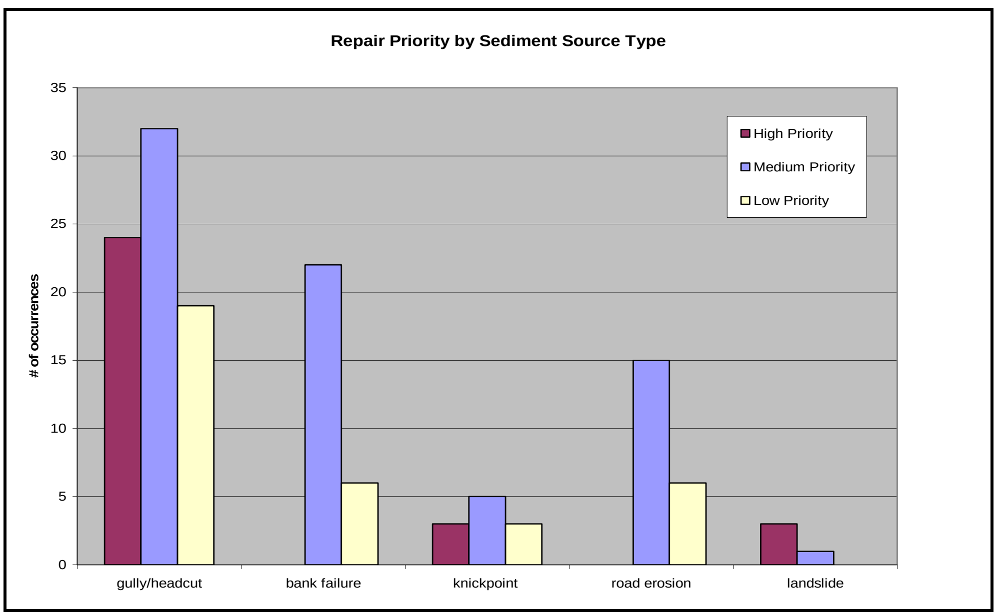


Figure 5-4. *Distribution of repair priorities by sediment source type. Gullies and headcuts are the highest priority because of their higher sediment yields. Gullies also irreparably damage productive grassland and forests. Instream knickpoints that will lead to additional headcuts and gullying were also chosen as high priority sites. Landslides are also high priorities because of the fine sediment they produce though it is unlikely that they can be repaired.*

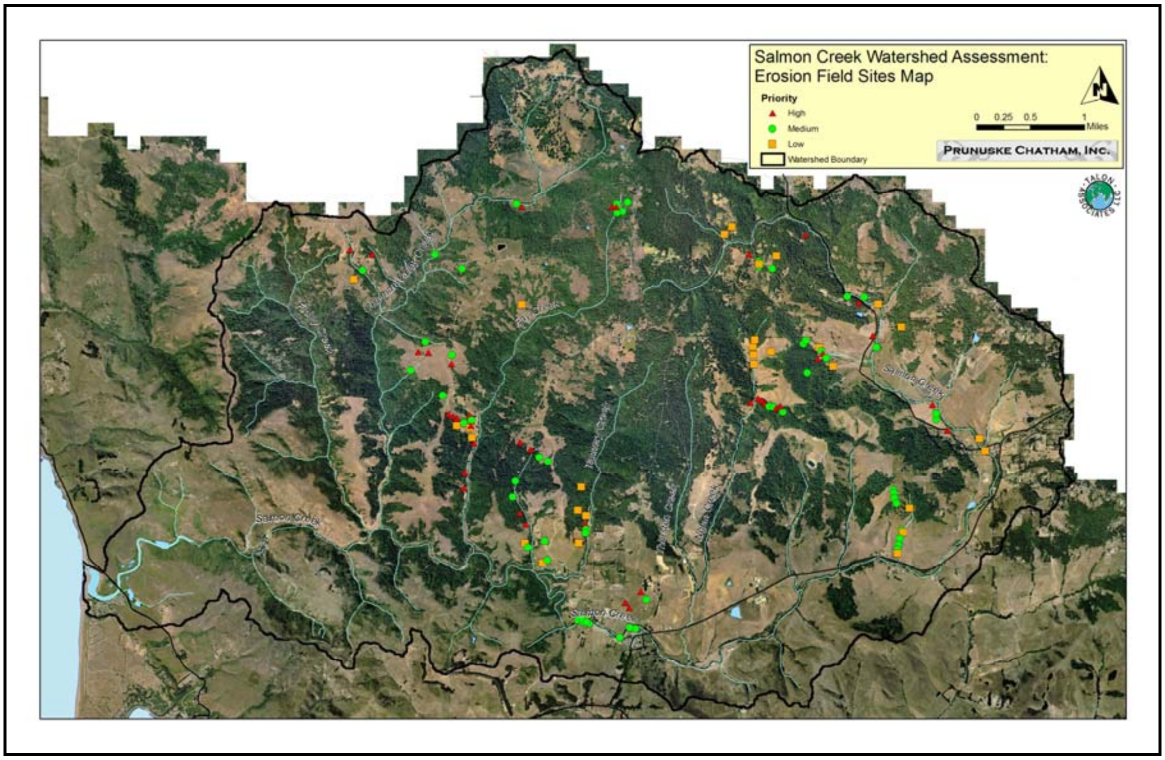


Figure 5-5. *Map of high priority erosion repair sites in the Salmon Creek watershed.*

It is recommended that funding be sought to manage and repair the sediment sources on the list of high priority sites in Table 5-5. These sites, as well as many of the medium priorities (Table 5-1), contribute to the high levels of fine sediment annually entering Salmon Creek and its tributaries. Landslides are extremely difficult to manage, are often naturally occurring, and provide woody debris and coarse sediment to the system. However, if possible, any factors contributing to their activity should be mitigated (i.e. road drainage). Gullies and headcuts make up the majority of the high and medium priority sites. These features are unstable, and during large rainfall events are likely to increase in length and width. Thus, it is important to monitor all gullies and headcuts for sudden changes.

Only 26 properties were assessed in this project due to funding and participation limitations. This accounts for less than 25% of the watershed. It is highly recommended that erosion inventories be performed on an ongoing basis to document additional sites for treatment. It is through a continual process of inventory and repair implementation that the high sediment loads impairing the stream system will be reduced.

Table 5-4. *High priority restoration and repair sites in the Salmon Creek watershed based on the erosion inventory survey of 26 properties. See Appendix C for details on each site.*

Inventory #	ID	Sub-watershed	Type
1	DM-1	Salmon/Marmar	gully/headcut
2	DM-2	Salmon/Marmar	gully/headcut
5	DM-5	Salmon/Marmar	gully/headcut
7	DM-7	Salmon/Marmar	knickpoint
9	DM-9	Salmon/Marmar	headcut
10	DM-10	Nolan	knickpoint
16	DM-16	Nolan	headcut
18	DM-18	Nolan	knickpoint
23	DM-23	Nolan	gully/headcut
28	WK-1	Coleman Valley	headcut
33	MJ-1	Coleman Valley	slide
64	Mo-11	Tannery/Moon	gully/headcut
78	WR-2	Coleman Valley	gully/headcut
79	WR-3	Coleman Valley	gully/headcut
81	WR-5	Fay Cr.	gully/headcut
82	WR-6	Fay Cr.	gully/headcut
83	WR-7	Coleman Valley	slide
85	WR-9	Fay	gully/headcut
86	WR-10	Fay	gully/headcut
97	GW-2	Salmon -mid	gully/headcut
98	GW-3	Salmon -mid	gully/headcut
100	GW-5	Salmon -mid	headcut
101	RA-1	Salmon -upper	slide
104	DUS-2	Fay	headcut
105	DUS-3	Fay	gully/headcut
106	DUS-4	Fay	gully/headcut
107	DUS-5	Fay	gully/headcut
108	DUS-6	Fay	gully/headcut
111	TP-3	Salmon -mid	gully/headcut
137	JG-5	Salmon -upper	gully/headcut

CHAPTER 6: Instream Restoration and Prioritization Recommendations

"There is little question that we are not going to be able to do everything we want to do for salmon immediately. So how do we decide what we should do first? There are millions of federal and state dollars being spent on salmon restoration right now. That expenditure presents both a significant challenge and opportunity. The challenge is to target all these expenditures to the most important efforts first. The opportunity is to actually make a difference for salmon. We can only do that if we pay attention to the biology -- not the politics, not the agency turf, not "the money's got to be spread over the landscape" -- but rather prioritizing our efforts based on the biology of salmon, which very quickly leads us to the biology of healthy watersheds." *Bradbury et al. (1996)*

Those working on the restoration of Salmon Creek certainly are aware that funding sources are not infinite. Consequently, the sequence and prioritization of restoration activities is of tremendous importance, if goals such as coho salmon recovery are to be attained, such a strategy must be science based. The Monitoring section (Chapter 4) of this report suggests how to determine whether progress is being made in improving riparian conditions and habitat.

A full basin instream habitat inventory of Salmon Creek was conducted by DFG in 2004 to discern the location of and quality of low flow refugia, priority habitat enhancement reaches, and factors limiting salmonid abundance. The tributaries vary in their habitat quality, as measured by; water temperature, pool depth and cover, degree of fine sediment intrusion in the spawning gravels, and percent riparian canopy cover for shade and food source (see Chapter 3 for details). An assessment of water quality throughout the watershed (Chapter 4) indicates that overall water quality is supportive for salmonids, however turbidity levels frequently go above detrimental levels during winter storm events. The erosion inventory (Chapter 5) located and prioritized sediment sources with the potential to deliver fine sediment to vulnerable habitat areas. The results of these studies have been integrated in the development of the following recommendations for habitat enhancement projects:

Recommendation 1: Creeks with existing supportive water quality conditions and riparian cover (Fay, Finley, Tannery, and Thurston) should be high priority for habitat enhancement practices such as pool improvements and fine sediment management.

Recommendation 2: Focus on reducing fine sediment delivery to the mainstem and all tributaries, with a priority on projects addressing gully development, headcut migration, and road issues.

Recommendation 3: Implement projects that will improve riparian canopy along Salmon Creek (main stem), Coleman Valley Creek, and Nolan Creek to reduce high water temperatures, increase bank stability, and provide cover.

Recommendation 4: Increase pool frequency and depths throughout system through LWD recruitment and placement.

Recommendation 5: Develop and support projects to monitor and improve summer low flows in the mainstem and tributaries.

It is imperative that additional erosion inventories are performed to identify sediment sources on properties not covered under this project. A long-term water quality monitoring program will document watershed improvements and guide continued habitat enhancement needs.

Chapter 7: Best Management Practice Recommendations

Best management practices (BMPs) are effective, practical, structural, or nonstructural methods which prevent or reduce the movement of sediment, nutrients, pesticides and other pollutants from the land to surface or ground water, or which otherwise protect water quality from potential adverse effects from a variety of land uses. These practices have been developed to achieve a balance of water quality protection and their economic impacts to particular landowner. The overall objective of the below BMPs are to protect and enhance salmonid habitat for many generations to come.

The Federal Water Pollution Control Act of 1972 requires the management of nonpoint sources of water pollution from sources including forest-related and agricultural activities. BMPs have been developed to guide landowners toward voluntary compliance with this act. Maintenance of water quality to provide "fishable" and "swimmable" waters is central to this law's objectives. The Environmental Protection Agency (EPA) recognizes the use of BMPs as an acceptable method of reducing nonpoint source pollution.

The adoption and use of BMPs will provide the mechanism for attaining the following water quality goals:

- To maintain the integrity of stream channels;
- To reduce the volume of surface runoff originating from an area of disturbance and running directly into surface water;
- To minimize the movements of pollutants and sediment to surface or groundwater;
- To stabilize exposed soil areas through natural or artificial revegetation.

The Gold Ridge Resource Conservation District (RCD) promotes voluntary implementation of BMPs. Any information presented below is not to be used as the basis for setting water quality standards or as the basis of required use of protection practices. The management measures listed are by no means the entire array of practices that could be used to control sediment or other pollutants from entering Salmon Creek. However, they are a guide to assist landowners in making that first step toward enhancing their part of the watershed so that the salmonid fisheries of Salmon Creek can be restored to what has been historically documented.

Land Management Measures that May Apply in the Riparian Zone

Objective: The following are management measures that can be implemented in the riparian area to buffer against detrimental changes in the temperature regime of the waterbody, to provide bank stability, and to prevent sediment from entering the stream channel. Riparian areas generally consist of native vegetation communities along the stream channel. The riparian areas not only act as buffers between land activities and sensitive ecosystems, but it also supports high biodiversity and valuable habitat. Streamside forests in Salmon Creek are a crucial source of large woody debris for fish habitat. These measures do not include land management practices specific to agricultural land, which is discussed later in this chapter.

The Riparian Management Zone is generally measured from the active channel, or bankfull stage, whichever is wider. The RMZ that has been established for other local watersheds is as follows:

- Class I and II watercourses, the Riparian Zone is recommended to be a 50-foot strip of land on each side of, and adjacent to, the watercourse.
- Class III watercourses, the Riparian Zone is recommended to be a 25-foot strip of land on each side of, and adjacent to, the watercourse.

Given the high degree of variability in site conditions within the RMZ, it is not possible at this particular planning level to provide either a comprehensive list of BMPs or a single prescription suitable for universal application. However, below is a very general list of management strategies that have been employed to protect this fragile area.

A. Landowners should be encouraged to maintain at least an 80% vegetative buffer in the RMZ of a Class I watercourses. The riparian area should be planted with native plant materials.

B. Brush and debris can kill existing bank stabilizing vegetation, inhibit the growth of vegetation and contribute to bank instability. Debris and other yard clippings should not be dumped on the streambanks.

C. When planning to build, it is important to stay away from the RMZ.

Development near the RMZ can disturb soils and vegetation. Avoid building and farming near the river as it can not only expose your structures or crops to flooding, but cause serious erosion problems.

D. Landowners should allow woody debris to remain on streambanks. Fallen logs, tree stumps and branches provide cover, food and shelter for fish and other aquatic animals, notably young coho salmon and steelhead.

E. Brush, weeds, grass clippings, or other small material should not be thrown into a creek or stored near creek banks to be carried downstream by wind or rain. The brush may create a debris jam downstream on someone else's property or block a culvert, which can cause flooding and erosion or block fish passage.

F. If you have a septic system, you should know where your septic system is located and how to maintain it. It is important to have your tanked checked professionals every other year, pump it every 3-7 years and replace failing systems.

Land Management Measures for Rural Roads

Objective: The following are management measures for the control of non-point source pollution from roads. Through proper planning on the part of the landowner, roads that are used during normal runoff periods should have minimal maintenance and provide for adequate water quality protection from erosion.

Landowners will be encouraged to participate in grant funded assessments of their roads, when available. However, should they choose not to participate or would like to manage their roads on their owns, the RCD recommends that they develop a long-term road system plan (Road Plan) which described the road system, and identifies all roads and watercourse crossing on their property. The road system described in the Road Plan should be designed and constructed to provide surfacing, drainage, and watercourse crossing to match the intended road use and maintenance abilities. Roads that are not needed should be scheduled for abandonment. It is recommended that a Road Plan contain the following information:

- The location of all roads and watercourse crossings within the ownership;
- The current status of each road, including road surface material, road and watercourse design, and use restrictions, and
- The future plan and schedule for each road.

The RCD can assist landowners with the development of Road Plans. These prescriptions should not be misconstrued as regulations, they are in fact Best Management Practices that have been adopted in other watersheds, and proven effective at reducing the amount of sediment coming off of a rural road. The following are the general recommendations for roads:

A. Roads used year round should be designed, constructed, reconstructed or upgraded to permanent road status with the application of an adequate layer of competent rock for surface material and the installation of permanent watercourse crossings and road prism drainage structures. These roads should receive regular and storm period inspection and maintenance.

B. Roads used primarily during the dry season but to a limited extent during wet weather should be designed, constructed, reconstructed or upgraded to seasonal road status with the application of spot rocking where needed to provide a stable running surface during the period of use.

C. Roads that are not used or maintained during wet weather should be constructed or reconstructed to a temporary road status. Spot rocking of the road surface should be used, where needed, to provide a stable running surface during the period of use.

D. All watercourse road crossings should, at a minimum, utilize the standards described on pages 64 - 79 of the *Handbook for Forest and Ranch Roads* (prepared by Weaver and Hagans, 1994). These standards include but are not limited to the design and installation of permanent crossings using a culvert with a minimum diameter designed to pass at least a 100-year flood frequency event.

E. Road design, construction, and reconstruction should use, at a minimum, the standards described on pages 39 - 54 and 81 - 120 of the *Handbook for Forest Ranch Roads* (prepared by Weaver and Hagans, 1994).

F. Straw bale check dams or silt fences should be installed at the outlet of all road drainage structures prior to use of the road for all roads.

G. There should be no construction, reconstruction, or use of skid trails on slopes greater than 40 percent within 200 feet of a watercourse, as measured from the channel or bankfull stage, whichever is wider.

H. There should be no use of roads or near stream facilities, when the activity contributes to the discharge of visibly turbid water from the road or near stream facility surface or is flowing in an inside ditch in amounts that cause a visible increase in the turbidity of a watercourse.

I. All roads within the Riparian Zone should be surfaced with competent rock to a sufficient depth prior to use of the road to prevent road fines from discharging into watercourses.

Land Management Measures that May Apply in Agricultural Areas

Objective: The following management measures are recommended for the control of non-point sources pollution from agricultural sources. Intensive agricultural land use in the watershed has led to accelerated erosion. Soil compaction and reduction of herbaceous vegetation from grazing have increased stormwater runoff and the occurrence of sheet, rill, and gully erosion. Increased flows instream channels, the filling of stream channels with sand and silt, and the denuding of stream corridors by livestock have exacerbated streambank erosion. On-farm and watershed-wide efforts to reduce nutrient loads to surface waterbodies will require a combination of management practices including better livestock management, manure management, vegetation management, and more controls to reduce or prevent commingling of stormwater runoff with animal wastes. The following "points of intervention" in the control of NPS pollution entering surface water drainage networks are recommended (Lewis et al., 2005b).

These practices prescriptions should not be misconstrued as regulations, they are in fact BMPs that have been adopted in other watersheds, and proven effective at reducing sources of pollution from agricultural property.

The following are general strategies for agricultural properties in Salmon Creek:

A. Increase the amount of plant cover, especially plants that promote infiltration.

B. Decrease the extent of compaction by avoiding intensive grazing and the use of machinery when soils are wet.

C. Decrease the formation of physical crusts by maintaining or improving plant cover or litter, thus reducing the impact of raindrops.

D. Increase aggregate soil stability by increasing the amount of organic matter added to soil through residue decomposition and vigorous root growth.

E. Managing the distribution, timing, frequency, and intensity of livestock use of various management units (e.g., pastures, corrals, feedlots) to reduce the quantity and availability of sediment, nutrients, and bacteria potentially discharged to surface waterbodies.

F. Managing the collection, storage, and distribution of manure to prevent contamination of stormwater runoff and potential discharges to surface waterbodies.

G. Managing vegetation to increase ground cover and streambank protection in order to decrease runoff and erosion, and promote infiltration and filtering of pollutants.

H. Installing infrastructure to better control surface runoff, and to either capture or filter out sediment, nutrients, and bacteria.

I. Off--channel water drafting and livestock watering locations should be developed to the extent feasible.

J. Agricultural activities on unstable slopes that have the potential to deliver sediment to a water of the state should be minimized to the extent practical.

K. Farmers and ranchers should be encouraged to use managed grazing to not only protect riparian areas, but also to improve pasture productivity.

L. Employing long-term rest from grazing when riparian areas are highly degraded.

M. Employing short-term or seasonal rest to protect wet streambanks and riparian vegetation that is emerging, regenerating, or setting seed.

There is little doubt that nutrient management plans of some form will be mandated in the near future, including nutrient land application requirements (Meyer and Mullinax, 1999). USDA's Natural Resources Conservation Service has developed a comprehensive nutrient management program (CNMP) to assist dairy producers in managing their facilities to meet water quality standards. It is recommended that a CNMP include the following information:

- Map of facility with a legend.
- Wastewater generated based on an animal inventory, length of confinement, milking schedule, milk barn sanitation, stall barn size and management, corral/feedlot size and management, and rainfall, among other necessary inputs.
- Manure storage availability based on existing measurements and management, as well as use and management of each structure.
- Facility inventory describing building sizes and uses, field sizes and uses, and corral/feedlot sizes and uses (each of these categories will have an annual use description).
- Monitoring: manure, soils and vegetation sampling
- Crop production and nutrient uptake requirements.
- Manure application rates and cost analysis.
- Overview of off-site (i.e., rented) property with all of the above included.

Land Management Measures that May Apply in Forest Lands

Identification and implementation of BMPs for forestlands is outside of the scope and expertise of the GRRCD. Specific BMPs that have been formally adopted by the USDA Forest Service can be found in their handbook *Water Quality Management for Forest Land System Lands in California; Best Management Practices* (USDA, 2000). The BMPs described in the above referenced document were compiled from Forest Service manuals, handbooks, contract and permit provisions, and policy statements. The goal of these BMP's are to directly or indirectly maintain, or improve water quality and abate, or mitigate impacts, while meeting other resource goals and objectives (USDA, 2000).

The GRRCD or its agents, are signatory to this document. Nor do they necessarily endorse the BMPs contained within. The document above is noted as one of many references that landowners may wish to utilize when searching for information on management measures in forested areas.

Land Management Measures that May Apply in Unstable Areas

Objective: The following very basic management measures address land management measures in unstable areas. Since, erosion and sedimentation processes in the Salmon Creek Watershed have been thought to be a significant factor contributing to the historic declines of salmonid in the basin unstable areas are briefly addressed in this report. Extensive unstable areas still exist within the watershed and the combined effect of floods and land use can be expected to cause additional habitat degradation in future floods unless widespread corrective work is undertaken soon. Identifying potentially unstable ground should only be done by a Certified Licensed Geologist (CEG). These professionals generally use a physically based model which can effectively design methods to reduce shallow landsliding hazards. The USDA's Forest Service has developed comprehensive BMP's for unstable areas (USDA, Water Quality Management for Forest System Lands in California). The following is just a small list of measures that can be implemented:

A. No construction should occur across unstable areas without the field review and development of site specific mitigation measures by a Certified Engineering Geologist registered in the State of California.

B. No more than 50 percent of the existing basal area[1] formed by tree species should be removed from unstable areas that have the potential to deliver sediment into a watercourse.

C. No concentrated flow should be directed across the head, toe, or lateral margin of any unstable area.

[1] **BASAL AREA** - (a) The cross-sectional area (in square feet) of a tree trunk at breast height (4.5 feet above the ground). For example, the basal area of a tree that measures 14 inches in diameter at breast height is about 1 square foot. (b) The sum basal areas of the individual trees within 1 acre of forest.

Conclusion

The primary purpose of this document is to both provide an assessment report that will be utilized as a basis for future restoration and monitoring activities in the Salmon Creek watershed and also present landowners and land managers with a plan of action to begin restoring salmonid fisheries in the watershed (Plan). Recent reports have indicated that water quality impairments in Salmon Creek are the result of cumulative, long-term impacts of various land use practices in the watershed, as well as the unanswered question of the very evident decrease in flow and water supply. Reducing nutrient and sediment impacts to these waterbodies to within limits established by state regulatory agencies will require concerted efforts at both the watershed and community scale. The RCD recognizes that to be successful in these efforts, recommended management actions need to be based on sound planning strategies. This Plan, funded from the DFG Fisheries Restoration Grant Program, has allowed the RCD to begin the first phase of planning needed in the Salmon Creek watershed. Through this grant, we have been able to document how sound research, assessment and monitoring information can assist landowners with a strategy for restoration that is straightforward, and will also provide resource agencies with a detailed strategy that is both systematic and well thought out.

The RCD has recently been awarded grant funding from the State Water Resources Control Board to develop a Salmon Creek Integrated Watershed Assessment Plan (Plan phase II). Through development of the second phase of this Plan, the RCD will build upon the recommended actions contained in this report and also develop a further detailed action plan devoted to improving the natural resources of the watershed. This second phase will not only provide an overview of the goals and objectives initialized during this DFG assessment and planning process, but also establish a framework of action that both landowners and resource agencies can build upon to improve the overall health of the watershed within the context of a viable agricultural economy. The RCD, along with its resource agency partners, is committed to providing both the agricultural and rural residential community the technical and funding support they need in order to improve fisheries habitat in our district.

REFERENCES:

Alaska Department of Environmental Conservation, *Contaminant Concentrations*. Series 1, Fact Sheet #7 of the Environmental Cleanup Education Tool Series. March 2004.

Barnhard, R.A., 1986 *Species Profile: Life Histories and Environmental Requirements of Coastal Fisheries and Invertebrates (Pacific Southwest).* U.S. Fish and Wildlife Service Biological Report 82 (11.60) U.S. Army Corps of Engineers, TR EL-82-4.

California Department of Fish and Game, 2004. Stream Inventory Reports for Salmon Creek and Tributaries, Central Coast Region, CA

California Department of Fish and Game. 2001. California's Living Marine Resources, A Status Report. Available online at: http://www.dfg.ca.gov/mrd/status/

California Department of Fish and Game. 2005. California Natural Diversity Database. Sacramento, CA.

California Department of Fish and Game, (Flosi, et al) California Salmonid Stream Restoration Manual, 1998 3rd Edition

Circuit Rider Productions, Inc. 1986. *Preliminary Draft, The Sonoma Coastal Wetlands Restoration Program, Phase 1 Report: Sonoma County Coastal Watershed Erosion Survey, November 20, 1986*.

Circuit Rider Productions, Inc. 1987. *Draft Sonoma County Wetlands Enhancement Plan*. Funded by the State Coastal Conservancy.

Ford, L.D. and L. Huntsinger. 2007. Central Coast Rangeland Coalition, Rangeland Health Indicators, Draft: February 19, 2007.

Hammack, L, Prunuske, L., Choo, C., Roth, J., Fawcett, M., Harrison, K., and Hunter, R. June 2006, *Salmon Creek Estuary Study and Enhancement Recommendations*. Prunuske Chatham, Inc. Funded by the State Coastal Conservancy Available online at http://www.bodeganet.com/SalmonCreek/

Heathwaite, L., A. Sharpley and W. Gburek. 2000. A Conceptual Approach for Integrating Phosphorus and Nitrogen Management at Watershed Scales. *Journal of Environmental Quality* 29: 158-166.

Hickey, P., et al. March 2007, *The Estero Americano Watershed Management Plan*. Gold Ridge Resource Conservation District Funded by the State Water Resources Control Board. Available online at http://www.goldridgercd.org

Lewis, D.J., K.W. Tate and J.M. Harper. 2000. Sediment Delivery Inventory and Monitoring: A Method for Water Quality Management in Rangeland Watersheds. University of California, Division of Agriculture and Natural Resources and California Rangelands Research and Information Center. Publication 8014.

Lewis, D.J., R. Atwill, K.W. Tate and M. Lennox. 2005b. *Water Quality Stewardship Concepts and Checklist for Livestock Producers.* University of California Cooperative Extension and the University of California, Division of Agriculture and Natural Resources.

Miller, Vernon C. 1972. *Soil Survey of Sonoma County, California*. U.S. Department of Agriculture, Soil Conservation Service, in Cooperation with the University of California Agricultural Experiment Station.

National Marine Fisheries Service. January 2000. NMFS California Anadromous Fish Distributions, Current Stream Habitat Distribution Table.

National Research Council. 2000. *Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution.* National Academy Press, Washington, D.C.

North Coast Regional Water Quality Control Board, *Water Quality Control Plan for the North Coast Region,* September 2006. Available online at http://www.waterboards.ca.gov/northcoast/programs/basinplan/083105-bp/06_plans_and_policies.pdf

North Coast Regional Water Quality Control Board, *The Action Plan for the Garcia River Watershed Sediment TMDL,* January 2002. Available online at http://www.waterboards.ca.gov/northcoast/programs/tmdl/garcia/garcia.html

Pacific Watershed Associates, et al. , January 1994 US Bureau of Reclamation and the Trinity River Task Force *The Action Plan for Restoration of the South Fork Trinity River Watershed and Its Fisheries* Available Online at http://www.krisweb.com/biblio/sft_usbor_pwa_1994_sftplan/pwa1.htm#ExecSummary

Ritchie, J.C., V.L. Finney, K.J. Olster, and C.A. Ritchie. 2004. Sediment deposition in the flood plain of Stemple Creek Watershed, northern California. *Geomorphology* 61: 347-360.

State Coastal Commission. 2002. Protecting Coastal Waters: State of California 2002 Critical Coastal Areas Draft Strategic Plan. Available online at: http://www.coastal.ca.gov/nps/cca-nps.html

State Water Resources Control Board. 2003. *2002 California 305(b) Report on Water Quality*. State Water Resources Control Board, Sacramento, CA.

University of California Cooperative Extension. 1998. *Sediment TMDL Site Inventory and Monitoring User Guide.* Davis, California.
U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). 1997. *National Range and Pasture Handbook*. Available online at: http://www.glti.nrcs.usda.gov/technical/publications/nrph.html.

U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). 1998. *Clean Water Action Plan (CWAP) – California Unified Water Assessment (1998).* Available online at http://www.ca.nrcs.usda.gov/features/projects/cwap/

U.S. Department of Agriculture, Forest Service. September 2000. *Water Quality Management for Forest System Lands in California – Best Management Practices.* Pacific Southwest Region

U.S. Department of the Interior, Bureau of Land Management. 1997. *Riparian Area Management: Grazing Management for Riparian-Wetland Areas.* Technical Reference 1737-14. Denver, CO.

U.S. Environmental Protection Agency. 2005. *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*. EPA 841-B-05-005. Available online at http://www.epa.gov/owow/nps/pubs.html.

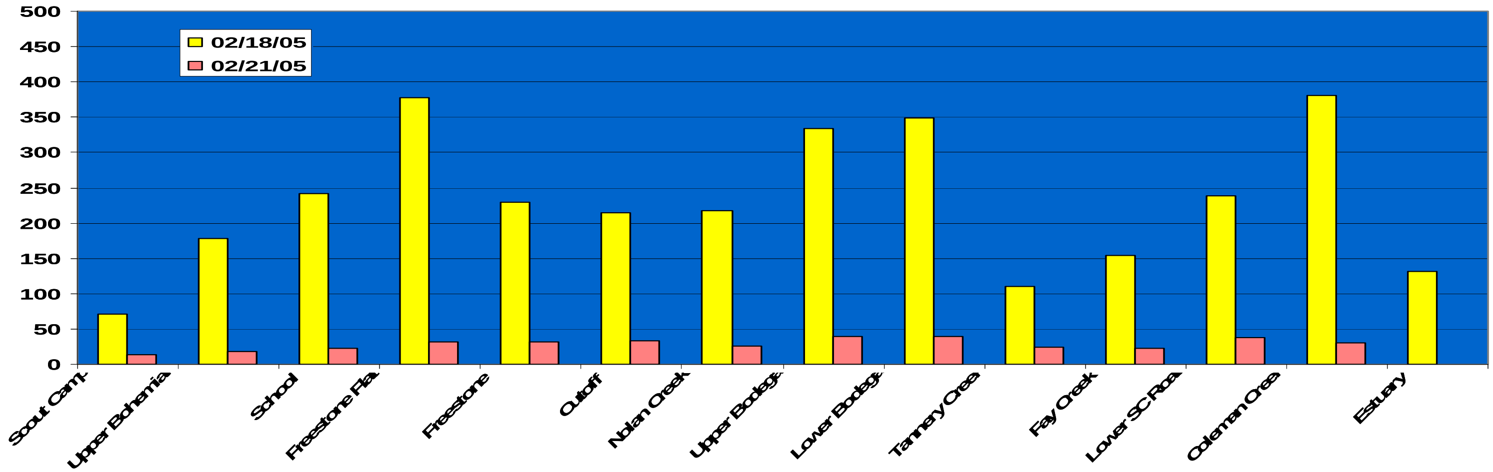
U.S. Environmental Protection Agency, *Forestry Best Management Practices in Watersheds.* Available Online at: http://www.epa.gov/watertrain/pdf/Forestry.pdf

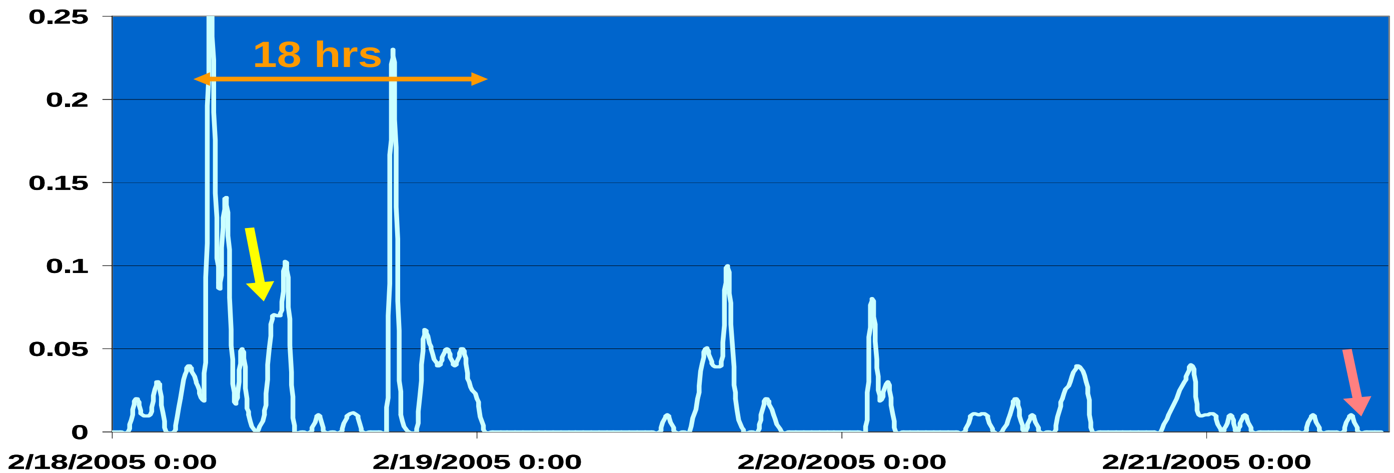
U.S. National Oceanic and Atmospheric Administration (NOAA). 2005. Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California; Final Rule (50 CFR Part 226). Federal Register **70** (170).

Weaver W.E. and D.K. Hagans. 1994. *Handbook for Forest and Ranch Roads: A Guide for planning, designing, constructing, reconstructing, maintaining and closing wildland roads.* Prepared for the Mendocino County Resource Conservation District in cooperation with the California Department of Forestry and Fire Protection and the

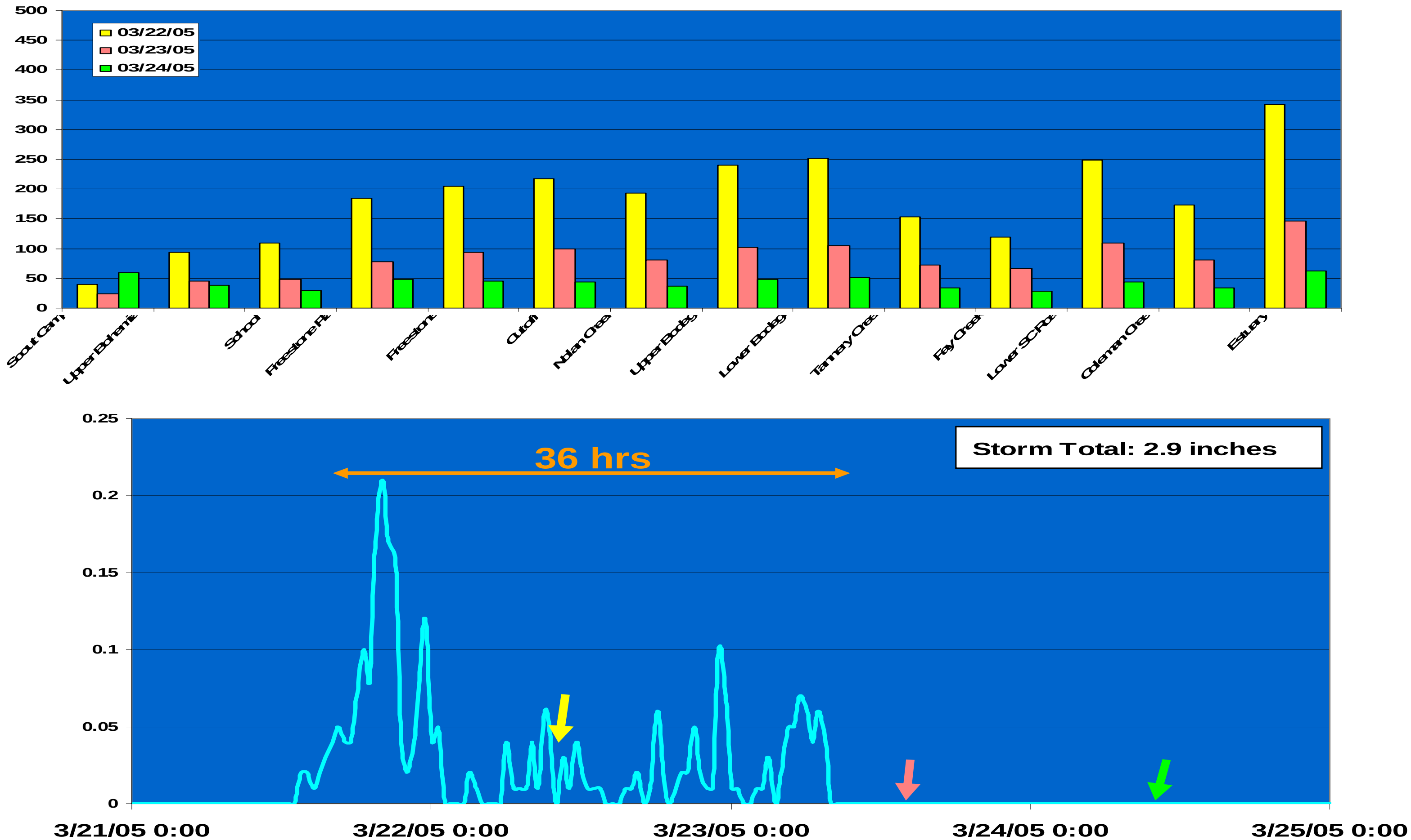
Zeiner, D.C., W.F. Laudenslayer, K.E. Mayer, and M. White. 1990. *California's Wildlife: Volumes I, II, & III.* California Department of Fish and Game. Sacramento, CA.

Appendix A: Turbidity Measurement Figures

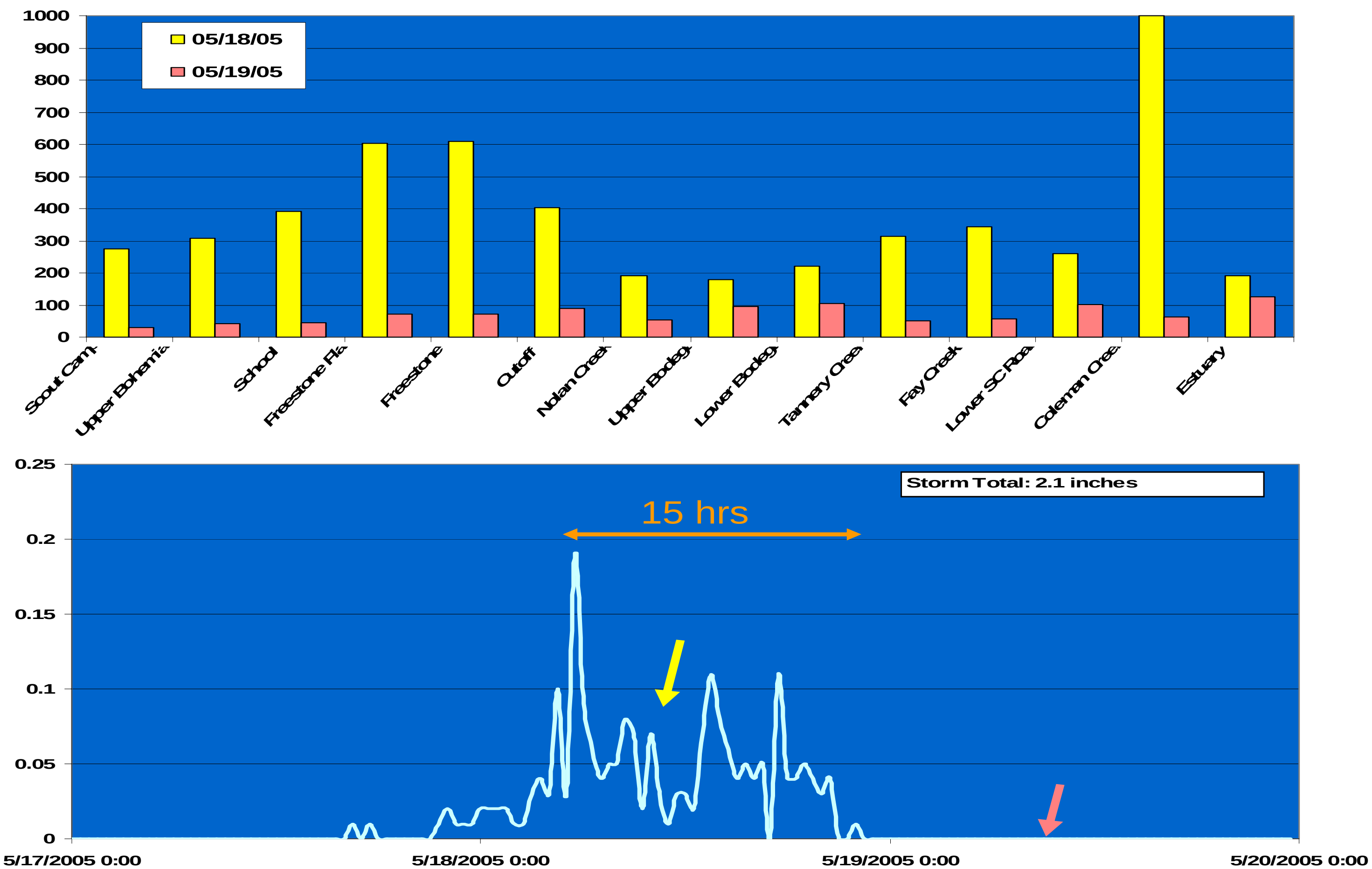




Results of the turbidity measurements taken on February 18th and 21st. Rainfall during the storm event in light blue with the colored arrows corresponding to turbidity samples taken above



Results of the turbidity measurements taken on March 22nd, 23rd, and 24th. Rainfall during the storm event in light blue with the colored arrows corresponding to turbidity samples taken above.



Results of the turbidity measurements taken on May 18th and 19th.

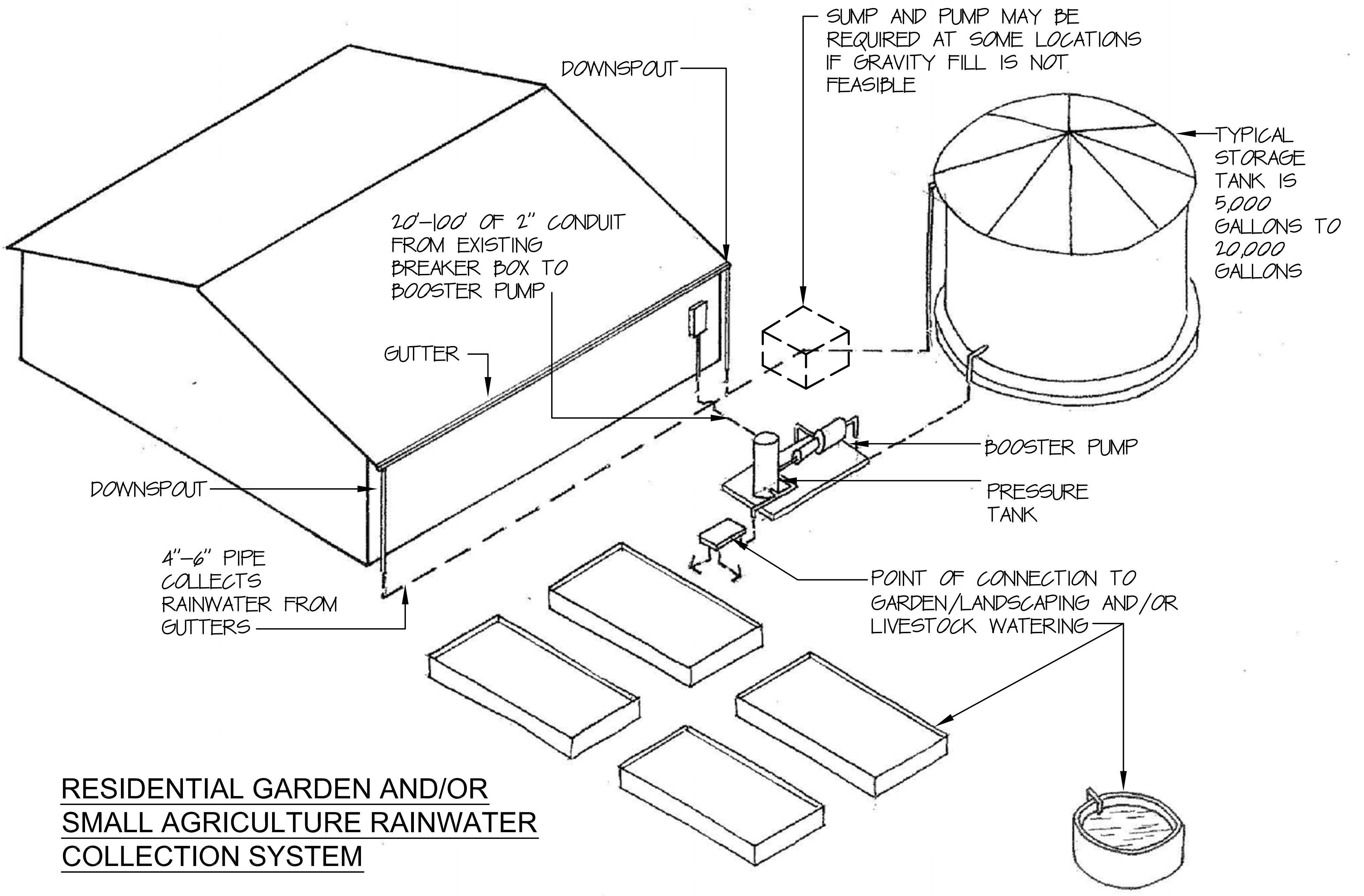
Appendix B: Salmon Creek Soils Data

Salmon Creek Watershed, NRCS, SSURGO Soils Data

SOIL NAME	RUNOFF CLASS	DRAINAGE CLASS	ACRES
ATWELL CLAY LOAM, 30 TO 50 PERCENT SLOPES	Very high	Moderately well drained	273.13
ATWELL CLAY LOAM, 50 TO 75 PERCENT SLOPES	Very high	Moderately well drained	72.18
BLUCHER CLAY LOAM, 0 TO 2 PERCENT SLOPES	Medium	Somewhat poorly drained	194.97
BLUCHER CLAY LOAM, 2 TO 5 PERCENT SLOPES	Medium	Somewhat poorly drained	457.38
BLUCHER LOAM, 0 TO 2 PERCENT SLOPES	Medium	Somewhat poorly drained	72.25
BLUCHER LOAM, 2 TO 5 PERCENT SLOPES	Medium	Somewhat poorly drained	507.67
GOLDRIDGE FINE SANDY LOAM, 15 TO 30 PERCENT SLOPES	High	Moderately well drained	2756.72
GOLDRIDGE FINE SANDY LOAM, 15 TO 30 PERCENT SLOPES, ERODED	Very high	Moderately well drained	42.45
GOLDRIDGE FINE SANDY LOAM, 2 TO 9 PERCENT SLOPES	Medium	Moderately well drained	335.96
GOLDRIDGE FINE SANDY LOAM, 30 TO 50 PERCENT SLOPES	High	Moderately well drained	2191.10
GOLDRIDGE FINE SANDY LOAM, 30 TO 50 PERCENT SLOPES, ERODED	Very high	Moderately well drained	17.23
GOLDRIDGE FINE SANDY LOAM, 9 TO 15 PERCENT SLOPES	Medium	Moderately well drained	454.49
GOLDRIDGE FINE SANDY LOAM, 9 TO 15 PERCENT SLOPES, ERODED	High	Moderately well drained	23.20
HELY SILT LOAM, 30 TO 50 PERCENT SLOPES	High	Well drained	1327.37
HELY SILT LOAM, 50 TO 75 PERCENT SLOPES	High	Well drained	300.20
HUGO VERY GRAVELLY LOAM, 30 TO 50 PERCENT SLOPES	High	Well drained	962.89
HUGO VERY GRAVELLY LOAM, 50 TO 75 PERCENT SLOPES	High	Well drained	1768.32
HUGO-JOSEPHINE COMPLEX, 50 TO 75 PERCENT SLOPES	Very Low	Well drained	286.45
JOSEPHINE LOAM, 30 TO 50 PERCENT SLOPES	High	Well drained	371.41
JOSEPHINE LOAM, 9 TO 30 PERCENT SLOPES	High	Well drained	47.03
JOSEPHINE LOAM,50 TO 75 PERCENT SLOPES	High	Well drained	227.56
KINMAN LOAM, 15 TO 30 PERCENT SLOPES	Very high	Moderately well drained	150.65
KINMAN LOAM, 30 TO 50 PERCENT SLOPES	Very high	Moderately well drained	503.78
KINMAN LOAM, 5 TO 15 PERCENT SLOPES	Very high	Moderately well drained	346.14
KINMAN-KNEELAND LOAMS, 30 TO 50 PERCENT SLOPES	Very high	Moderately well drained	323.62
KNEELAND LOAM, 15 TO 30 PERCENT SLOPES	High	Well drained	284.57
KNEELAND LOAM, 30 TO 50 PERCENT SLOPES	High	Well drained	268.66

KNEELAND LOAM, 5 TO 9 PERCENT SLOPES	Medium	Well drained	91.48
KNEELAND LOAM, 9 TO 15 PERCENT SLOPES	Medium	Well drained	5.68
KNEELAND ROCKY COMPLEX, 30 TO 75 PERCENT SLOPES	Very Low	Excessively drained	1172.76
KNEELAND ROCKY SANDY LOAM, SANDY VAR., 9 TO 30 PERCENT SLOPES	Medium	Well drained	186.13
KNEELAND SANDY LOAM, SANDY VARIANT, 15 TO 30 PERCENT SLOPES	Medium	Well drained	244.46
KNEELAND SANDY LOAM, SANDY VARIANT, 2 TO 15 PERCENT SLOPES	Low	Well drained	110.98
LAUGHLIN LOAM, 2 TO 30 PERCENT SLOPES	Medium	Well drained	44.48
LAUGHLIN LOAM, 30 TO 50 PERCENT SLOPES	High	Well drained	79.47
LAUGHLIN-YORKVILLE COMPLEX, 30 TO 75 PERCENT SLOPES	Very Low	Moderately well drained	68.63
LOS OSOS CLAY LOAM, 15 TO 30 PERCENT SLOPES	Very high	Well drained	137.03
LOS OSOS CLAY LOAM, 2 TO 15 PERCENT SLOPES	High	Well drained	202.72
LOS OSOS CLAY LOAM, 30 TO 50 PERCENT SLOPES	Very high	Well drained	108.93
LOS OSOS CLAY LOAM, 30 TO 50 PERCENT SLOPES, ERODED	Very high	Well drained	25.26
LOS OSOS CLAY LOAM, THIN SOLUM, 30 TO 50 PERCENT SLOPES	Very high	Well drained	198.89
LOS OSOS CLAY LOAM, THIN SOLUM, 5 TO 15 PERCENT SLOPES	Very high	Well drained	37.46
MONTARA COBBLY CLAY LOAM, 2 TO 30 PERCENT SLOPES	High	Well drained	9.39
MONTARA COBBLY CLAY LOAM, 30 TO 75 PERCENT SLOPES	Very high	Well drained	39.62
PAJARO CLAY LOAM, OVERWASH, 0 TO 2 PERCENT SLOPES	Medium	Somewhat poorly drained	12.27
PAJARO FINE SANDY LOAM, 0 TO 2 PERCENT SLOPES	Very low	Somewhat poorly drained	216.81
RED HILL CLAY LOAM, 30 TO 50 PERCENT SLOPES	Very high	Moderately well drained	27.39
ROCK LAND	Very high	Excessively drained	12.97
ROHNERVILLE LOAM, 0 TO 9 PERCENT SLOPES	High	Moderately well drained	108.06
ROHNERVILLE LOAM, 9 TO 15 PERCENT SLOPES	High	Moderately well drained	25.65
SOBRANTE LOAM, 30 TO 50 PERCENT SLOPES	High	Well drained	12.86
STEINBECK LOAM, 15 TO 30 PERCENT SLOPES	High	Moderately well drained	403.22
STEINBECK LOAM, 15 TO 30 PERCENT SLOPES, ERODED	High	Moderately well drained	284.37
STEINBECK LOAM, 2 TO 9 PERCENT SLOPES	Medium	Moderately well drained	723.69
STEINBECK LOAM, 30 TO 50 PERCENT SLOPES	High	Moderately well drained	300.95
STEINBECK LOAM, 30 TO 50 PERCENT SLOPES, ERODED	High	Moderately well drained	424.87
STEINBECK LOAM, 9 TO 15 PERCENT SLOPES	Medium	Moderately well drained	1075.38
STEINBECK LOAM, 9 TO 15 PERCENT SLOPES, ERODED	Medium	Moderately well drained	375.52
SUTHER LOAM, 30 TO 50 PERCENT SLOPES	Very high	Moderately well drained	50.73

YOLO LOAM, OVERWASH, 0 TO 5 PERCENT SLOPES	Low	Well drained	38.10
YORKVILLE CLAY LOAM, 30 TO 50 PERCENT SLOPES	Very high	Moderately well drained	570.46
YORKVILLE CLAY LOAM, 5 TO 30 PERCENT SLOPES	Very high	Moderately well drained	31.96
YORKVILLE-LAUGHLIN COMPLEX, 30 TO 50 PERCENT SLOPES	Very Low	Well drained	227.24



RESIDENTIAL GARDEN AND/OR SMALL AGRICULTURE RAINWATER COLLECTION SYSTEM

PRUNUSKE CHATHAM, INC.
400 MORRIS STREET, SUITE G
SEBASTOPOL, CA 95472
(707) 824-4600

DATE: 4/1/09
SCALE: 1"=10'
DESIGNED BY: SC
DRAFTED BY: JB
CHECKED BY: MJ

PREPARED FOR:
GOLD RIDGE RESOURCE CONSERVATION DISTRICT

SAVE OUR SALMON
THE SALMON CREEK HABITAT REHABILITATION PROGRAM PHASE 1

SHEET

Salmon Creek Estuary: Study Results and Enhancement Recommendations

Prepared for:
Salmon Creek Watershed Council
&
Occidental Arts and Ecology Center

With funding from
State Coastal Conservancy

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June 2006

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Tim Laughlin

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EXECUTIVE SUMMARY

Salmon Creek, like many of California's coastal streams, has lost its coho *(Oncorhynchus kisutch)* salmon run in the last 10 years and is left with a dwindling steelhead trout *(Oncorhynchus mykiss)* population. This project is part of a larger community effort to assess the reasons for the decline of the salmonid runs and to develop an integrated, effective restoration strategy.

The Salmon Creek Estuary Enhancement Plan summarizes the results of sampling and assessment of factors that affect estuarine function and its value as salmonid habitat, and presents recommendation for additional data collection and habitat enhancement. The estuary bed and beach at the mouth were surveyed at the beginning of the study in fall of 2004 and then again after 3 storm events. The topography was described and compared to historical accounts. Upstream factors, particularly water quantity and sediment were assessed through monitoring and review of existing information. Temperature, dissolved oxygen and salinity in the estuary were monitored monthly for one year and then at one additional time in fall of 2005. Biotic monitoring of the estuary to examine fish use was conducted on the same schedule. Historical information was gathered from many local sources as well as oral history interviews.

Although the study only allowed for a limited period of data collection under a very narrow range of weather conditions, sufficient information was gathered to increase understanding of the Salmon Creek system and to develop initial habitat recommendations. Increased water consumption in the upper watershed from groundwater and direct stream withdrawals has reduced base stream flows during critical periods. Low spring and summer flows increase pool stratification in the estuary to create bottom saline layers too hot and low in oxygen to sustain salmonids. Fish are confined to the upper freshwater layer and to the well-mixed area near the sandbar where they are vulnerable to predation by birds. Low spring and summer flows also reduce lagoon elevations and delay the breaching of the sandbar. If the sandbar opens after or near the end of the coho upstream migration period, as occurred in the 2004/2005 winter, coho have little if any chance of returning to Salmon Creek. Low summer flows also reduce viable salmonid rearing habitat in the main channel and tributaries.

Significant amounts of course sediment have dramatically decreased the areal extent and depth of the estuary since the mid 1800s. Over the study period, over 2 feet of sediment was deposited upstream and downstream of the Highway 1 bridge. Summer lagoon depths now range from 2 to 6 feet as compared to 6 to 12 feet in the 1950s and 1960s. Erosion of fine sediments from the upper watershed creates high turbidity levels that impair salmonid physiological functioning and behavior.

Recommendations call for enhancing habitat diversity in the estuary through woody debris structures and possible restoration of side channels and pond connectivity; maintaining beneficial freshwater flows through water conservation and better management of diversions; expanding erosion control, riparian protection and stormwater management practices in the upper watershed; and enhancing upstream rearing habitat to provide alternatives to poor quality estuarine habitat. The recommendations also include continuing the biological and water quality monitoring in the estuary for at least 5 more years, installing a USGS stream gage at the upper end of the estuary as well as several additional flow monitors higher in the watershed, and implementing community education programs on a variety of topics including water conservation and erosion control Best Management Practices. The final recommendation calls for integrating all of the current planning and restoration efforts into a coherent strategy for managing the Salmon Creek watershed to enhance and sustain viable salmonid runs.

CHAPTER 1: INTRODUCTION

Coho salmon and steelhead were once abundant in Salmon Creek, its estuary, and its tributaries. Tales of their numbers, sizes, and favorite pools are still a vital part of the local history and lore. Unfortunately, in Salmon Creek, as in many streams along the California coast, their numbers have dropped substantially. Now only a small population of steelhead continues to return each year, and the last coho was seen in 1996. The residents are intensely interested in and many are actively working towards returning the anadromous fish to their creeks.

Residents and local watershed groups, as well as public agencies have worked to assess the ecological health and functioning of the Salmon Creek watershed, and to document specific sites and/or activities that may be degrading the riparian system and impairing critical fish habitat. The Department of Fish and Game (DFG) conducted an instream habitat assessment of Salmon Creek and its tributaries in 2001 and 2002. Gold Ridge Resource Conservation District (RCD) teamed with the Salmon Creek Watershed Council (Watershed Council) to receive a grant from DFG in 2003 to complete a watershed assessment and plan. This DFG grant provided funding to begin a volunteer water-quality monitoring program, document erosion in the watershed, research land use history, and identify potential restoration projects. UC Cooperative Extension is currently studying the sources and transport processes of pathogens in 5 coastal estuaries, including Salmon Creek. The Community Clean Water Institute has been supporting residents in the Joy Road area and Salmon Creek School in monitoring upstream water quality.

This piece of the watershed planning effort is focused on the estuary. Estuaries provide essential food, cover, migratory corridors, and breeding/nursery areas for many coastal and marine organisms. Recognition of their importance for anadromous salmonid fish has grown as salmon and steelhead populations plummet. Adults use estuaries for staging in preparation for their upstream migration. Juveniles use them for rearing and for completing the physiological adjustment from fresh to salt water that will allow them to live in the ocean. Juveniles may linger in the estuary for weeks and may move in and out several times before remaining in the ocean. Adequate flow, good water quality, sufficient cover, habitat complexity, and invertebrate food source within the estuary are all very important factors for the survival of anadromous fish.

In 2004, the State Coastal Conservancy approved a grant to the Salmon Creek Watershed Council and the Occidental Arts and Ecology Center (OAEC) to investigate the physical condition and functioning of the Salmon Creek tidal estuary and how it is used by salmon and steelhead, assess upstream factors that directly affect critical habitat in the estuary, collect historical information and develop recommendations to enhance the estuary for salmonid habitat. A Technical Advisory Committee was formed to review the study plan and findings. This report contains the results of the investigation along with overall enhancement recommendations and short term actions needed to initiate restoration or collect additional data.

CHAPTER 2: SETTING

2.1 Physiography

The Salmon Creek watershed drains 34.5 square miles of western Sonoma County and enters the ocean just north of Bodega Bay (Figure 2.1.). Its estuary extends approximately 1.3 miles inland from the coast. The lower estuary is part of the Sonoma Coast State Beach and is managed by the California Department of Parks and Recreation. As in most small northern California streams, the mouth of the estuary is closed by a sandbar in spring or summer every year and remains closed until after the first significant storms. Under conditions of adequate summer streamflow, the closed estuary converts to a largely freshwater lagoon.

The small unincorporated communities of Occidental, Freestone, Bodega and Salmon Creek are within the watershed. Grazing based agriculture still dominates the western part with cattle and sheep ranches and a handful of dairies. Rural residential housing is the primary current land use in the upper watershed although in the past ten years, numerous commercial vineyards have been developed around Occidental and Freestone.

The rock formations underlying the watershed are primarily Franciscan complex or melange with Wilson Grove formation overlying much of the eastern portion (Figure 2.2.). Many of the soils associated with these geologic formations are highly erodible on steeper slopes. Vegetation in the watershed closely follows the geology with dense hardwood conifer forests dominating the northeastern area and an abrupt transition to the rolling grasslands of Bodega and the coast (Figure 2.3.). Average rainfall in Occidental is 56 inches per year.

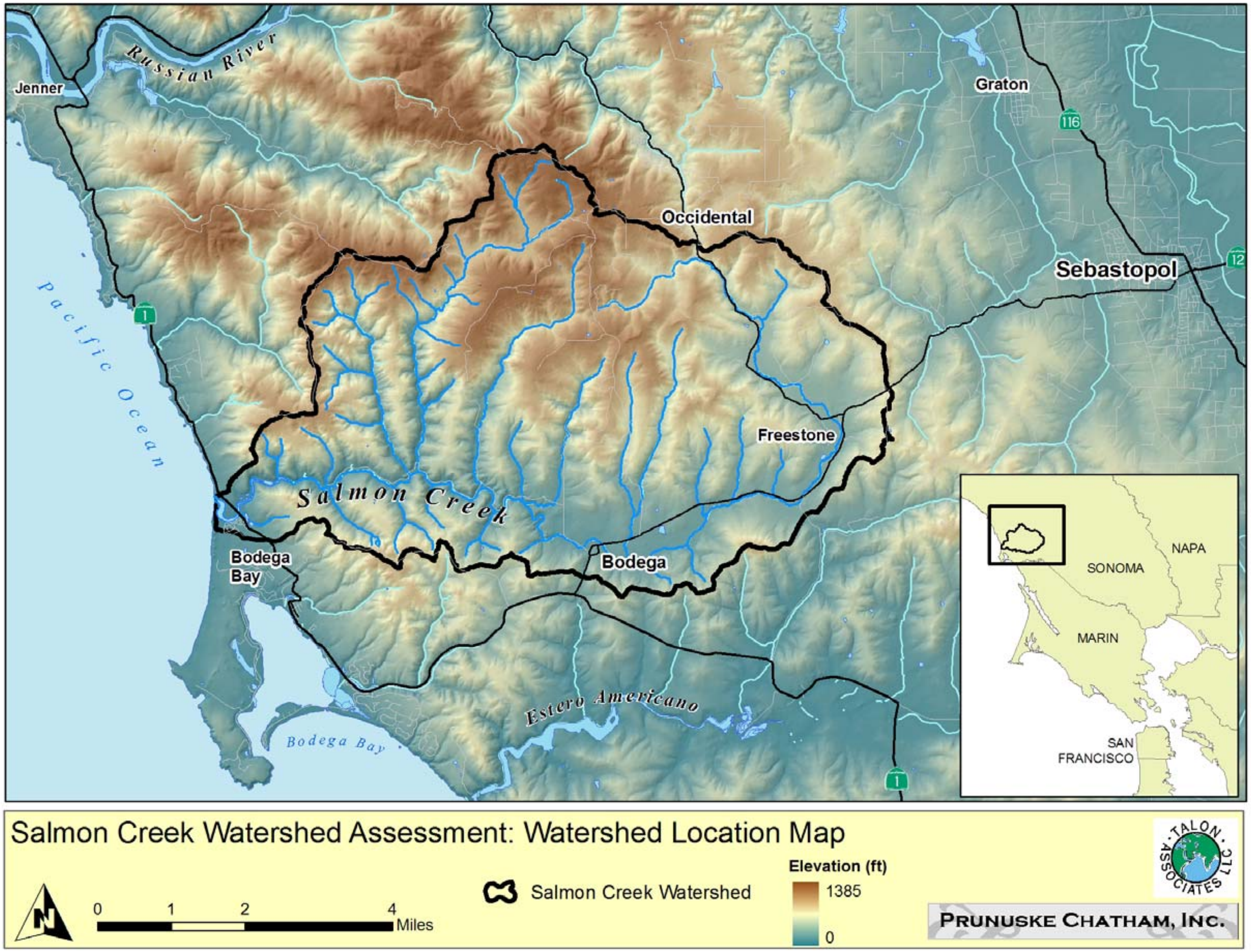


Figure 2.1.1 *Salmon Creek watershed showing locations of towns, roads, streams, and topography.*

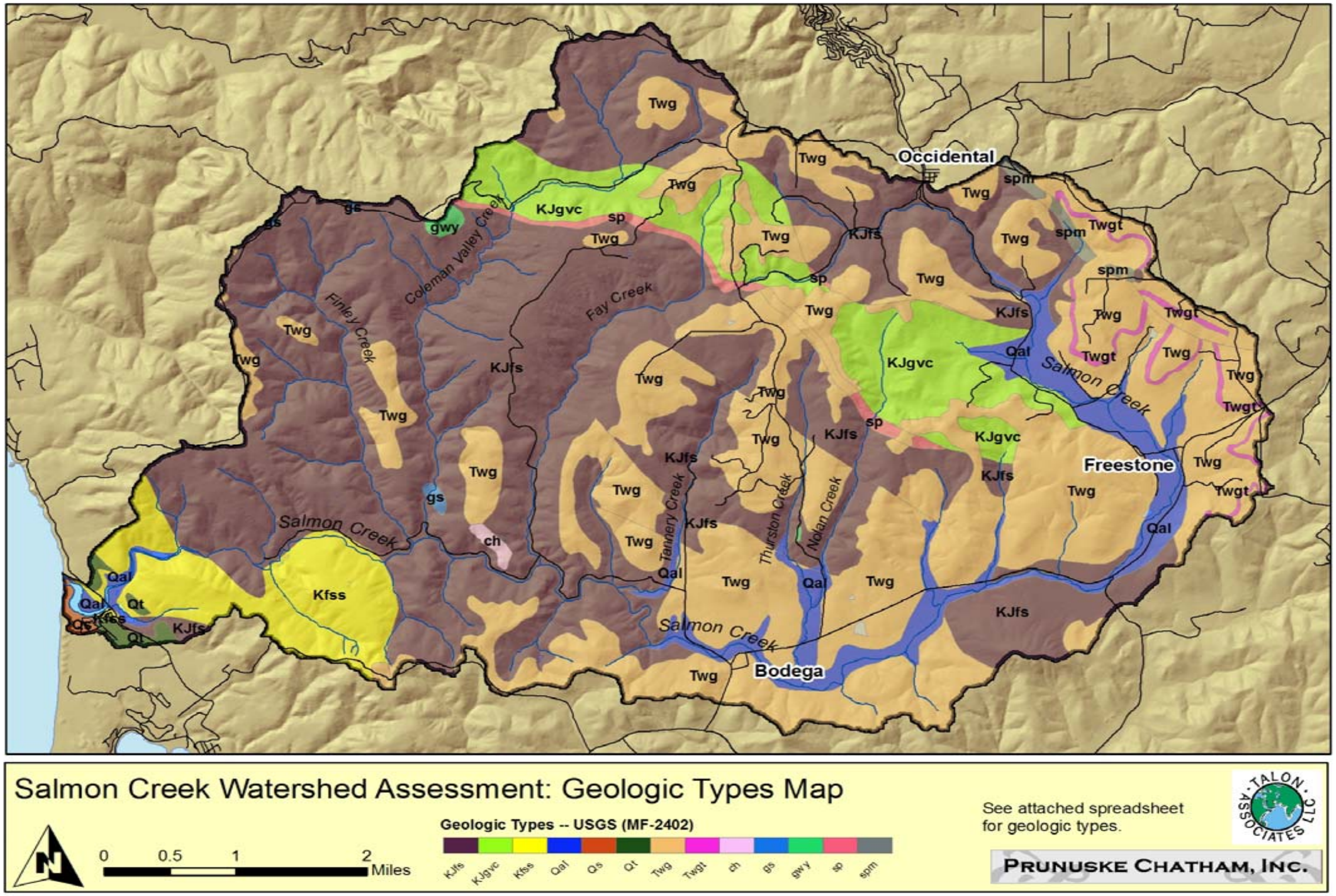


Figure 2.1.2 Watershed geology.

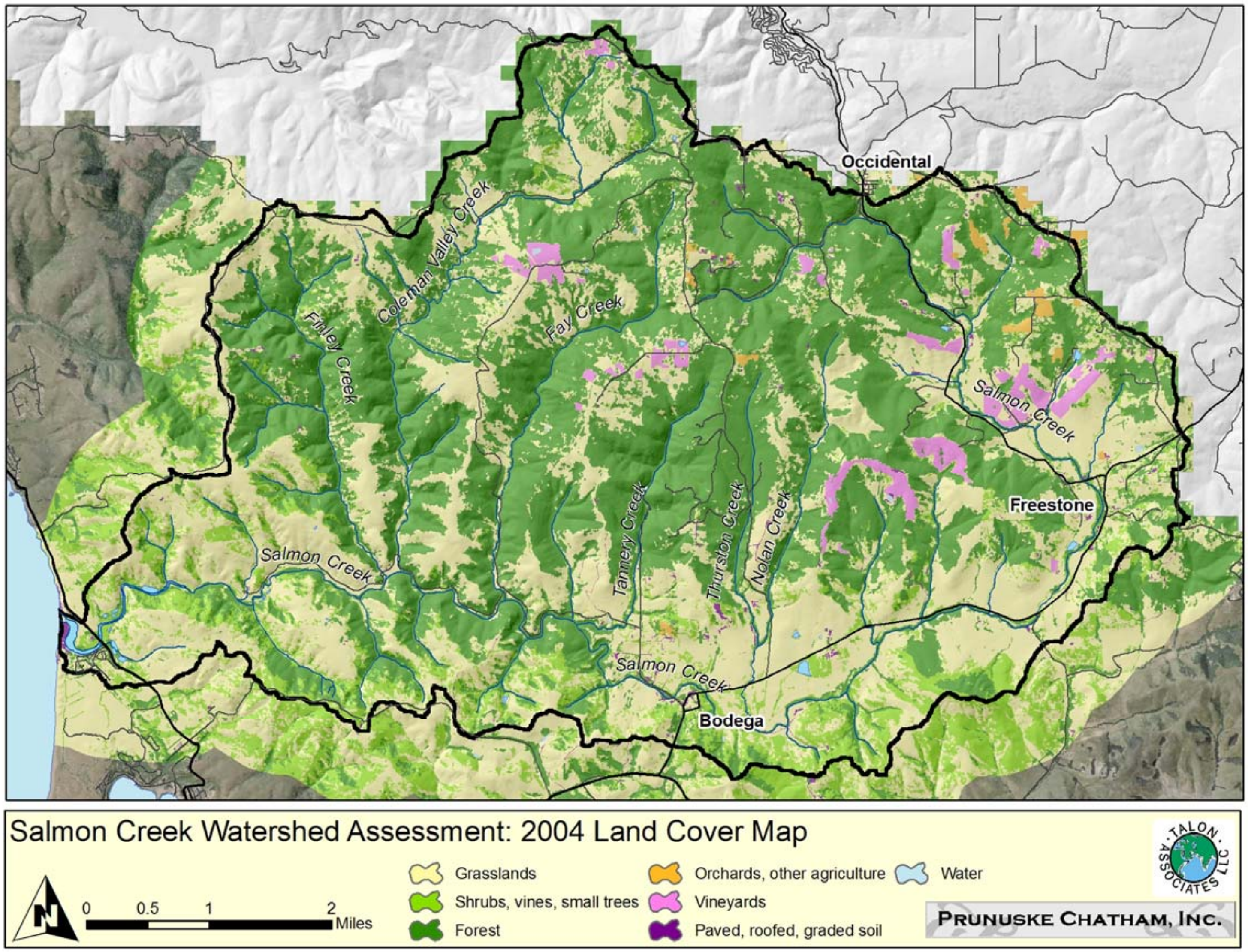


Figure 2.1.3 *Landcover and use in the Salmon Creek watershed.*

2.2 *History*

Coast Miwok people were living in and managing the Salmon Creek watershed when Russians established farms in Bodega and Freestone in 1812. European settlers began to arrive in the 1840s and immediately began logging for their own needs as well as for the developing city of San Francisco. Salmon Creek farms produced dairy products, potatoes and grain for California's growing population. The following timeline includes some of the events that have lead to profound changes in the watershed that have in turn affected fish populations. Appendix A contains a more thorough history, including numerous oral histories of the Salmon Creek watershed.

Historical Timeline of Salmon Creek Watershed

Date	**Activity**
Prehistory	Native Americans may have occupied the area for 8,000± years. Coast Miwok people were the latest indigenous people to live in SCW, with communities in areas of Freestone and Bodega into mid-1800s. Indigenous management techniques were used to manage productivity and populations of forest, grassland and riparian species. (Anderson, 2005)
1775	Don Juan Francisco de la Bodega y Cuadra, Spanish explorer, sails into "Bodega" Bay and claims the region for Spain. Plans to return to develop the area, but never does. (Hill, 2005)
1776	Since Mexico is a colony of Spain, California is too. Missions in San Francisco, San Rafael and Sonoma recruit local indigenous people for religious conversion and labor. Salmon Creek Watershed remains just beyond the edge of their influence and control.
1812	A party of Russians and Native Alaskans establish Fort Ross and come to Bodega Bay to found farming settlements in Bodega, Freestone and Coleman Valley. The first timber cutting occurs, also tanoak harvesting for tanning hides. (Wilson, 1999)
	California's first shipment of grain leaves from the port of Bodega, bound for Russian settlements in Alaska
1817	Russians plant Sonoma County's first vineyards in Coleman Valley; also first apple orchards, possibly the first Gravensteins. (Wilson, 1999)
1835-1846	To create a buffer from Russian settlement, Mexico gives huge land grants (8,000 to 60,000 acres) in the coastal range. The first Anglo settlers in Salmon Creek watershed were given farmland in Freestone with instructions to bother the Russian settlements nearby. (Wilson, 1999)

1836	Mexican General Vallejo in Petaluma Hacienda forbids continuing native practice of quickly burning the grassland and wooded hills in late fall, a practice which fertilized the fields, and helped prevent weed competition, brush accumulation, and forest blights.
1837-1841	Smallpox epidemic decimates North Coast Indian population; 80-90% die. Decrease in land and resource use and management may be affected harvesting, hunting, fishing and those species' populations.
1842	Russians depart from Sonoma Coast, sell their holdings and equipment.
1843-1844	Captain Stephen Smith delineates and receives 35,000 acre land grant called Rancho Bodega, which includes most of Salmon Creek watershed, plus land north to Russian River. He introduces the first steam engine in California, sets up a steam-operated lumber mill and flour mill in the Bodega area, as well as a tannery.
1848	Kolmer family immigrates from Germany, lease land from Capt. Smith, settles in Coleman Valley. Years later a mapmaker changes spelling from Kolmer to Coleman.
1848-49	After defeat in Mexican-American War, Mexico cedes California to the United States. Pioneering European, Canadian and American settlers establish holdings in Salmon Creek watershed (Occidental, Freestone, Bodega).
1849-50	Land rush after the 1849 Gold Rush brings Anglo-Americans, Canadians and Europeans to West Sonoma County. Era of large-scale farming, ranching and timber-cutting begins in Salmon Creek watershed. William "Dutch Bill" Howard clears trees on Occidental ridge to start cattle ranch. Salmon Creek watershed soon becomes known for its potatoes, pigs, chickens, sheep, beef cattle and dairies. Logging begins, boards hand-hewn. Sawmills later proliferate. Lumber and goods shipped from Bodega Bay or taken by wagon to Petaluma River, then carried on barges to SF Bay. (Hill, 2005)
1849?	Potato and pork farming begins to be established in Salmon Creek valley.
1850s	Era of road building is launched along with era of logging. With settlement and logging, dozens of roads are built over the hills and through the creeks in Salmon Creek Watershed. When easy to reach trees are gone, logging roads delve deeper in to more remote areas. Roads are heavily used by wagons drawn by team of 4-12 oxen or many horses, often with heavy loads. Some roads become stagecoach roads. (Wilson, 1999)
1859	"Squatters' wars" break out in Sonoma County, between settler and large landowners. In Bodega, Tyler Curtis, the second husband of Capt. Smith's widow Manuela, sold much of her land, permanently drove off the Coast Miwok population, and tried to evict hundreds of pioneers whom Smith had encouraged to farm Rancho Bodega and to populate the town of Bodega. Curtis brought in troops, who engaged in a stand-off with 300 of Bodega's angry pitchfork-wielding squatters on the road to Petaluma. They defeated him and stayed to get deeds of their own

	and build the local ranching and dairy industries. (Wilson, 1999)
1865	The first lumber mill in Coleman Valley was built in 1865. It was moved around the valley to be near the timber, as was the custom of that time. A succession of owners logged that valley with multiple mill sites until 1913, when the last mill owner, Wade Sturgeon operated a mill there until 1923. (That restored mill is now set up on Green Valley Road, near Sebastopol.) (Historical newletters, SCHS)
1866	"Boss" Meeker built a sawmill southwest of Occidental, expanded in 1866-67 with a half-mile long railroad to it. In 1868 he cleared and homesteaded Wyammy Ranch area on Bittner Rd., headwaters of Salmon Creek. The one-lane "Long Bridge" was built across the 'headwaters' canyon and lasted into the 1920s. (Hill, 2005)
1873-1876	Narrow-gauge railroad is built to carry lumber and goods from West Sonoma County to San Francisco Bay. Runs from Tiburon through Tomales, Valley Ford, Freestone, and Occidental to Duncan's Mill. Local populations swell for several years, while ~1,500 people work on construction. (1,300 workers in Freestone-Occidental were Chinese, later driven from the county in an 1886 boycott.) The tallest timber trestle in the U.S. is built over Salmon Creek, in Brown's Canyon, lifting the train between Freestone and Occidental (575 ft. elevation). Freestone becomes known as "Gateway to Sawmill Country." All local building is done with local lumber.
1890s	Clara Tarwater, daughter of Bodega Finleys, describes Finley dairy of the 1890s: Cows grazed in fields, milked twice daily, for large-scale production of butter, cream, milk. By-products of curds and whey used to fatten pigs. Goods traded at Freestone Creamery or delivered to "Bodega Roads" train depot near Freestone for transport to San Francisco markets. Every town had a creamery. (Journal of the Sonoma Co. Historical Society, 1964)
1876	Town of Occidental, built up by presence of construction workers and lumbermen, is formally established and named by Boss Meeker. Town of "Howard's" co-exists on north end of Occidental for `15 years. Train brings first boom in tourism to the region, with hotels, summer cabins and service for their needs.
1870s-1920s	Redwood timber industry thrives. Timber cutting has major impact on watershed. Mills are built and moved, sometimes to several locations within upland and lowland areas of each tributary. Douglas fir is harvested for lumber, oak for firewood, tanoak for charcoal production and tanning. Felled logs are dragged by long teams of oxen through creekbeds and over rough roads on slopes, then trucked out or, later exported by train.
1870s-1920s	Tanoak bark industry thrives. Tan oaks are skinned, bark dried and warehoused in Occidental, shipped to Bay Area tanneries.
1885-1890s	Early Sonoma County environmental concerns arise, concerning county-wide over-fishing of salmon and trout species; rules regarding fishing season and take are implemented. Concern expressed over effect of

	coastal logging on local climate change. (Santa Rosa newspapers)
1890s	Clara Tarwater, daughter of Bodega Finleys (of Finley Creek), describes Finley dairy of the 1890s: Cows grazed in fields, milked twice daily, for large-scale production of butter, cream, milk. By-products of curds and whey used to fatten pigs, who became sausages, etc. Goods traded at Freestone Creamery or delivered to "Bodega Roads" train depot near Freestone, for transport to San Francisco markets. Major local industry; many dairies along Salmon Creek and every town had a creamery. Most dairies continue into mid-1900s and a couple to present day. (Journal of the Sonoma County Historical Society, 1964)
1900	Huge forest fire started at Coleman Valley Rd. just above Occidental, "burned out thirty ranches" as it ran down to Freestone, through Joy Woods and over to the edge of Bodega. Scars still visible in old Doug Firs in year 2000. Cleared the skyline of trees.
~1900	Railroad introduces refrigerated cars, which are boon to local dairy industry.
1906	Great San Francisco Earthquake shakes this area badly. Many buildings damaged. Santa Rosa devastated, affects railway and urban markets for dairy goods, etc. Cities rebuilt with North Coast lumber.
1920	Era of Prohibition begins. West Sonoma County forests and county roads hide many private vineyards and stills. Alcohol smuggled from offshore through Bodega distribution system. (Tuomey, 1926)
1920s	By the 1920s, automobile travel is on the rise, for trucking and tourism. After years of residents' complaints about bad west county roads, the tourist drivers of private automobiles, out to see the coast, push Sonoma County Road Dept. to improve many roads near Salmon Ck. And along the coast. In 1926, grading, culverts, walls and bridges are constructed to meet higher demand, especially along Bohemian Hwy., Bodega Hwy., Hwy. 1 and Salmon Ck. Rd. (Coleman Valley Rd. remains privately maintained by ranchers until the 1960s.) (Rancho Bodega Historical Society and Wilson, 1999)
1928	Late in logging era, Finley descendant sells upper part of Finley ranch to Meeker descendant, who logs it, by building and operating another sawmill there. (Another late-era mill is the Chenoweth Mill, right on Salmon Creek in Bodega, which operated until the 1970s.)
1929	Sportsmen call attention to the falls at Salmon Creek. On the property of Mr. Farrel of Freestone, who does not want them removed. Sufficient spawning areas exist below the falls, DFG estimates that 5 miles of spawning gravels are upstream. The falls are estimated to be 12' high. DFG does not think the cost is worth the spawning grounds and believes at times of high water, fish could pass.(DFG, April 1929)
1930	The Northwest Pacific Railroad Co. closes down the train that passed through west Sonoma County for 54 years, so Bodega, Freestone and Occidental no longer have the shipping and tourism the train provided. Trestles and tracks are gradually removed, leaving roadbeds. (Wilson, 1999)

1930	Great Depression: WPA projects in area include road-building, culverts, walls, grading. Colonies of CCC workers camp and work locally, for several years.
1934	Sonoma Coast State Beach established, including mouth of Salmon Creek. Later expanded to include estuary. (Wilson, 1999)
1935	Prohibition repealed. Salmon Creek watershed wineries officially reopen, such as Indian Mound Winery on Joy Road. (Wilson, 1999)
1937	The Golden Gate Bridge opens. Automobile tourism to Bodega and Bodega Bay area greatly increases. Road use increases. Trucking goods from region to cities increases. Dairies thrive with this development. (Wilson, 1999)
1941	World War II starts in Pacific. Lookouts and patrols begin on Salmon Creek Beach; soldiers stay in camps that CCC had used during the Depression. (Wilson, 1999)
1951	Salmon Creek falls were partially eliminated, probably by blasting, and the stream above is now easily accessible to SH. The party or parties who removed the barrier are unknown, but it is suspected that the county did it on the recommendation of the local sportsmen." (DFG, 1951)
1953	DFG recommends that catchable rainbow trout be planted in the estuary anytime after June 1, and periodically thereafter. The 1953-54 winter steelhead fishery creel census: 20 anglers fishing for 39 hours caught 13 silver salmon ranging from 2.5 to 10 lbs. Staff estimated a total of 50 fishermen. (DFG, 1953)
1950s	At least 12 dairies still operating along Salmon Creek between Freestone and Bodega. (John Mache, interview)
1961	Proposal to construct a saltwater barrier 2 miles upstream from the mouth for Bodega Bay Public Utility District (BBPUD) and a dam and reservoir on Finley Creek, approximately 1¾ miles upstream from the well site. Dam would be constructed of earth fill 75' high to impound 700 acre feet. The water will be discharged during the dry season to "maintain adequate stream flow at their well site, thus recharging the underground gravels and preventing the intrusion of salt water." DFG notes that the dam may delay the opening of the mouth which would delay spawning and migration to the ocean. To evaluate the project, a complete survey of Salmon Creek and its tributaries is underway. (DFG, 1961)
1961	Fish found during DFG field visit: sculpin, 3 adult steelhead, 2 adult silver salmon (coho), 1 grilse (unknown), 3 mechanically injured (poaching) silver, no young observed (3 weeks after first major rain). (DFG, December 1961)
mid-1960s	Two significant wildfires in the northern portion of the watershed. The Robertson Fire in 1961 burned ~2000 acres in Fay Tannery, and Coleman Valley Creeks. The 1965 Coleman Valley Fire burned 1,840 acres on the ridge between Fay and Coleman Creeks, burning almost to Salmon Creek. This fire took out most of the trees and the understory.

1964	Fish found during DFG field visit: Majority of fish are silver salmon 1½ to 2", 20% steelhead 1-2". 50-100 fish/100 feet. Steelhead 4-8" observed below Bodega. (DFG, March 1964)
1965	Fish found during DFG field visit: Silver Salmon (2" avg) 150 per 100 feet; Steelhead (2" avg) 100 per 100 feet; Stickleback (1-2" avg). 149 fingerlings caught: 85 Silver Salmon, 64 Steelhead (DFG, August 1965)
up to 1970s	Observers report an old practice: eager "fishermen" annually broke through the sandbar just as creek flow rose to nearly high enough and as coho were seen gathering in the waves outside the bar. Good fishing at the estuary as soon as the bar broke and the fish rushed in. Practice continued to at least late 1970s. Some say they "always" had salmon for Thanksgiving.
Early 1970s	Bodega Hwy. west of Freestone was very narrow country road, barely two lanes. County widened and surfaced it in early 1970s, some of that along riparian area between Freestone and Bodega. Early 1970s was also the last time the County Flood Control crew came to clear the willows out of the center of Salmon Ck., which the ranchers had also done every summer for years, for flood control and to maintain channel. (Mache interview)
1970	Fish found during DFG field visit: Silver Salmon (3-4") and Steelhead (1-2") 25-40 per 100 feet; Stickleback (1-3") 60+ per 100 feet (DFG, Dec 1970)
9/1974	Record salmon catch at sea off Salmon Creek (Grady, 1996)
1975	Salmon fishing fleet begins to diminish due to economic factors (Grady, 1996)
1976	Salmon Creek watershed briefly becomes world-famous in art world, due to Christo Javacheff's Running Fence, which partly ran through the valley and near the creek.
1977	Survey from Freestone to Occidental. Intermittent pools with 1 tributary ½ mile downstream of Occidental flowing at 1 cfs. Notes that the area would be good habitat for California freshwater shrimp "if the need arises to transfer them from areas lower in the drainage." Juvenile salmonids observed 200 feet upstream of tributary, sculpin and CA roach seen throughout. No freshwater shrimp. (DFG, August 1977)
1977	Fish found during DFG field visit: Stretches near Watson School: threespined stickleback, California freshwater shrimp, sculpin, crayfish ½ mile downstream of Occidental at tributary: sculpin, crayfish. (maps) (DFG, Sept 1977)
1977	Very dry winter, after several years of drought. Local residents report that the number of steelhead and coho declined significantly after this period, with the fall run of steelhead never returning to "normal".
1978	Observers noticed that sand excavated to free a beached boat in 1970 was slowly moving eastward, into the estuary. Attempts to truck it out failed. (Grady, 1996)
1979	More dune grass is planted on the dunes at the mouth of Salmon Creek, to hold sand back. Helicopter provides aerial fertilization to dunes. (Grady, 1996)

1/1982	Coast reports 9" rain in 36 hours, heavier inland; very heavy simultaneously in both lower and upper SCW, flooding at Bodega and all the way downstream. Town of Bodega overwhelmed. Welling Ranch above estuary loses ground and ranch equipment. Everyone, including DFG, reports astonishing quantity of sediment washed down the tributaries. Some note that Coleman Valley Creek, Finley Creek and Fay Creek particularly fill up with sediment above and at their confluences with SC and downstream. Pools throughout SC fill up. Estuary breadth and depth changes dramatically both above and below Hwy. 1 bridge. Large amounts of sediment deposited in the channel and on floodplain; changing tidal wetlands to terrestrial upland. North abutment of SC bridge is destroyed, Hwy. 1 closed.
1982	Request for a hatch box program on Salmon Creek. Results of Bill Cox's electrofishing: steelhead population healthy, 6 silver salmon. (Fisherman's Marketing Assoc. of Bodega Bay, 1982). DFG turns down the request for a hatchbox program due to predation by yearling steelhead. DFG plans to stock 20,000 Noyo strain coho yearlings in Salmon Creek in spring. (DFG, 1982)
1983	DFG writes to inform that the Noyo facility had a poor egg take and the Mad River hatchery had disease problems. DFG does not have enough coho to meet brood stock requirements. They do have several thousand YOY coho from Warm Springs Hatchery to stock Salmon Creek later that spring. (DFG, April 1983)
2/1986	Very wet week-long rainstorm (with 12" in 24 hrs in Occidental) referred to as "Valentine's Day Flood" or "Massacre." Mentioned as second biggest to 1982 storm. Effects on Salmon Ck. watershed are not detailed, but probably continued erosion and deposition.
1988	(DFG response to Sonoma County Public Works) Letter appears to respond to a County desire to breach the sand bar at Salmon Creek lagoon. DFG states that they have not studied the lagoon, though they cite other research in CA which proves breaching has a negative impact to fish populations. DFG states they know that the tidewater goby (candidate for endangered status) use the lagoon. DFG states that until it is shown that the opening of the bar would have no significant adverse effects, they are opposed to the artificial opening during the dry season. (DFG, June 1988)
1996	Last documented coho salmon seen in Salmon Creek (Bill Cox, DFG Biologist)
2000	Logging of private land in upland watershed continues, e.g. 60 acres of up to 100 yr. old Douglas firs harvested in upland Tannery Ck. Selective harvesting methods for forest health are employed in some areas of the watershed.

CHAPTER 3: PROJECT STUDIES AND RESULTS

3.1 Morphology and Hydrodynamics *(prepared by Lauren Hammack)*

Introduction

In this study we have examined several of the physical drivers of estuary dynamics in relation to summer lagoon formation and fall sandbar breaching—key factors for critical habitat conditions for juvenile salmonid rearing and adult migration patterns. Hydrologic factors related to sandbar breaching in the late fall are examined to answer the question: "Has the fall lagoon breach timing changed over time, affecting salmonid spawning runs?" The topography of the estuary was described and compared to historical accounts of the size, shape, and sediment distribution to document long- and short-term changes due to upstream, watershed conditions.

Methods

A detailed survey of the estuary was performed in October and early November 2004. Thirty-four cross sections were surveyed between the mouth and the upper summer extent of the lagoon. Within this 1.3 mile reach barrier beach dimensions, channel topography, pool locations and depths, bank heights, and floodplain pond and drainage features were measured. During the winter/ spring of 2005 the channel bed and beach at the mouth were surveyed twice to document changes after large storm events. Changes to the lower and middle estuary following the 2005/6 New Year's Eve storm were surveyed in February 2006. Topographic maps for each survey time and location were produced using AutoCAD. Estuary volumes at specified water surfaces, changes in thalweg elevations and cross section dimensions over the study period, and sediment erosion/deposition volumes were calculated based on the detailed fall 2004 baseline survey and subsequent surveys.

Estuary stage level was monitored at half hour intervals with a pressure transducer water-level logger. The level logger was initially installed in early November 2004. However, due to equipment failure and the associated loss of data, continuous stage measurements were collected for the period February 2 to December 31, 2005. During the summer and fall of 2004 water surface elevations were marked once a month during the biological sampling cruises. In addition to estuary stage levels, hydrologic data used in the hydrodynamic analyses includes daily rainfall totals at Occidental (1948-2005), rainfall at Bodega (2004-2005), and discharge records at Bodega (1964-1975, late 2004, 2005).

Mean daily discharges at Bodega were converted to acre feet and proportioned to total watershed area to estimate daily flow volumes entering the estuary. Annual rainfall statistics were calculated for the entire period of record in Occidental. Monthly and seasonal (Oct 1st- Dec 15th, Apr 1st-Jun15th) statistics were also calculated, including totals, averages, and cumulative rainfall.

Morphology

The estuary can be divided into three distinct reaches; the lower estuary from the mouth to the Highway 1 Bridge, the middle estuary from the bridge to river mile 1.1, and the upper estuary from river mile 1.1 through Chanslor Ranch. Channel form, substrate size and distribution, habitat features, and hydrologic characteristics are unique to each.

Lower Estuary

The complex interplay of waves, wind, and stream flow shape the mouth of the estuary, determining where and when it opens, the depth of the channel, and the movement of sediment and water. From the mouth, the lower 1000 feet of channel parallels a long, broad barrier beach and then turns inland. Longshore currents tend to keep the channel mouth at the north end of the beach. This pattern was broken in the late 1990s when the sandbar breached at the southern end of the barrier beach, cutting through a high vegetated dune. Over the next three years the channel migrated north, systematically eroding the entire length of protective dune.

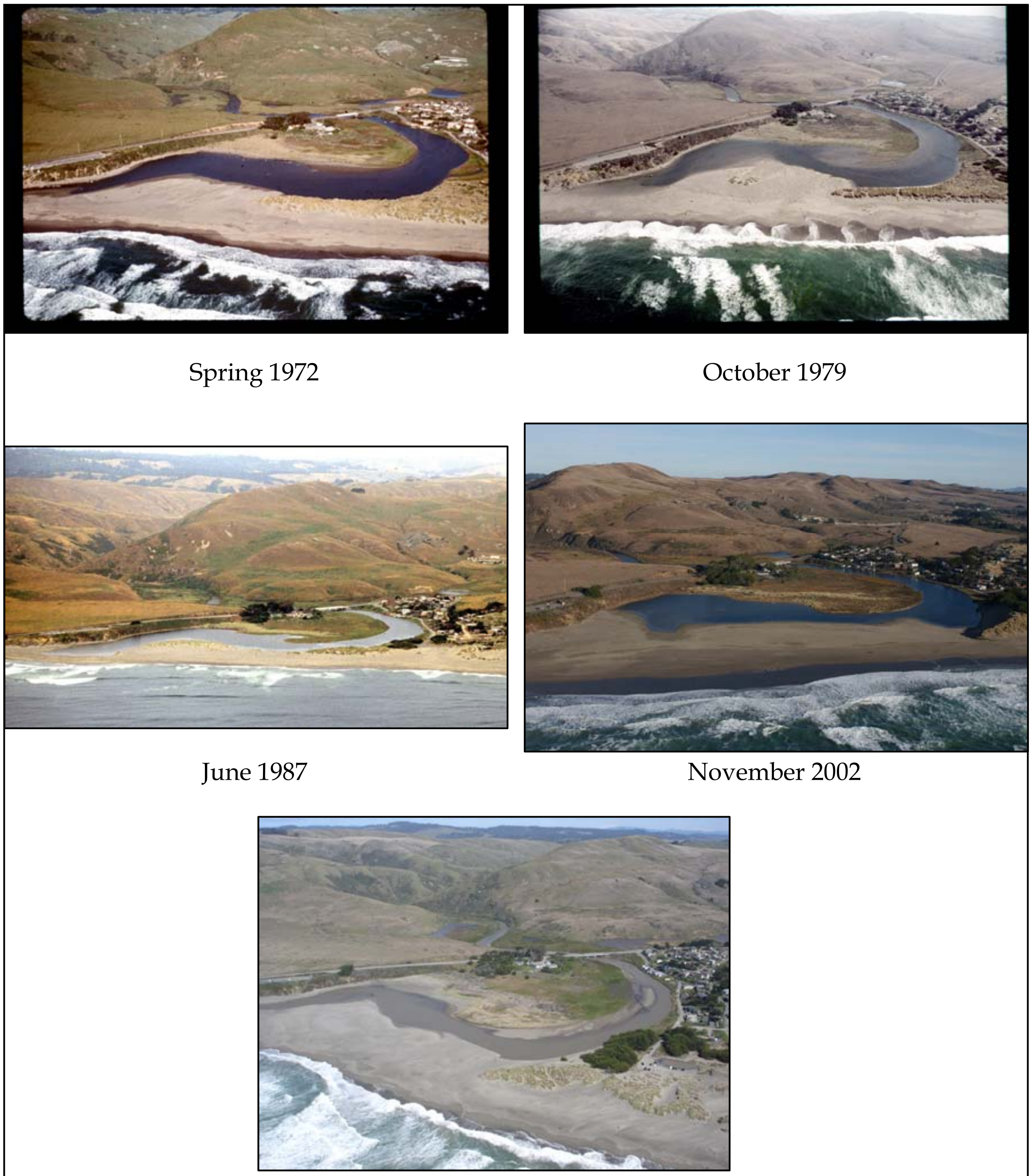
At the start of the study (October 2004) the barrier beach ranged in elevation (in NGVD) from 14 feet near the middle to nearly 12 feet at the northern breaching area. Average elevation of the channel bed along the sandbar was 3 feet NGVD during the baseline survey. Surveys of the channel bed from the mouth along the sand bar after winter storms showed localized bed incision, as well as deposition, of 1 to 7 feet. The greatest bed elevation fluctuations occurred within the breach channel and immediately upstream, while at the southern end of the sandbar the channel aggraded 1 foot over the study period. Maximum scour during large runoff events was not documented, but is assumed to be several feet.

In the lower reach the deepest areas are found along the entire south side of the channel from the bridge to the beach. Elevations along the thalweg range from 1 to 2 feet NGVD, producing pool depths of 4 to 7 feet during summer lagoon periods. The channel shallows on the north side where large amounts of sediment are deposited during storm events. Local residents have noted that the estuary has been gradually filling in over the last 30 years, with the January 1982 storm contributing a substantial volume of sediment to the estuary. Repeat surveys during this project indicate that the bed aggraded 1 to 2 feet over a two year period.

In addition to bed elevation, the composition of the bed in this reach appears to have changed in the last 30 years. Sediment sizes generally found in estuary/lagoon systems and coastal floodplains are sand, silt, and mud. The floodplains adjacent to the channel adhere to this convention. In 1970 the channel substrate through this lower reach appears to have been the typical fine-grained size distribution (Friese, 1971). Today the bed sediments are composed primarily of sand and gravel—a significant coarsening.

Tall dunes are located on the outer bank where the channel bends and begins to parallel the beach. The dunes and sand transition upstream to vegetated, high banks demarcating a stable floodplain. Repeat photography since the early 1970s (Figure 3.1.1), as well as aerial photographs from 1941, 1960, and 1980, show that the dunes and floodplain area on the south bank were once much more extensive. These high dunes would have provided protection from wind and wave washed sand. They also show a small island/side channel complex on the south bank. Since the 1970s the side channel has filled in with sediment, and the banks and dunes have retreated (Figure 3.1.1). Five to 10 feet of lateral bank retreat occurred downstream of the bridge over the project period, the majority taking place during the storm of December 31st, 2005. While the south bank and barrier beach has gone through cycles of deposition and erosion over the past 60 years the area of stabilized wetlands on the north bank has increased by 60% since 1941.

Early historical photos from the 1920s and accounts from the 1940s and 50s describe the lower estuary as deep and wide, with extensive tidal wetlands and channels. A snapshot of what this looked like in the 1920s is seen in Figure 3.1.2. Remnants of the tidal wetlands are still present in 1941 (Figure 3.1.3), but have disappeared by the early 1950s in the lower estuary. By the 1980s the channel-margin wetlands had aggraded to the extent that they are rarely inundated and are no longer connected to the channel. Increased sediment delivery from intensive land use and channel clearing practices in the upper watershed likely led to infilling of the wetlands and transition to upland habitat. Complex wetlands such as these provide diverse, important habitat for foraging, rearing, and high flow refugia. Loss of this habitat has reduced the ecological value of the system and has likely contributed to the degradation of the salmonid fishery.



Spring 1972

October 1979

June 1987

November 2002

March 2006

Figure 3.1.1 *Sequential photos of the lower Salmon Creek estuary. (1972-2002 photos: Copyright © 2002-2006 Kenneth & Gabrielle Adelman, California Coastal Records Project, www.Californiacoastline.org)*

Figure 3.1.2 *1920s photo taken from the first Highway 1 Bridge looking downstream at the lower estuary. Note the extensive tidal wetlands (dark area) covering much of the area in front of the high dunes. This diverse, productive habitat was quickly disappearing by the 1940s and completely gone from the system by the 1960s. (Photo provided by Charles Beck)*

Middle Estuary

Upstream of the bridge the channel narrows and is bordered by high, steep, heavily vegetated banks. Two deep pools (-1.0 feet NGVD) have formed at bedrock-controlled meander bends. Long, shallow runs connect the pools. Broad floodplains have developed on either side where small drainages enter the valley. Currently, seasonal freshwater ponds and wetlands develop in winter and spring along the valley walls, fed by overbank flows and tributary drainage. A larger, perennial pond is found on the south floodplain immediately upstream of the Highway 1 Bridge. Historically this pond area was connected to Salmon Creek by a tidal channel (Figures 3.1.3). A new bridge abutment constructed in the late 1940s filled a portion of the floodplain and effectively disconnected the pond from the mainstem. Evidence of small drainage channels in the north-bank floodplain were observed during the study, and were documented as active in 1971 (Friese, 1971).

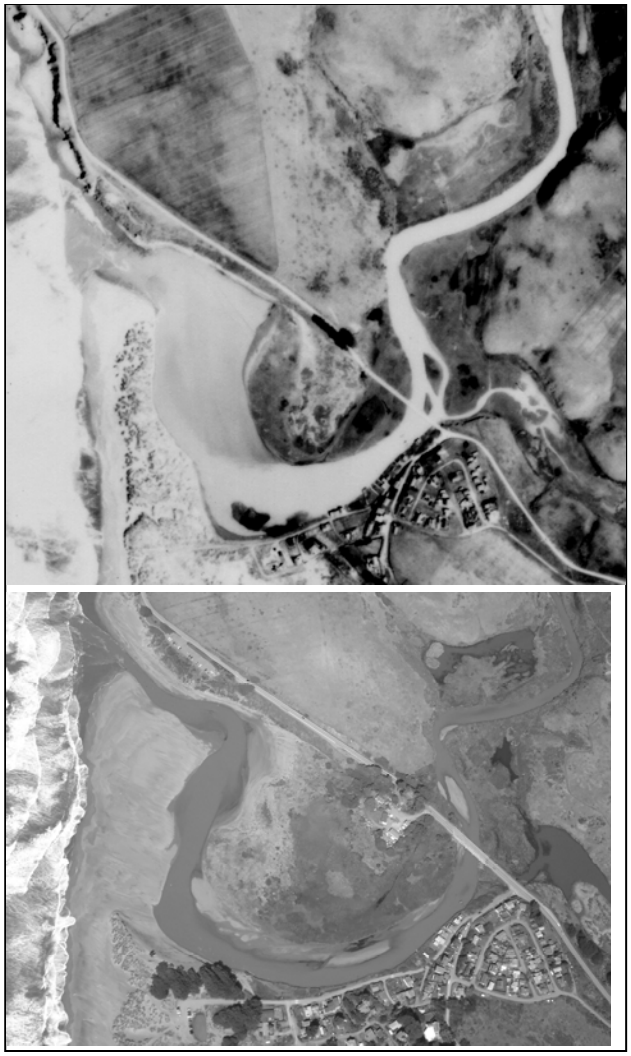


Figure 3.1.3 *Comparative photos of the lower and middle estuary from April 1941(upper) and March 2006. In 1941 several vegetated islands were upstream of the bridge and a tidal channel network was formed in the southern tributary valley. This area was disconnected from the main channel by the new bridge construction in the late 1940s.*

Maps from the late 1800s show the area of open water in the estuary to have been much larger, extending into what are now floodplains (Figure 3.1.4). If these maps are accurate representations of the estuary during the early settlement period the tidal prism was more than twice the current volume. The floodplain dimensions seen today were formed by the early 1940s (Figure 3.1.3). An exception is upstream of the bridge, where, in the early 20th century the estuary was wider with two islands and multiple side channels (Figure 3.1.5). By 1950 a new bridge was built, the channel had narrowed, and the floodplain resembles the current form.

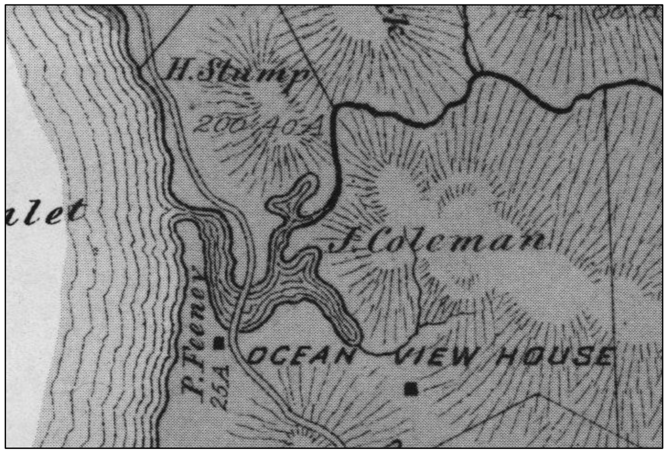


Figure 3.1.4 *1877 map of the Salmon Creek estuary indicating a large, open body of water. Southern and northern branches of the estuary shown in this map are now extensive floodplains and the lower estuary has narrowed.*

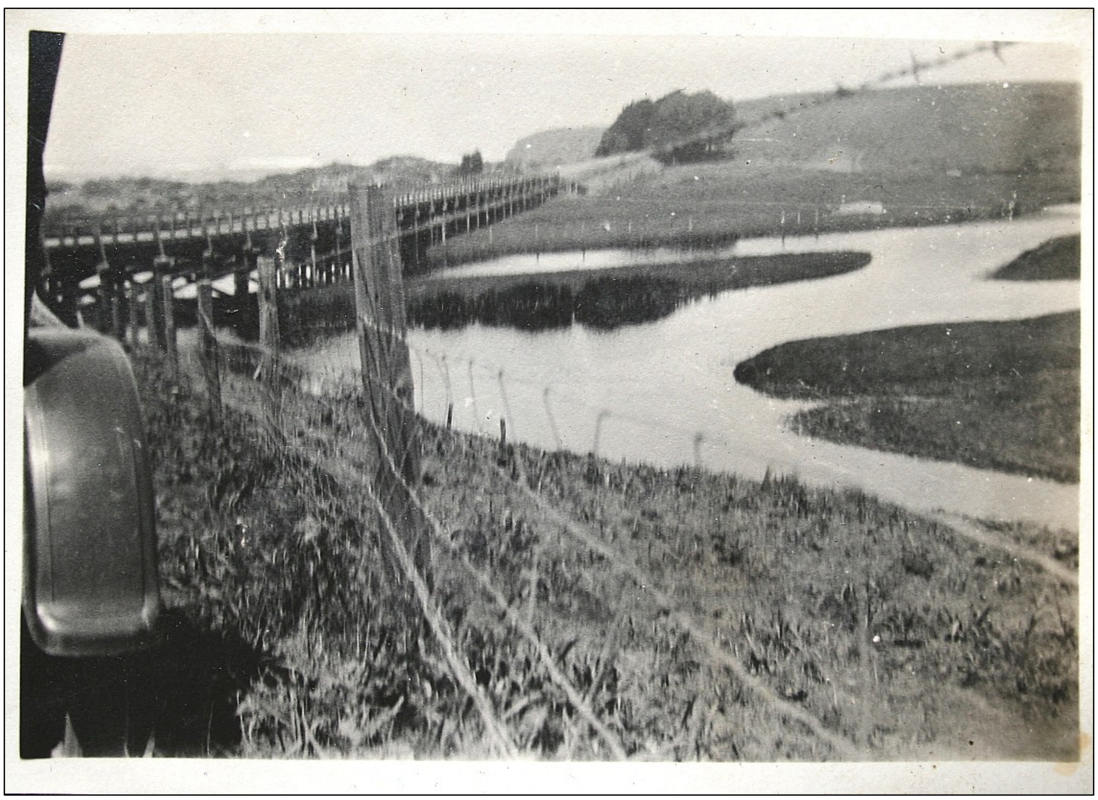


Figure 3.1.5 *1920s photo taken from Highway 1 looking south across the estuary. Note the vegetated islands, side channels, and bank elevations that are at the water surface elevation. All of these features provide complex habitat that supports a healthy ecosystem and strong salmonid population. (Photo provided by Charles Beck)*

The floodplain sediments in the middle reach appear to be similar to those in the lower estuary—fine-grained, interlayered silts and sands. Bed sediments are coarser and are composed primarily of gravel and sand. Gravel point bars are developing on inside meander bends and a large mid-channel bar has formed upstream of the bridge. This gravel bar aggraded two feet during the project period. As in the lower estuary, bed composition has coarsened from the sand and mud deposits described by Friese (1971).

Upper Estuary

The upper estuary is the transition zone from freshwater stream channel to estuary/lagoon system. In late summer freshwater flows into the lagoon near river mile 1.1, while during full lagoon conditions and high flow periods slow, saline water extends approximately 2 miles upstream. Pool/riffle sequences, alternate gravel bars, and low elevation floodplains characterize channel form in this reach. Several deep, bedrock controlled pools are found in this reach. Bed material ranges from silt to coarse gravel and cobble.

Lagoon Formation and Breaching

The timing, intensity, and volume of rainfall in the late spring (April-June) strongly influences barrier bar development and lagoon conditions. A detailed description of the interactions between rainfall, beach channel scour and deposition, and estuarine tidal action during the study period is found in the Water Quality Chapter. In 2004 the barrier bar closed in May after a very dry spring (1.9 inches, 35% of average) and conversion to a freshwater lagoon did not occur. In contrast, spring rainfall in 2005 was 220% of average (11.6 inches). The bar did not close until early August and streamflows were still adequate to largely convert the lagoon to freshwater. Implications of this for water quality and fisheries habitat is discussed in subsequent sections. The two extreme hydrologic conditions resulted in very different lagoon water surface elevations in the late fall. During the drought year of 2004 the lagoon water surface was 2 feet lower than in late summer/early fall 2005. In Figure 3.1.6, rainfall data from the period of record (1948-2005) shows the variability and distribution of spring rainfall totals.

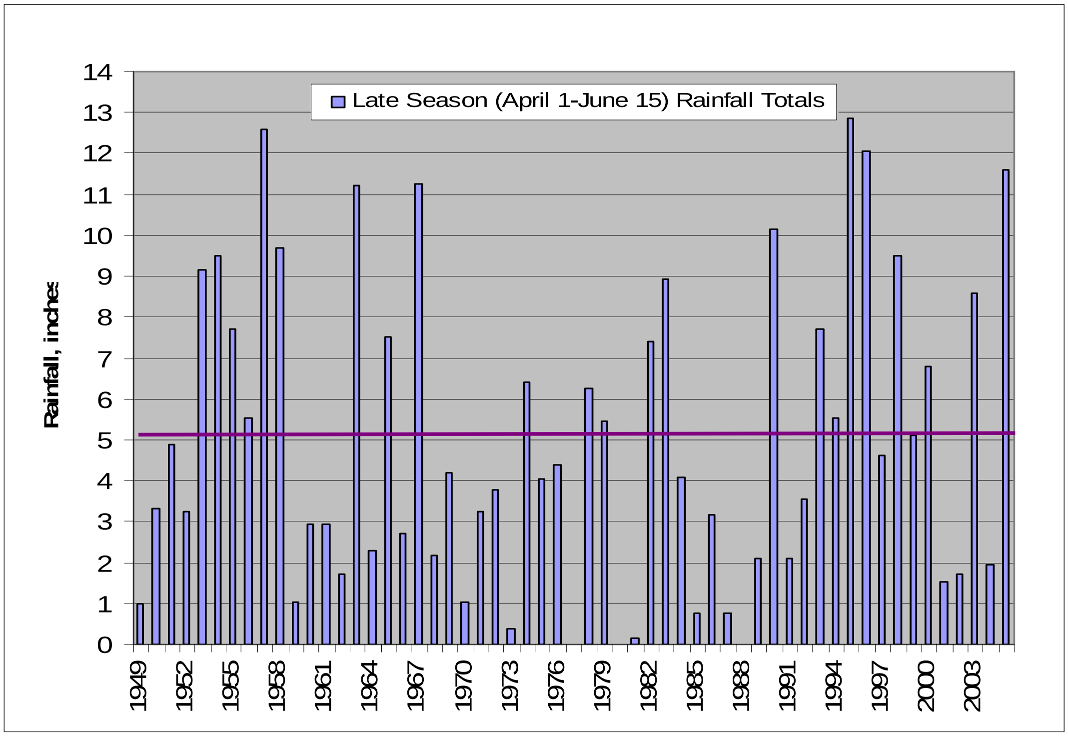


Figure 3.1.6 *Spring rainfall totals for the period of record. Higher rainfall during this part of the year translates to longer bar-open conditions in the estuary, higher lagoon elevations in the fall, and sustained summer streamflows in the upper watershed. Conversely, low rainfall during the spring means exacerbated summer drought conditions and poor in-stream and estuarine habitat.*

Fall sandbar breaching is governed by antecedent lagoon conditions and rainfall/runoff intensity and timing. Lagoon water surface elevation prior to the first rains influences the amount of streamflow required to raise the lagoon level to the barrier sandbar elevation for breaching. In fall 2004 and 2005 the barrier sandbar elevation was at approximately 11 feet. The volume of water in the lagoon at a water surface elevation of 11 feet is approximately 200 acre-feet. This represents the volume of water needed in the lagoon to breach the barrier sandbar. Under the drought conditions of 2004 the late summer lagoon volume was approximately 30 acre feet, thus 170 acre feet of additional water was necessary to raise the water surface to the sandbar crest. In 2005 the antecedent lagoon volume was 65 acre feet, requiring an additional 135 acre feet to breach.

The breaching conditions were reconstructed for fall 2005 using estuary stage data, daily streamflow at the estuary as estimated (watershed area ratio) from discharge at Bodega, rainfall, and an approximation of loss through the barrier beach. Loss from evaporation and sandbar seepage was estimated to be 5 acre feet per day. This was based on the daily inflow volume during a three week period of stable lagoon elevations, and is comparable to flow rates calculated using standard groundwater formulas. Figure 3.1.7 illustrates the inflow/lagoon volume/breach relationship for fall 2005. It appears that the sandbar breached after approximately 180 acre feet of water had accumulated in the lagoon from rain induced streamflow increases.

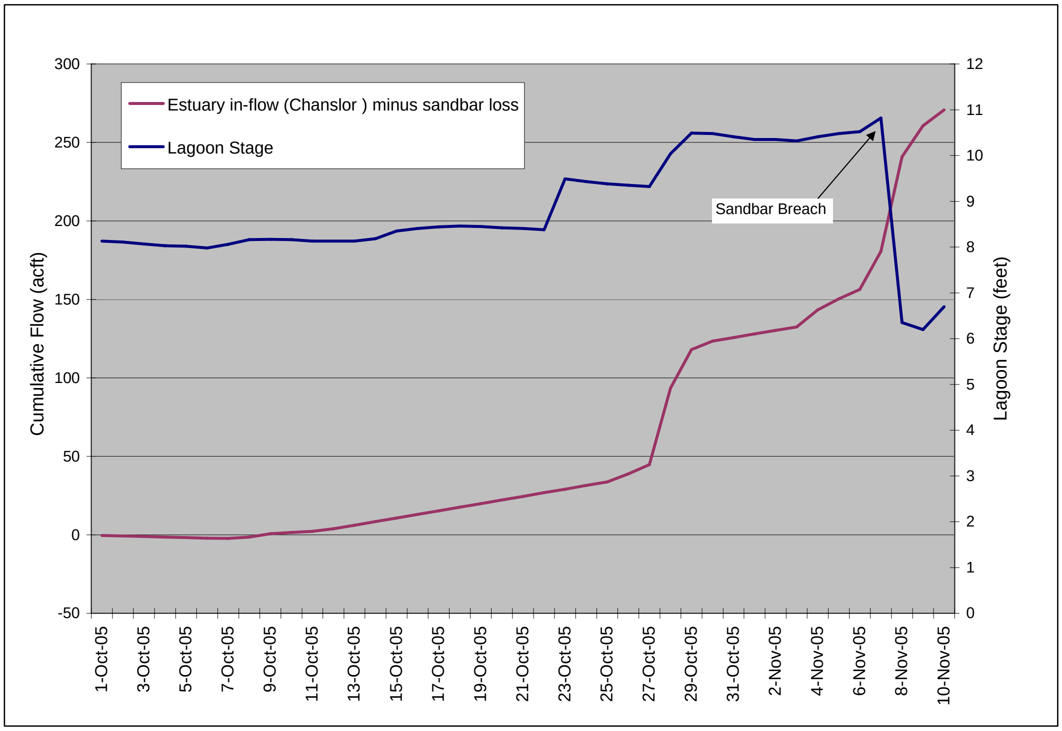


Figure 3.1.7 *Lagoon water surface elevations pre- and post-breach 2005 as they relate to stream flows. The sandbar breached on November 8th. Cumulative inflows were calculated to be approximately 180 acre feet at the time of breach. Given the level of approximation in these estimates, this correlates well with the volume of 135 ac ft needed to fill the lagoon.*

Historical early-season streamflow accrual in the lagoon from October 1st to December 15th was calculated for 1962 through 1974 using flow records at Bodega (USGS Station 11460920 SALMON CREEK AT BODEGA CA). As for the 2005 data, the Bodega streamflows were ratioed by watershed area to reflect the additional contributing tributaries between Bodega and the estuary. Cumulative runoff minus the daily sandbar seepage loss was plotted for each of the eight years of record along with daily rainfall totals (Figure 3.1.8). From these graphs the amount of rainfall that produced runoff conditions required to breach the barrier sandbar was ascertained. Seasonal rainfall totals that produced a minimum of 200 ac ft of storage in the lagoon (the generalized breaching volume) ranged from 9 to 13 inches, with an average of 10 inches. This rainfall value also appears to represent the soil saturation point for the watershed, in that streamflow increases rapidly with any subsequent rainfall.

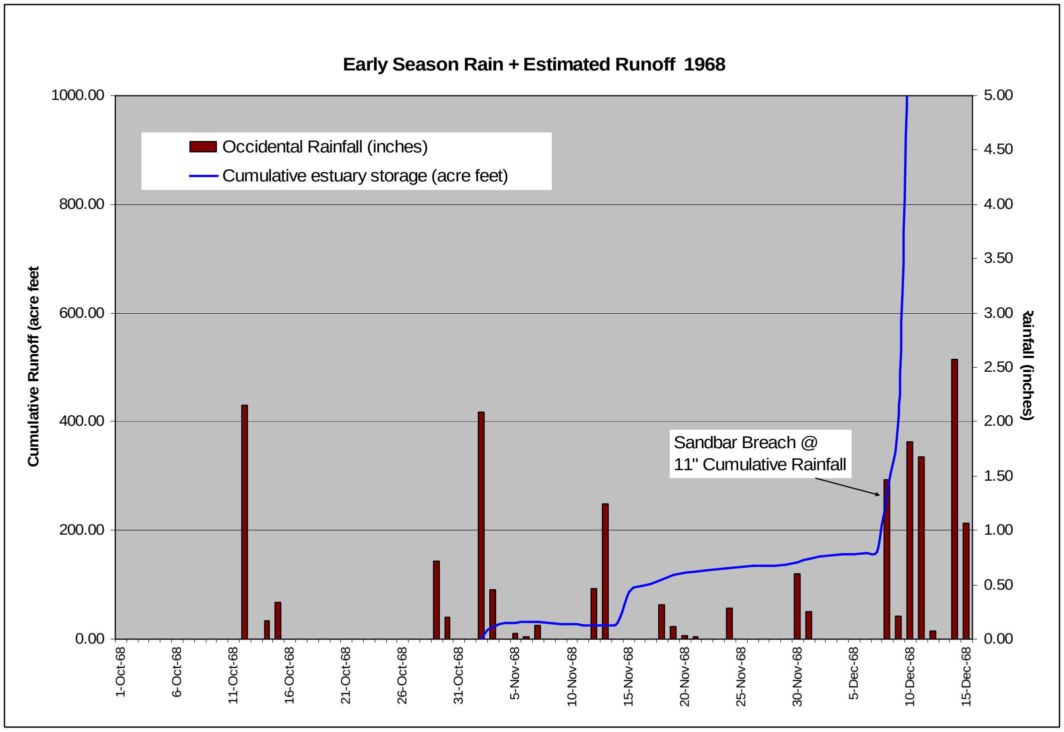


Figure 3.1.8 *Example of rainfall/runoff graph used to determine the cumulative rainfall preceding lagoon breaching. As illustrated in this example, runoff during the first rainfalls of the season is minimal, as the majority of the water infiltrates the soil. When the ground reaches saturation, streamflows respond and the flow volumes entering the estuary increase exponentially. Thus, any significant rainfall after the watershed is saturated will likely initiate breaching, regardless of variation in estuary size or antecedent lagoon conditions.*

Early season daily rainfall was cumulated for each year of record for the watershed (1948-2005 @ Occidental) to determine the date on which 10 inches of rainfall was reached. Four years during the period of record have incomplete datasets (1977, 1978, 1980, and 1999). The estimated breaching dates based on watershed saturation of 10" of rainfall are plotted in Figure 3.1.9. During the past 58 years the Salmon Creek lagoon breached on average by December 3rd (median date is November 30th). October 10th, 1957 is the earliest opening on record, and February 21st, 1976 the latest. These are approximate dates of breaching, as the system is driven by the complex interactions of antecedent hydrologic conditions, date of lagoon closure, summer lagoon volume, and changes in estuary size over time. The breaching dates in the figure can only be considered an indicator of the initial breach date. The barrier sandbar may reform after initial breaching depending on rainfall patterns and watershed conditions. An example of this was the winter of 2004/2005; initial breaching occurred on December 8th after a cumulative 14 inches of rain. The bar closed again two days later and did not reopen until December 27th when an additional 4 inches of rain fell.

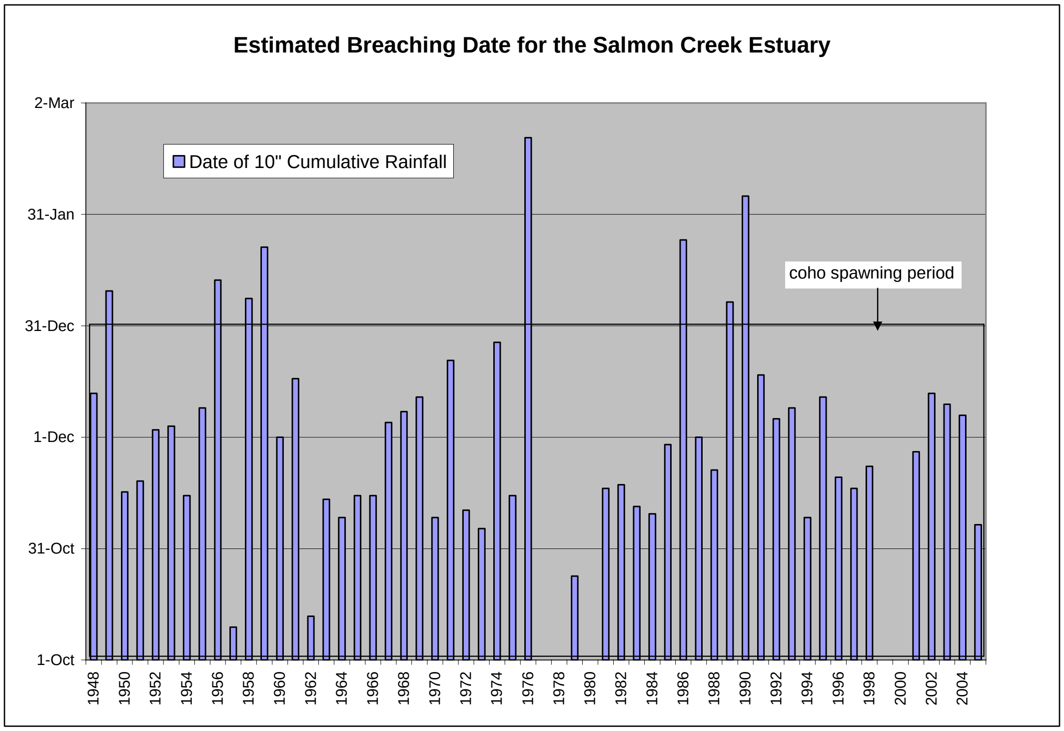


Figure 3.1.9 *Dates of initial sandbar opening each fall from 1948 through 2005. It does not appear that the average timing or variation in estuary breaching has changed significantly in the last 60 years. In half of the years there is at least a one month window for coho to enter the watershed for spawning. Occasionally the bar does not open during the coho run period.*

The sandbar breaching analysis, as shown in Figure 3.1.9, is based on a rainfall/streamflow/lagoon-form dynamic that is present under today's conditions. Using the data available, timing of initial sandbar breaching varies annually within a five month period. There are no observable, significant shifts in the timing of the breach over the period of record (as based on 10" rainfall accumulation date). The average annual breach date (December 3rd) does not change from first 30 years of record to the last, while the median date shifts 4 days; from December 2nd to November 28th.

Have the breaching dynamics changed in the last 30 years? Historical anecdotal stories say that prior to the 1970s the locals would manually breach the sandbar to let in the salmon that were gathering off shore, and that "they always had Salmon for Thanksgiving". It is likely that the summer lagoon water surface was higher than we see now because of higher summer inflows, and thus would require less rainfall-augmented streamflows to initiate breaching. It is also possible that today's smaller tidal prism does not initially flush a deep enough breach channel to allow migratory passage; creating a half-closed, overflow mouth instead of a deep, sustained channel.

3.2 *Upstream Factors* ***(prepared by Lauren Hammack)***

Introduction

Streamflow and turbidity in the upper watershed, and their influence on estuary habitat conditions, were assessed during this study. The quantity of freshwater entering the estuary is the primary factor determining habitat quality and dynamics of lagoon formation and breaching. Local memories of the system in the 1950s, 60s, and 70s suggest that summer freshwater flows were much higher than typically occur today, and that even during drought years there was sufficient inflows to keep lagoon levels high (interviews w/ Charles Beck and Dr. Cadet Hand, 2006). Population growth in the watershed, and associated increases in water consumption, has likely reduced dry season flows. Adequate streamflow in the lower watershed, immediately upstream of the estuary, is critical for providing fresh, cool, oxygenated water to upper pools and the lagoon. The local community and government agencies have expressed concern over private and public water supply wells located adjacent to the creek throughout the watershed. Observers have noted that the streambed near Bodega Bay's public supply well, located ~ upstream of the estuary often goes dry in late summer while other reaches still have flow. The effect, if any, of groundwater pumping on streamflow was investigated.

In addition to decreased summer flows, increased sediment loads from the upper watershed have contributed to reductions in summer rearing habitat. As discussed in Chapter 3.1, the areal extent of the estuary has dramatically decreased since the mid 1800s. By the 1940s the estuary had narrowed considerably since historic times, with the northern and southern branches transitioning to marsh and floodplain features. Up until the 1950s and 60s the channel, however, was still deep; with depths of 6 to 12+ feet during summer lagoon conditions (interviews w/ Charles Beck and Dr. Cadet Hand, 2006). Annual winter storm events transport gravels and sand from the upper watershed, gradually filling in the upper and middle estuary. Over the study period 2+ feet of sediment was deposited upstream and downstream of the Highway 1 Bridge. Summer lagoon depths now range from 2 to 6 feet, with a few deeper pools.

While coarse sediment delivery has caused aggradation of the estuary bed, fine sediments suspended in the water can impair juvenile salmonid growth, feeding, and territorial behavior. Excessive turbidity in the system can delay upstream migration of adults and impede spawning behavior. Turbidity levels in the watershed were documented and analyzed for salmonid impairment.

Methods

Initial plans to document streamflows entering the estuary and the effect of well pumping on those streamflows involved monitoring of surface flows at multiple sites in the vicinity of the Bodega Bay Public Utility District (PUD) groundwater wells. By mid July 2004 it became apparent that streamflow was going to drop below easily measurable levels. An alternative method was devised. Water table monitoring wells were installed at four locations within a 1000 foot reach of channel adjacent to the PUD wells (Figure 3.2.1). Perforated PVC pipe was installed to a depth of 8 feet in the gravel bars and pressure transducers were dropped down the observation well. The water surface level loggers recorded water depths at 30 minute intervals. In 2004 the level loggers were installed on July 30th and removed on October 29th. The wells were sealed for the winter. Three loggers were reinstalled in July of 2005 and ran from July 13th through November 2nd. Topography of the study reach was surveyed, and included elevations of the wells in relation to important channel features.

***Figure 3.2.1** Location of observation wells in relationship to the Salmon Creek estuary.*

Higher in the watershed rainfall, streamflow, and turbidity was monitored with continuous loggers. Flow and turbidity monitoring equipment was installed in early December 2004 in Freestone and Bodega. Flow stage was recorded at these sites at half hour intervals through December 2005. Discharge measurements were taken at both Freestone and Bodega over a range of flows and a stage/discharge rating curve was produced for Bodega. The compilation and use of the discharge and rainfall data is described previously in more detail (Chapter 3.1).

The turbidity sensors experienced catastrophic failure due to a manufacturers defect. Thus, continuous turbidity was not collected. To compensate for this loss of data a hand-held turbidimeter (Hach 2100P) was used to collect longitudinal profiles of turbidity at single points of time during storm events. Volunteer water quality monitoring data at discrete locations throughout the watershed was also examined.

Groundwater Withdrawals

Severe drought conditions were present in the summer of 2004. Spring rainfall totals were 35 percent of normal. Streamflows declined rapidly throughout the watershed. Continuous monitoring of the water table elevation captured the decline over a 3 month period (Figure 3.2.2). By mid August the riffles were dry, disconnecting the pools. In early September the pools in this reach dried completely. At its lowest point in the season, the water table was a foot below the channel bed. Stream and water table levels were very different in 2005 after a very wet spring (4^{th} highest on record). The water table remained at a stable level throughout the season (Figure 3.2.3). In both years the first significant rainfall event produced a noticeable change in the water table—in 2004 it brought the level up 3 feet.

Additional observation wells were installed 350 ft upstream and 450 ft downstream of the PUD water supply well (Figure 3.2.1). In 2004 the water table decline pattern was consistent in all three observation wells, with maximum water surface lowering over the study period of 2.5 ft at the upstream and middle wells and 2.0 ft at the downstream well. In 2005 the shallow water table remained relatively stable at the three observation wells over the measurement period, similar to what is seen in Figure 3.2.3.

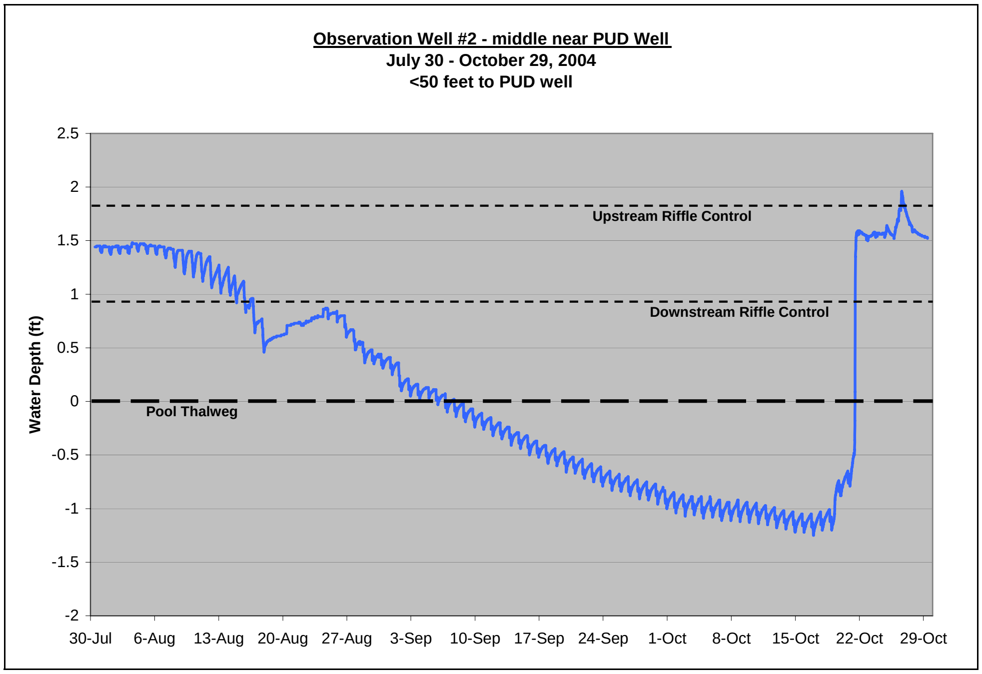


Figure 3.2.2 *Water table levels upstream of the estuary in late summer 2004. Timing of pool disconnection and drying is shown when the water levels go below the feature elevations, as well as water table response to the first rain of the season. Daily fluctuations appear to be responses to periods of well pumping.*

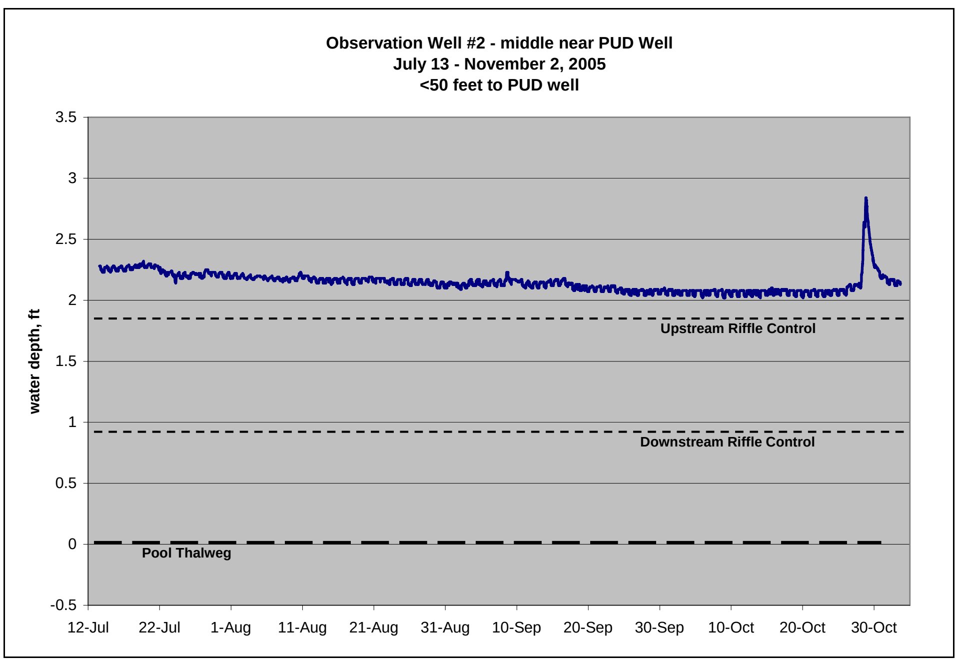
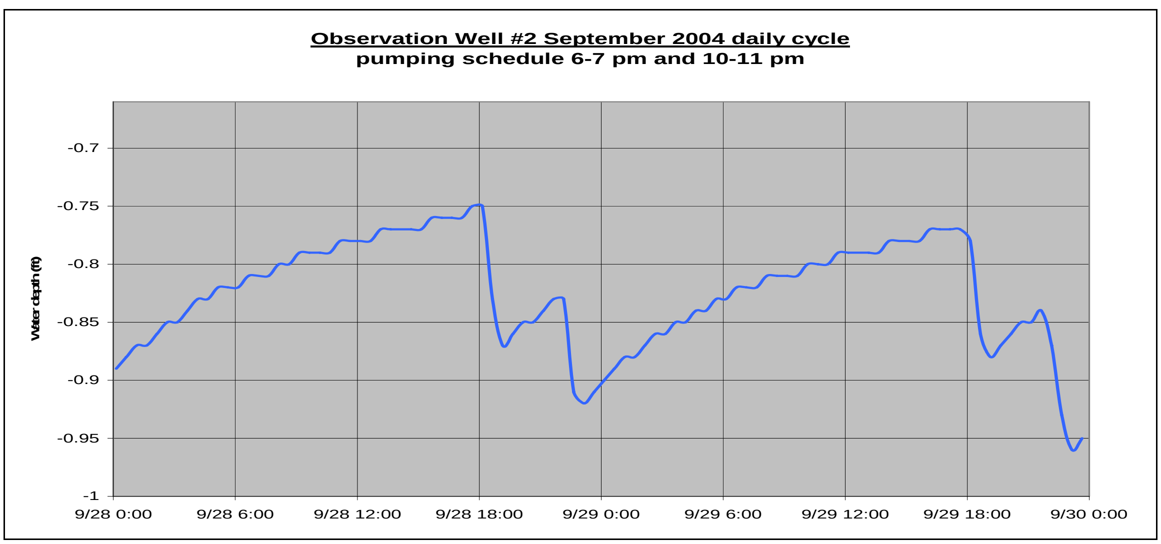


Figure 3.2.3 *Water table levels in summer 2005. A wet spring kept the stream and shallow groundwater levels high and consistent through the season. Flows remained well above pool and riffle elevations. Daily pumping of the wells is detectable in the daily fluctuations.*

Daily fluctuations in the water table are observable in the recordings. The daily patterns are very different between the two years (Figure 3.2.4) and were analyzed against possible fluctuations due to water uptake from the riparian vegetation for photosynthesis, tidal cycles, and groundwater pumping from the adjacent well. Lowering of the water table during daylight hours would be expected if the pattern was due to photosynthesis activity of the riparian willow and alder community. In both years the water table declined only at night. Nor were the patterns consistent with tide cycles. The periods of decline and recovery do correspond closely to the PUD well pumping schedule and are illustrated in Figure 3.2.4.

The daily response of shallow groundwater levels to the PUD pumping cycle (Figure 3.2.4) is also observable in the upstream and downstream wells in 2004; indicating that shallow groundwater flow in the area was very low, and thus the water supply withdrawals had a large area of influence during this drought season. In 2005 the downstream observation well was not reoccupied and an additional well was installed 1100 feet upstream of the PUD supply well. The daily pumping cycle is not observable in the 2005 upstream well logs. Shallow subsurface flow was strong throughout the summer, as it was able to maintain a stable water table and nullify the effects of local groundwater withdrawals.



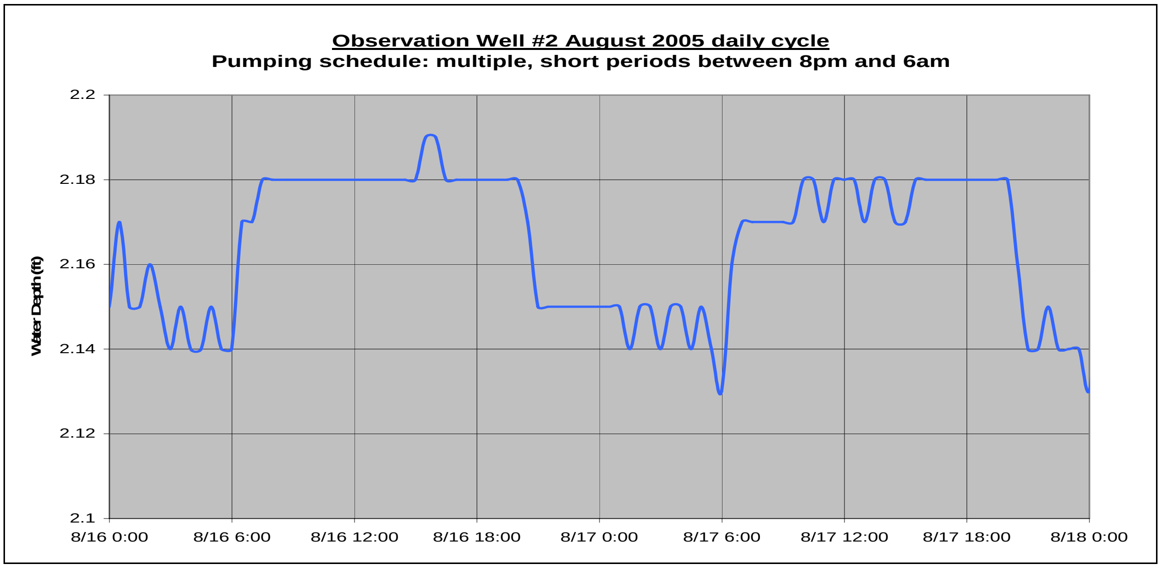


Figure 3.2.4 *Examples of daily water table fluctuations in 2004 and 2005. Pattern differences are related to changes in water supply well pumping routines between the two years. Note that in the drought year (2004) the fluctuations were over 2 tenths of a foot, while in the wet year (2005) the fluctuations were only over 6 hundredths of a foot.*

These results indicate that the groundwater well adjacent to the creek does have an effect on local water table levels during pumping. The drawdown and inability of the water table to recover appears to be more pronounced during drought years when groundwater recharge volumes and head is significantly decreased. Streamflow levels at any point in the stream network are determined by surface flows from upstream and the groundwater conditions locally. Shallow groundwater flow rates and volume is a function of topography, bedrock type, and depth and composition of the alluvial fill in the valley. During drought years the groundwater conditions along the channel are such that a large cone of depression and zone of influence forms around the water supply wells. Groundwater flow is not sufficient to recharge the system after pumping and the water table elevation gradually declines over time. This reduces the amount and quality of water available for habitat in the immediate area of the wells as well as downstream to the estuary.

The study site is at the bottom of the watershed, directly upstream of the estuary. Adequate freshwater flows in this reach are critical to summer rearing habitat in the downstream pools and lagoon. Streamflows at this point are a result of all the water diversions and extractions occurring in the whole watershed, as well as the adjacent well withdrawals. This shallow groundwater investigation was limited in extent, and a quantitative analysis of the effects of the groundwater pumping at this site cannot be made. However, the data does show that the aquifer that the well is withdrawing from is connected to the shallow groundwater and that the water table is highly responsive to extractions. During low flow, or drought, conditions the streamflow is highly dependent upon local groundwater contributions, while in wet years the in-channel flow and shallow groundwater will sustain some instream flow.

Turbidity

Base-flow turbidity during the summer and between winter storms is typically below 10 NTUs throughout Salmon Creek. This is well within the levels considered to be beneficial for juvenile and adult salmon. During storm events turbidity increases appreciably, with watershed-averaged turbidities ranging from 150 to 400 NTUs (Figure 3.2.5). Instantaneous peak turbidity values often go above 1000 NTUs and have sustained periods of 150 to 600 NTUs. Measurements of turbidity at fourteen sites within the watershed during high runoff indicate that there are extended periods of "significantly impaired" conditions for Salmonids during storm events in both the mainstem and tributaries.

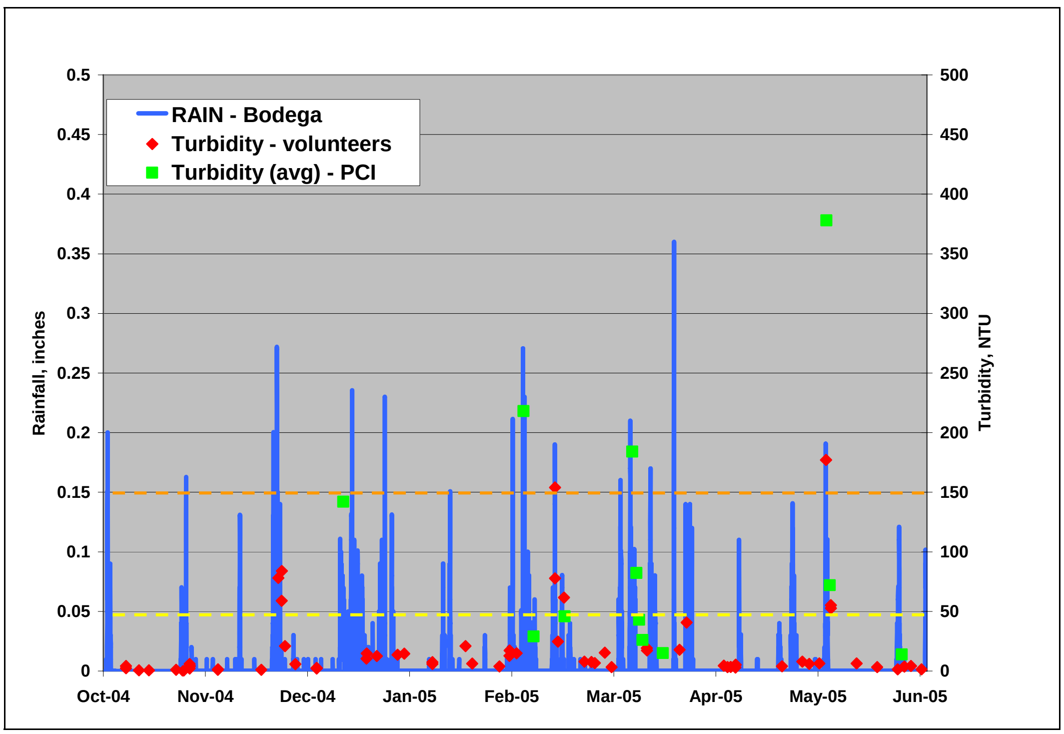


Figure 3.2.5 *Turbidity in relation to rainfall in the Salmon Creek watershed. Slight impairment of salmonids occurs under turbidity conditions above the yellow line and significant impairment occurs above the orange line (see Figure 3.2.6)*

Newcombe (2001) has developed an empirical model to assess the severity of impacts caused by increasing the duration and concentration of suspended sediments (Figure 3.2.6). He found that the longer fish are exposed to high concentrations of fine, suspended material that reduces clarity of the water, the greater the ill-effects. Chronic mid-level turbidity (50-100 NTUs) can have much the effect on the fishery as a short period of very high turbidity (1000 NTUs). Suspended sediment in the water can contribute to marked declines in the entire aquatic ecosystem. Direct effects include mortality, reduced physiologic functioning, and habitat alienation. Decreased growth rates (from reduced food supply) and reproduction are indirect effects of high turbidity.

Figure 3.2.7 shows turbidity levels and their approximate duration in the lower estuary during three storm events in spring 2005. Widespread erosion from roads, slides, gully, and channel banks in the upper watershed produces high turbidity in the stream and estuary. The elevated turbidity during storm events may contribute to reductions in the fishery by indirect or direct impairment of juvenile and adult salmonids. Adults may wait to enter the estuary and watershed until the waters clear to more favorable levels, thereby reducing the time and opportunities for spawning. Juveniles entering the estuary to feed and prepare for transition to the ocean will experience reduced feeding opportunities and potential physiologic impairments that will lessen their survivorship. No turbidity refuges currently exist within the estuary or upper watershed.

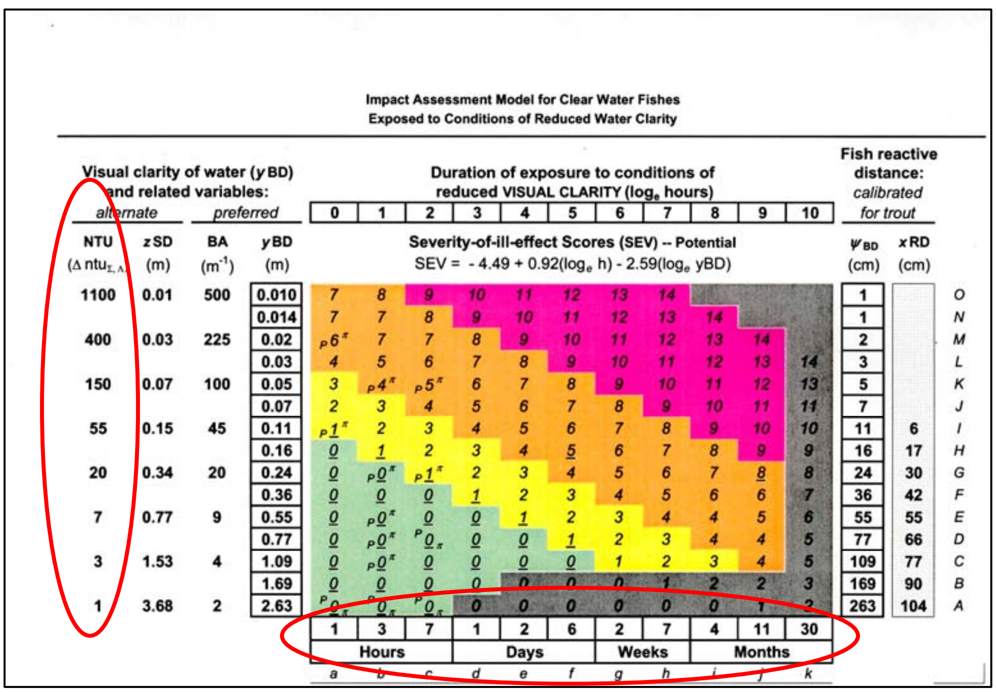


Figure 3.2.6 *Newcombe's (2001) turbidity impact model. Severity of impact to salmonids and other clear water fishes increases with NTU (y axis) and time (x axis). Green indicates ideal conditions, yellow slightly impaired, orange significantly impaired, and red is severely impaired. Increasing severity leads to reduced growth and habitat, and/or physiologic impairment.*

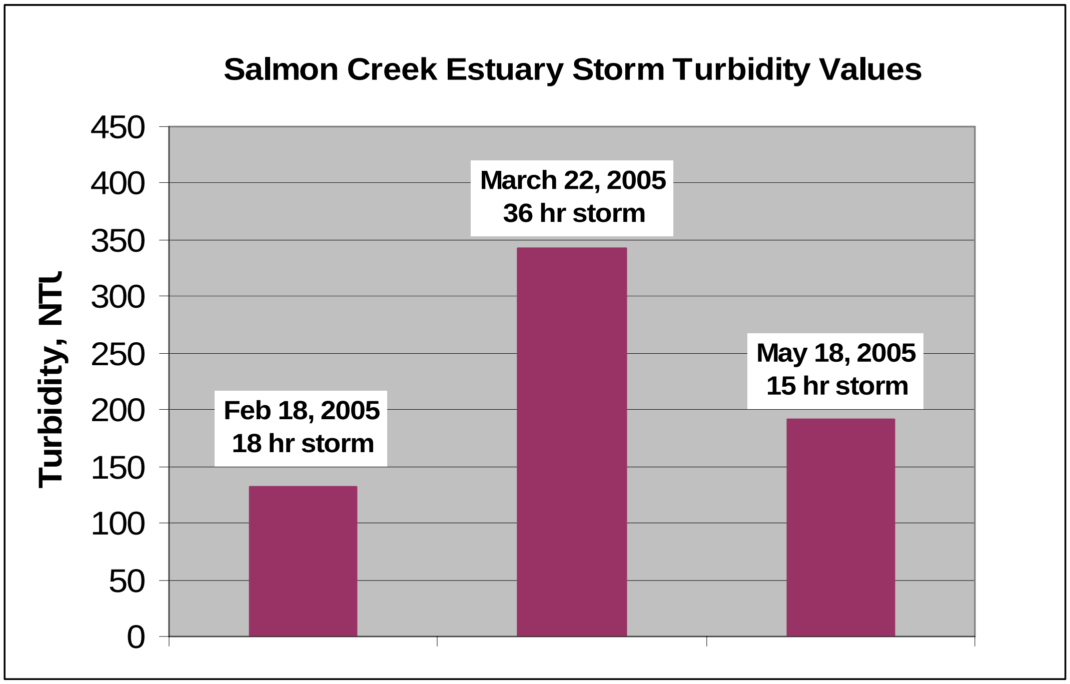


***Figure** 3.2.7 Examples of turbidity values and durations during three storm events in 2005. Conditions within the estuary during these periods were slightly- to significantly impaired for Salmonids. Habitat alienation and physiologic impairment occurs at these levels.*

3.3 Water Quality ***(prepared by James C. Roth)***

Note: Complete figures for Section 3.3 are located in Appendix B

Introduction

Water quality in the Salmon Creek estuary was studied intensively for one year beginning in June 2004. Monthly profiles were made of temperature, salinity, and dissolved oxygen at six sampling stations between the estuary mouth and the upstream limit of tidal action near the Chanslor Ranch. Continuously-recording datasondes placed at three stations logged the time course of signal water quality events in the near-bottom environment. The first data were collected on 3 June 2004, shortly after the growing beach berm closed the estuary mouth, and monthly cruises were made thereafter. Regular monthly sampling ended on 1 June 2005, at which time datasondes and tidbit recorders were removed. Stage recording was continued through the summer of 2005, however, and this report includes stage data through 22 September 2005, as well as water quality profiles made on that date. Water quality sampling stations were located in deep pools, and ranged from the estuary mouth upstream to near the observed upstream limit of seawater excursion.

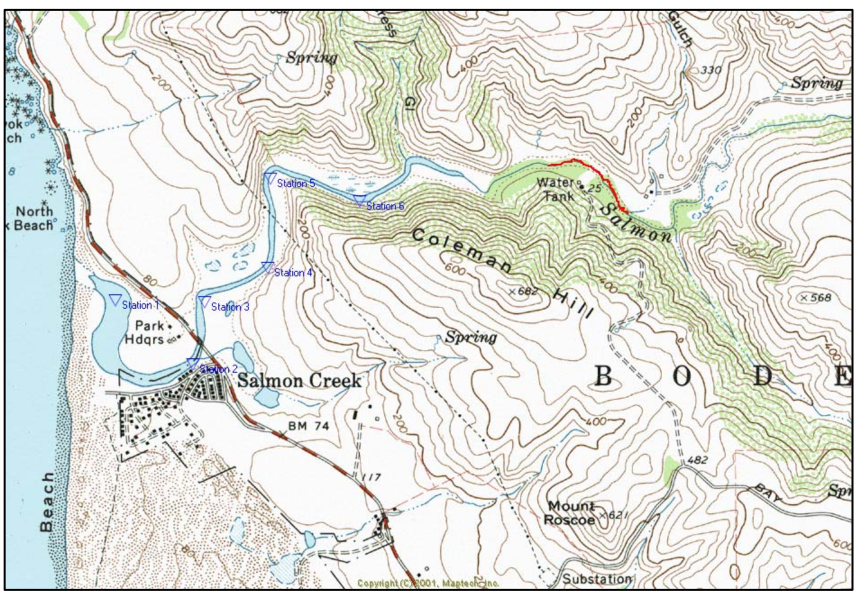


Figure 3.3.1 *Study area with sampling stations indicated by blue triangles. Red track indicates the freshwater study reach near the off-channel well.*

Methods

On each sampling date profiles of temperature, salinity, and dissolved oxygen were made at half-meter intervals from the surface to just above the bottom, using YSI meters. Profiles were made at each of six sampling stations. Recording datasondes (Stations 1-3) or Tidbit temperature recorders (Stations 4-6) were deployed on 3 June at each station, logging hourly data. The datasondes (Hydrolab Datasonde 3) recorded temperature, salinity, and dissolved oxygen just above the bottom. They were downloaded and serviced on each subsequent monthly visit. The water level in the estuary was measured relative to an arbitrary mark made on one of the Highway 1 bridge piers. These levels were later converted to stage data when a stage recorder was installed. Stage data are roughly equivalent to feet above Mean Lower Low Water (MLLW). Rainfall in the Salmon Creek watershed is based on data from gauges in Bodega, Willow Creek Road, and Freestone. For dates when data are available from more than one of these stations, the daily means have been used.

Results

Based on the station locations and the water quality results, the estuary can be divided into three habitat zones:

- The lower estuary (Station 1)
- The middle estuary (Stations 2 and 3)
- The upper estuary (Stations 4, 5, and 6)

Because the condition of the sandbar or beach berm located at the mouths of small estuaries in California is a major determinant of water quality conditions in the estuaries, the results of this study are presented in terms of the alternating states, bar-open (i.e., mouth open) vs. bar-closed (mouth closed).

Water Quality in the Salmon Creek Estuary during Bar-Closed Conditions, June 2004 through November 2004

<u>The Lower Estuary</u>

The lower estuary is the broad and relatively shallow area adjacent to the beach berm. This section is exposed to the wind—brisk most afternoons—which keep it unstratified when the berm isolates it from tidal action. Sampling station 1 was located in the deepest part of the lower estuary (~ 2 m deep on 3 June 2004). On 3 June the water column was stratified, and the profile represents conditions established before the beach berm closed: warm fresh water overlying cool salt water, with dissolved oxygen near saturation from top to bottom. By early July most of the water column had mixed, and surface salinity was around 7 ppt.

Profiles made in August, September, and October show a well-mixed system, with cool (15-20 °C), brackish (~ 7 ppt), and well-oxygenated water from surface to bottom.

Datasonde records at Station 1 show the time course of signal events in the lower estuary. In June and early July on at least four occasions, seawater (high salinity and low temperature) spilled over the berm. These dates coincide with the highest (spring) tides, and probably also with high surf events. None corresponded to neap tides.

After 4 July the beach berm had achieved sufficient height to prevent additional seawater incursions. By 10 July the lower estuary was well-mixed, and it remained so all summer and fall. During this period the salinity was constant, and the temperature showed a diel variation of about 2-3 °C. Dissolved oxygen ranged from around 5 ppm at night to around 10 ppm during the day. The lower estuary in summer had cool temperatures, moderate salinity, and adequate dissolved oxygen. It was thus a relatively benign habitat for fish in terms of water quality.

Salmon Creek flows were very low in the summer of 2004, and the water level in the estuary in the summer of 2004 fell steadily after the berm closed. At Station 1 (the deepest part of the lower estuary) the maximum depth from August through early October was only 1.5 m. On 1 November the beach berm was intact and its crest was ~ 2 m above the water level in the lower estuary. On that date, near-bottom waters at Station 1 showed increased salinity, as well as higher temperatures and dissolved oxygen values. The October datasonde trace shows that the warm, salty water entered the system on 20 October and 27 October. These came immediately following the first two rainstorms of the season, which occurred on 19 October and 26 October (Figure 3.3.2). Salinity increases in the bottom of the lower estuary in October resulted not from seawater incursions over the berm, but from high salinity water being flushed from stratified pools upstream following rains. The water level rose over 0.5 m following the October rains, but did not breach the berm. Saltwater was also flushed down following rains in mid-November, but the berm was not breached until early December.

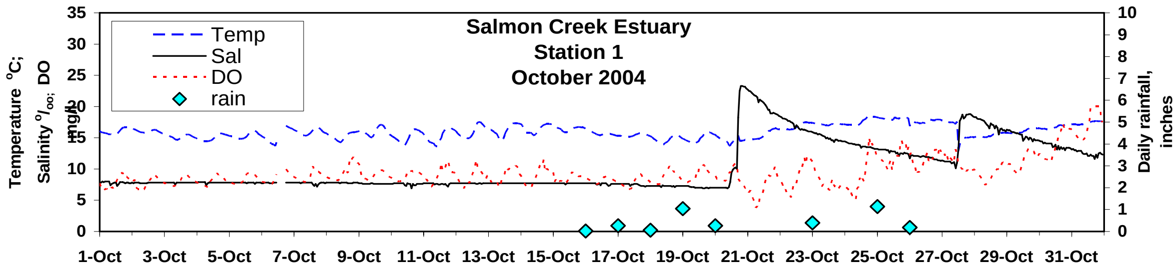


Figure 3.3.2 *October, 2004 records show two peaks of saline water entering the lower estuary from upstream. These peaks followed rain events; the beach berm has not been breached to allow tidal waters to enter the estuary.*

The Middle Estuary

The middle estuary is the relatively narrow section just upstream of the broad lower estuary. Being narrow it provides less fetch to the wind, and in summer growth of the pondweed *Ruppia spp.* (ditch grass or wigeon grass) is much more extensive than in the lower section. *Ruppia* in the middle zone in summer fills the entire water column. These features combine to prevent vertical mixing in middle zone pools, and they remained strongly stratified throughout the summer and fall. Sampling stations in the middle zone were located near the old piers on the south side just downstream from the bridge (Station 2, 2.5 m deep on 3 June 2004), and on the north side near the bend with willows ~ 60 m upstream of the bridge (Station 3, 3.5 m deep on 3 June 2004). Conditions at Stations 2 and 3 proved to be substantially similar; the following discussion is based primarily on data from Station 3.

On 3 June 2004 most of the water column was salty (~ 25 ppt), with a layer of relatively fresh water in the near-surface meter of the water column. The bottom waters were cool (17.5 °C) and dissolved oxygen levels were high. This represents conditions established while the berm was still open and tidal exchange occurring. The salinity gradient provides a large resistance to mixing, and conditions in the salty layer soon developed in a striking manner. The lower layer began to heat up, so that temperatures as high as 30 °C occurred after only 1 month of stratification, and reached 31.6 °C by September. The mechanism of heat accumulation in salty water overlain by a freshwater layer is well known and is the principle behind the "solar pond," which has been used as an alternative energy source in hot climates. The freshwater layer acts like a lens, which focuses solar radiation to the salty layer where heat accumulates because the stratification prevents exchange with surface layers. Concomitant with this heating of the saline layer, the near-bottom dissolved oxygen became reduced, and was depleted for most of the summer and fall. However, dissolved oxygen in the upper part of the salty layer was extremely high, due to photosynthesis by *Ruppia* and algae growing in and on it. On several occasions dissolved oxygen levels in the warm, salty layer were highly super-saturated—off-scale on the meter (> 20 ppm)—during daytime profiles.

Datasonde records from Station 3 clearly show the steady increase in near-bottom temperature from ~ 16 to 28 °C during June. The datasondes were deployed on racks which were intended to place the probes close to, but not in contact with the bottom (within 15 cm). However inspection of the datasonde rack after the 1 July to 11 August deployment indicated one end of the rack had been exposed to anoxic sediments and the other was not so exposed. This indicated that the rack was standing on end during that period, and the probes were therefore located about 75 cm above the bottom, not closer to it as had been intended. The high density of the *Ruppia* probably played a role in maintaining the vertical position of the rack. Although deployment of the probes 75 cm above the bottom was inadvertent, it proved to be serendipitous in that it illustrated how greatly the dissolved oxygen levels can vary within a few vertical centimeters in the salty layer. On several occasions during the first half of July the dissolved oxygen within 75 cm of the bottom was off-scale (>20 ppm; these are plotted as 20 ppm). After the datasonde was redeployed on 11 August (now weighted to insure probes were 15 cm above bottom), the records indicate that the water near the bottom was anoxic, and it remained anoxic or nearly so for the rest of the bar-closed period. There was a slight increase in near-bottom dissolved oxygen (to ~ 2 ppm) in September, which was probably due to photosynthesis, since it appeared to have a diel component. The datasonde records for Station 3 do not show when the near-bottom water became anoxic because this occurred while the probe was higher in the water column. However, based on events at the other stations, anoxia probably occurred sometime in July.

These data indicate that pools in the middle estuary do not provide much reliable habitat for fish. Much of the water column is too warm, and furthermore, is either anoxic or so high in dissolved oxygen that it may become toxic to fish. Only a relatively narrow zone about one meter thick near the surface is suitable for occupation by fish. However, *Ruppia* provides some cover for fish in this zone.

Increases in salinity in the lower zone following rainstorms in October evidently eroded the upper part of the salty layer in the middle zone, but the runoff was insufficient to overcome the stratification in the middle zone.

<u>The Upstream Estuary</u>

Upstream from Station 3 the estuary is quite shallow in summer but a few pools scoured in bends are deeper, and the upper stations (Stations 4, 5, and 6) are located in such pools. The development of stable stratification in upper estuary pools in the summer of 2004 was similar to that found in the middle zone in that a lower layer of salty and very warm water developed which is anoxic at the very bottom but very high in dissolved oxygen just above the bottom. However, pools in the upper zone differ from those in the middle zone in that the bottom salinity is lower and the salty layer is not as thick. The maximum salinity in the bottom layer at Stations 4, 5, and 6 was ~ 23, 14, and 10 ppt, respectively. This discussion will focus on conditions at Station 6, the uppermost station. Station 6 is located on the north side of the channel just upstream of the gravel beach on the Chanslor Ranch (Figure 3.3.1). The channel just downstream of the gravel beach became very shallow and narrow by September, and was dry by October.

On 3 June the temperature and dissolved oxygen were uniformly distributed from top to bottom, at 20 °C and ~ 10 ppm. A thin freshwater layer occurred over a saline bottom. This represented conditions established while the system was tidally influenced (bar open). The maximum salinity observed on 3 June was 5.4 ppt. It is possible that the profile on 3 June was not taken in the deepest part of the pool, because subsequent profiles there showed a deeper column and a maximum salinity of 10-13 ppt. After only one month of stratification, the inverse temperature stratification was well established, with temperatures as high as 29 °C near the bottom. As was the case in the middle stations, dissolved oxygen concentrations were very high in the salty layer but away from the bottom, sometimes > 20 ppm.

Tidbit temperature recordings made on the bottom at Station 6 show that the temperature increased from 20 to 29 °C in the first two weeks of June. A diel temperature fluctuation of up to 2 °C was apparent in the first 3 + months, but was less apparent after mid-September. There was also a longer-term undulation in the temperature record with a range of ~ 25 to 29 °C in August. Bottom temperatures showed a steady decline in September and October, from ~ 26 to 22 °C by mid-October. There was a sharper temperature decrease recorded in the last week of October, but profiles made on 1 November still showed a bottom temperature of 22 °C. (Profile bottom temperature on 1 November was 24 °C.) The Tidbit may have been buried in the sediments or displaced to a shallower depth by the runoff from the rainstorms during that period. (The tidbit recorder placed at Station 5 was pulled up and left out of the water, evidently by a curious or malicious person. It appeared to be logging air temperatures for most of November 2004.)

Storm runoff in October and November 2004 did not overcome the stratification at Station 6, which still had near-anoxic, salty water near the bottom. The loss of heat in the near-bottom water occurred during stratified conditions. The most likely explanation for the heat loss would be that shorter days reduce heat inputs, so that there is a net loss of heat to the sediments. This may also be partly an artifact of the sensor being buried in the sediments, which are cooler than the near-bottom water in summer. This may also be the mechanism for near-bottom heat losses observed at middle estuary stations.

Water Quality Profiles at Sites Between the Primary Stations

Data based on profiles at Stations 2 through 6 in summer 2004 showed that unrelieved stratification limited the available habitat for fish. The primary stations were located in deep pools. In order to determine whether conditions in 2004 were equally severe in shallower parts of the estuary, additional profiles were done on 29 November 2004 at four extra stations, located between Stations 1 and 2 (Station 1.5); between Stations 2 and 3 (Station 2.5); between Stations 3 and 4 (Station 3.5); and between Stations 4 and 5 (Station 4.5). Most of these stations were less than 2 m deep when sampled. These profiles showed that the shallow stations had only slight salinity and temperature increases near the bottom, and were generally well-oxygenated. There was a significant increase in salinity (to 15 ppt) and decrease in dissolved oxygen (to 0.8 mg/L) near the bottom only at the deepest of these extra sites (Station 2.5).

Water Quality in the Salmon Creek Estuary During Bar-Open Conditions, December 2004 through May 2005

The Lower Estuary

The beach berm at the estuary mouth was breached on 8 December 2004, and except for a few days in late April 2005, the berm remained open until after the last set of monthly profiles were made on 1 June 2005. The interplay between tidal action and rainfall in determining estuary stage heights and bar closure in the estuary is discussed in a separate section below.

Bar-open water quality profiles in the lower estuary were of two types. Profiles made following flushing flows after rains show a water column uniformly fresh, with temperature and dissolved oxygen uniformly distributed from top to bottom. A second type of profile was observed after winter base flows returned. Such profiles show a surface freshwater layer overlying a saline bottom layer of varying thickness. During these situations, stream flows were inadequate to repel the entrance of seawater at high tides. Temperature and dissolved oxygen were relatively uniform vertically.

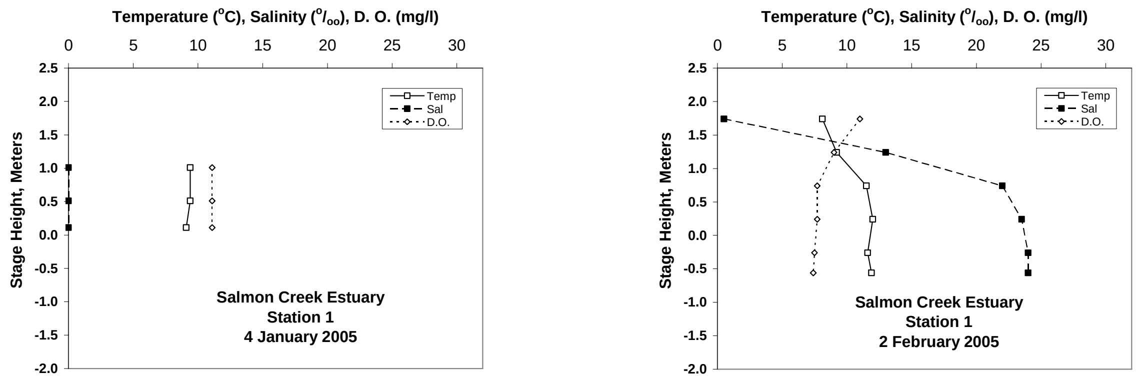
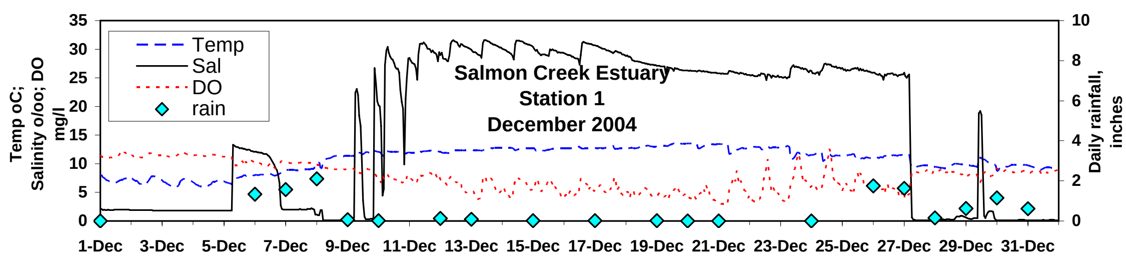


Figure 3.3.3 *Bar open water quality profiles. Storm flows sufficient to flush out saltwater are shown on the left and saltwater intrusion after normal base flows return is shown on the right.*

Datasonde deployment in the estuary during bar-open conditions is fraught with hazards, especially in the lower estuary where sediment erosion and deposition extensively re-arrange bottom contours after storms. Datasonde records from Station 1 are incomplete after 5 March 2005. The instrument was not lost, but was buried in fine sand on two occasions, which eventually rendered the unit inoperative. The December data clearly show that the water column went fresh on 8 December 2004 following a total of 5 inches of rain which fell during the previous 3 days. Seawater soon entered the near-bottom layer as the system was once more open to tidal action. The saline bottom layer persisted until 27 December after which a series of rainstorms kept seawater out—except for isolated spikes associated with high tides—until 19 January 2005. (Figure 3.3.4.) The saline bottom layer then persisted for a month, when rains in mid-February flushed seawater out for the next 5 days. The saline layer returned on 23 February and persisted until 28 February 2005.



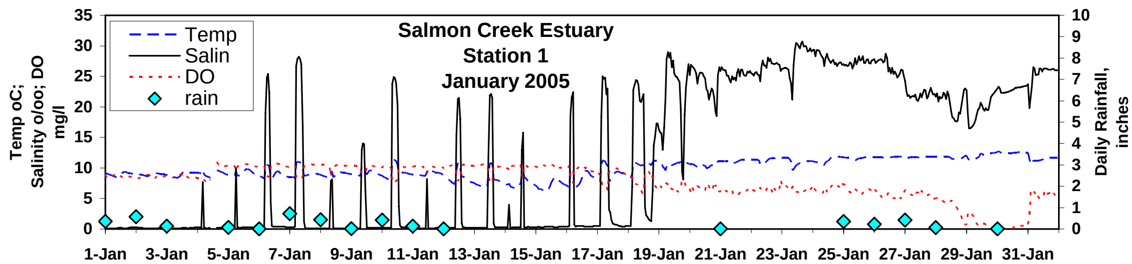


Figure 3.3.4 *Records show the influence of tidal and freshwater (rainfall) influx as the estuary mouth is breached.*

Near-bottom dissolved oxygen in the lower estuary was generally high during tidal conditions. The role of tidal action in maintaining dissolved oxygen levels adequate for fish is illustrated by the records for the period 11-19 February 2005 (Figure 3.3.5.), when dissolved oxygen decreased from ~ 8 mg/L to <1 mg/L. This was a period of neap tides, during which seawater did not reach into the estuary. Another low-dissolved oxygen episode occurred around 29-30 January 2005, which was also during neap tides, but since estuary stage data are unavailable for that period, it is not known if tidal exchange was occurring then.

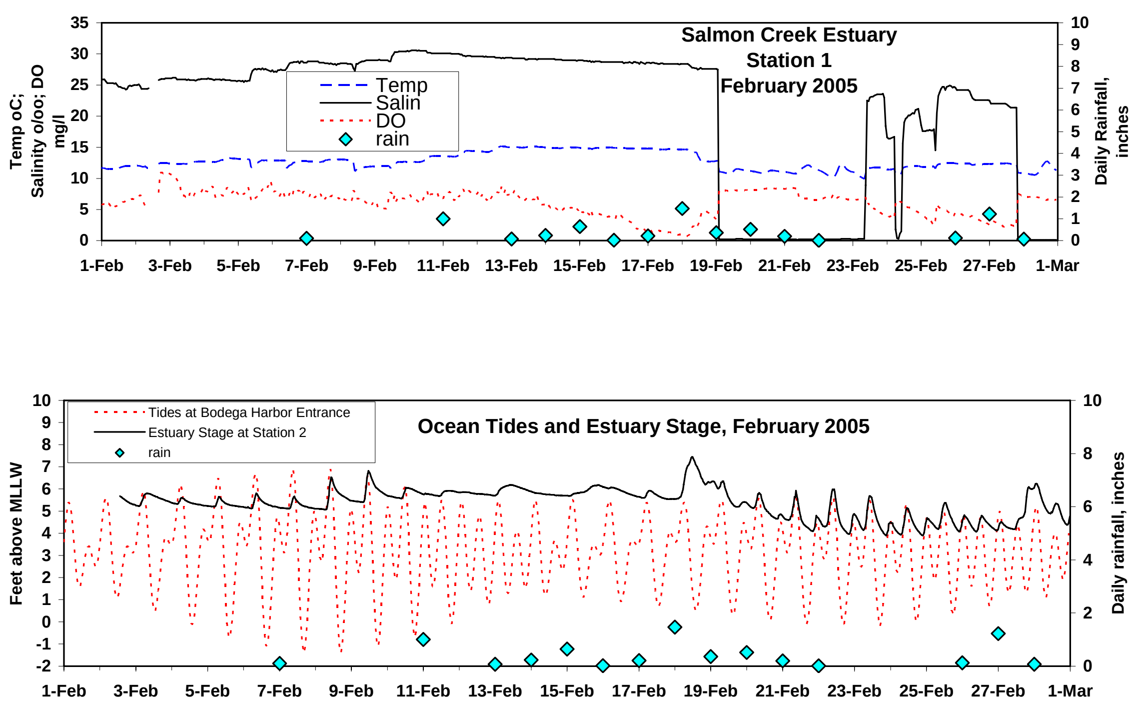


Figure 3.3.5 *Water quality and water surface elevation conditions shown with corresponding tidal and rain records.*

The Middle Estuary

Water quality profiles in the middle estuary during bar-open conditions were similar to those in the lower zone: fresh and unstratified during flushing flows, and stratified with saline water overlain by fresh during tidal action.

Datasondes deployed in the middle estuary did not get buried, but continuous dissolved oxygen data could not always be logged because deposition of fine silt following storms sometimes occluded the dissolved oxygen sensors. During December 2004 the datasonde deployed at Station 3 began to experience shortened battery life. The unit was retrieved on 22 February 2005 and was sent away for repairs. The repaired unit was re-deployed on 1 March 2005.

The datasonde records made at Station 2 show patterns similar to those made in the lower zone, with the onset of flushing episodes occurring at about the same time after each storm. (For example, fresh water was first sensed on 8 December between 4 and 5 am at both Stations 2 and 1.) But at Station 2 it took longer for seawater to return after each storm than in the lower zone. For example, following the flushing episode of 19 February 2005, seawater re-entered Station 1 on 23 February, but freshwater persisted at Station 2 for two days longer.

Episodes of flushing flows that repulsed seawater from Station 2 also persisted following storms in March, April, and May. The middle estuary was totally fresh for nearly half of May 2005. Such extended freshwater periods would deter the establishment of marine and estuarine organisms to which fresh water is toxic.

Farther up the middle estuary at Station 3 the datasonde records show that freshwater episodes were of still longer duration than at Station 2. For example, the freshwater episode that lasted at Station 2 from 9 to 13 April 2005 persisted at Station 3 until 17 April. Low dissolved oxygen found at Station 3 around 19-21 April was associated with temporarily bar-closed conditions.

The Upper Estuary

Water quality profiles made in the upper estuary show that on nearly every date from December 2004 through early June 2005 the water column remained fresh. Salty bottom water was found at Station 4 on one date, 2 February. All profiles at Station 5 were unstratified and fresh. At Station 6 the near-bottom layer on 1 June 2005 had 1.5 ppt salinity; on all other dates during bar-open conditions, the water was fresh at all depths.

Temperature records often show an abrupt decrease with the onset of flushing flows and re-opening of the bat to tidal exchange. (See 8 December below.) During bar-open conditions temperatures often allow a diel fluctuation pattern of a few degrees

Celsius. This is typical of an unstratified water column free to exchange heat to the air.

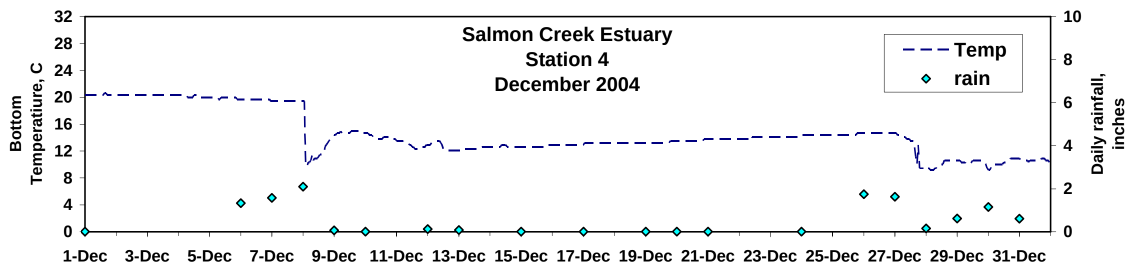


Figure 3.3.6 *Temperature response to rainfall events.*

The Response of Salmon Creek Estuary to Tidal Action and Rainfall, February 2005 though September 2005

Observations made on monthly monitoring cruises in Salmon Creek Estuary during bar-open conditions led to the conclusion that the tidal amplitude inside the estuary is much smaller than the tidal range in the nearby ocean. We have noted that following heavy rains the creek flow cuts deeper into the beach, which results in greater tidal amplitudes inside the estuary. Outflow from the creek when it returns to baseline winter flows after the immediate runoff from storms is too small to keep the beach opening deep, and the tidal amplitude inside the estuary is reduced as the beach cut gets shallower. For example, over 3 inches of rain fell on 26 – 27 December 2004, and direct observations showed that the beach berm was cut to a depth of 8 feet or more immediately thereafter, but the channel was 6 feet shallower by 4 January 2005.

A continuously-recording water level gage was installed at Station 2 in the estuary, and it became operative on 2 February 2005, logging every 30 minutes. With the availability of continuous estuary level data, the roles of tides and rainfall in estuary dynamics can be elucidated in greater detail. The following discussion is based on estuary stage, rainfall and tide data from 3 February through 22 September 2005, and illustrates how the estuary responds to the spring-neap tide cycle during baseline winter flows, and how this is modified by runoff from rainstorms.

Tides at Bodega Harbor Entrance are shown, with the estuary height data superimposed, in Figures WQ-26 (February through May 2005) and WQ-27 (June through September). The stage data have not been surveyed to precisely establish their vertical datum, but are here plotted to the same datum as the tide data (feet above MLLW). That the high tide peaks in the two plots often coincide suggests that the stage gage datum is roughly equivalent to MLLW. Rainfall data are plotted on a separate scale.

The general pattern is that during winter baseflows and spring tides (7-9 February 2005, Figure 3.3.7.) the estuary levels track the higher high tides but do not drop to the level of the lower high tides. During neap tides and moderate runoff (12-17 February), the estuary is not tidal at all because it is higher than the highest neap tides. Larger runoff pulses such as 18 February and 28 February briefly raise the estuary level above the highest tides. Runoff events that flush the estuary (19-25 February) erode the beach channel deep enough to reflect peaks associated with both the higher and lower high tide each day, and the amplitude of the tides in the estuary can then be as high as 2 feet. (During this study period there was never an event that eroded the channel deep enough to reflect ocean *low* tides.) More major runoff episodes eroded the berm deep enough to reflect both daily high tides, but increased outflow prevented estuary water level from reaching tide heights outside the estuary.

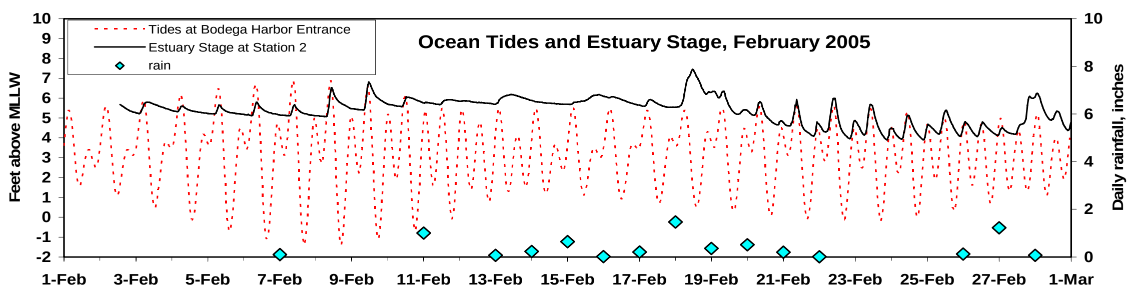


***Figure 3.3.7** Ocean tides, estuary stage, and rainfall*

The beach berm evidently partially closed on 17 April 2005 and appears to have completely closed on 24 April. Water level in the estuary rapidly increased to ~ 9 ft above MLLW before the berm breached itself on 1 May. The breaching was not associated with a rainstorm. The berm appears to have closed briefly again around 4 June but became tidal again following rainfall on 8 June. The estuary was closed again around 8 July and remained so until 20 July 2005. It opened for a few days during spring tides on 20 – 24 July 2005, and then evidently closed for the remainder of the period of record.

September 2005 Water Quality Profiles, With a Comparison Between Estuary Conditions in 2004 and 2005

An additional set of water quality profiles was made on 22 September 2005, to determine whether estuary conditions in summer 2005 were as severe as those observed in 2004. They suggest that conditions in the estuary were more benign in 2005. In the upper estuary there was no saline layer at all at Stations 5 or 6, and at Station 4 the maximum salinity was only 3 ppt near the bottom. Unlike the situation in 2004, the upper estuary habitat in September 2005 was not stratified and the whole water column was suitable for fish.

In contrast to the upper estuary, profiles made in the middle estuary were quite similar to those observed in September and October 2004. Once again there was a stratified system with an inverted temperature curve and a salty anoxic layer near the bottom.

The lower estuary profile on 22 September 2005 was similar to the 1 November 2004 profile. There was an increase in salinity near the bottom, which in 2004 was attributed to warm salty water pushed downstream by rains in October. The September 2005 profile had adequate dissolved oxygen near the bottom (as was the case in November 2004), so it is unlikely that the salinity stratification had been in place for very long. Rain may have played a similar role in the lower estuary in 2005 (0.3 inches fell on 14 – 16 September).

The September 2005 profiles clearly show that the habitat quality was improved in 2005 over 2004, and this was reflected in better survivorship of juvenile steelhead in 2005 than in 2004 (see Fisheries Chapter 3.4).

Discussion

It is apparent that the major difference in the estuary between the two years is the difference in rainfall and resulting flow levels in the creek. Water levels observed in the estuary in the two years are compared in Figure 3.3.8. The bar closed in late May in 2004, and summer creek flows were so low that salinity had already reached the upper estuary stations before the bar closed. The estuary level began dropping as soon as the bar was closed. It continued to drop until rains fell in October. In 2005, in contrast, the bar did not close until late July, and flows were adequate at the time of bar closure to prevent the encroachment of salinity into the upper estuary stations. Estuary levels in 2005 continued to rise for a month after bar closure. September water levels were about 2 feet higher in 2005 than in 2004, which means that a much greater area of suitable habitat was available for fish in 2005.

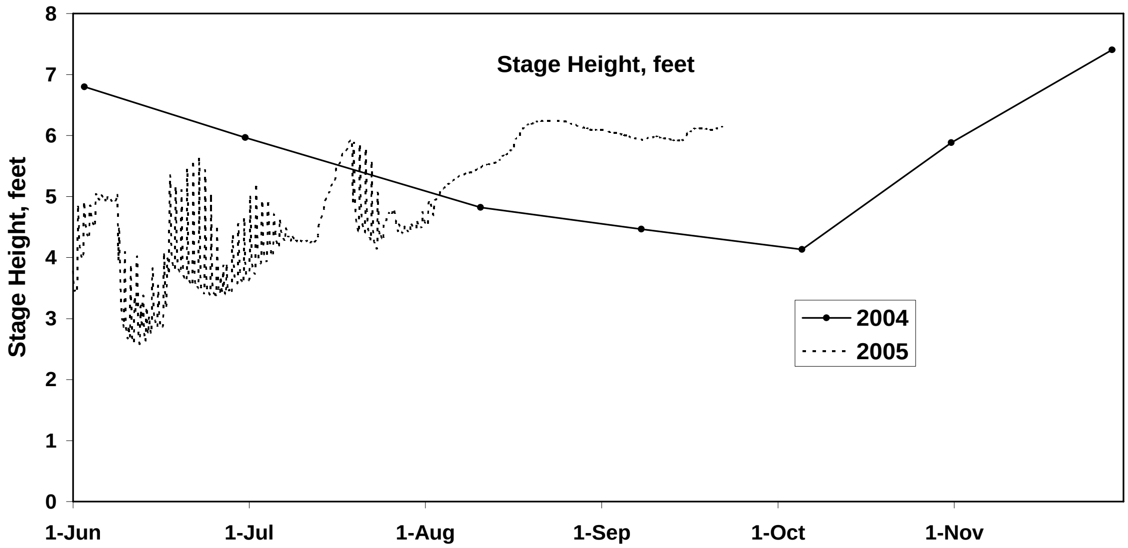


Figure 3.3.8 *Comparison of summer stage heights between 2004 and 2005.*

It is instructive to examine the seasonal rainfall patterns. Long-term rainfall records are available for Occidental, which is located near the headwater area of Salmon Creek. Figure 3.3.9 is a comparison of monthly Occidental rainfall totals in the October-through-June period. Data for 2003-2004 are compared with those for 2004-2005, and to the monthly averages for the previous ten years. It is apparent that the biggest difference between the 2003-2004 year and the following one is not just the total rainfall (50.2 inches *vs*. 56.8—both below average) or winter rainfall (December 2003 and February 2004 had *above* average rainfall), but the amount of rainfall in spring that is different: March and April 2004 had about half of the average rainfall for that period, and no rain at all fell in May or June 2004. In contrast, the spring rains in 2005 were above average in March, and especially so in May and June. Coastal watersheds such as in Sonoma County lack a snowpack storage reservoir, so that rains that fall early in winter do not contribute much to the creek flows in the following summer. A similar conclusion was reached by Fawcett et al (1993) who found that summer juvenile steelhead survivorship in Sonoma County creeks was related to rainfall the previous spring, but not rainfall the previous winter.

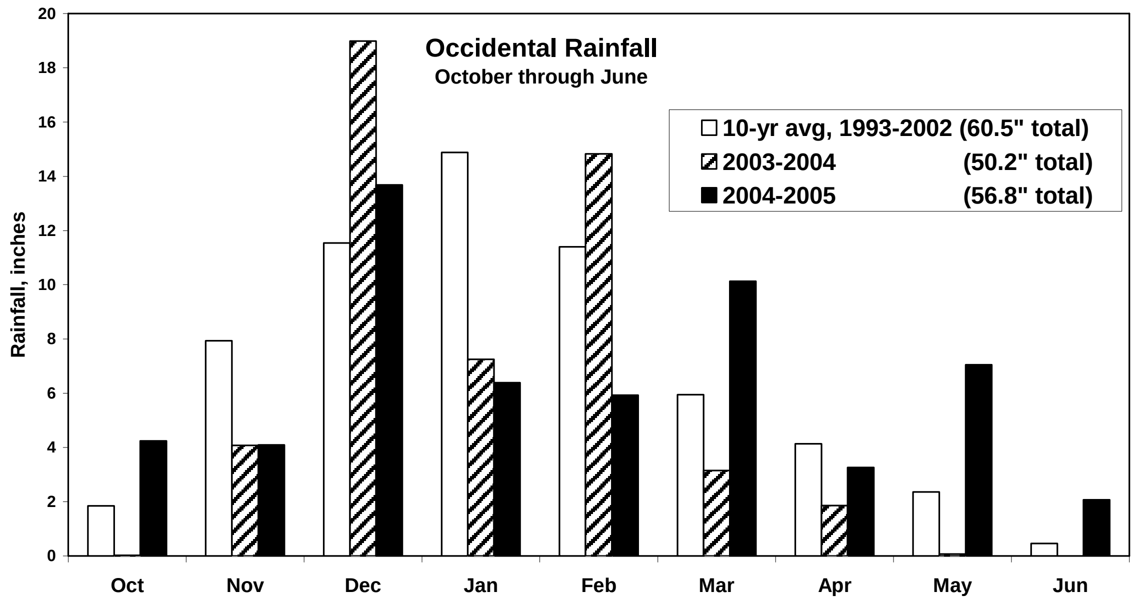


Figure 3.3.9 *October through June monthly rainfall summary, 2003-2004 and 2004-2005 seasons compared with the average rainfall for the 10 previous years.*

3.4 Fisheries (prepared by Michael H. Fawcett)

Introduction

The biological monitoring portion of the Salmon Creek Estuary Study was begun in May 2004, with the objective of characterizing existing biotic conditions in the estuary by a program of monthly sampling of biota over a one-year period. During the same period, studies of physical conditions in the estuary, including water quality, hydrologic, and geomorphic processes were also conducted. The monthly biotic sampling was conducted from early June 2004 through early June 2005 in conjunction with monthly water quality monitoring (Chapter 3.3), and with some aspects of the hydrologic study (Chapter 3.2). Since the stage recording (i.e., water level) portion of the hydrologic study continued through summer and fall of 2005, an additional round of biotic and water quality sampling was conducted in September 2005, to provide a basis for comparison between the two years.

A secondary objective of the estuary study was to monitor aquatic biota in the vicinity of an off-channel well located just upstream of the estuary during the observed annual draw-down of surface water at the site, as part of a study to evaluate potential impacts of this and other water diversions (off-channel wells and direct diversions) in the watershed. Seasonal flow conditions at this location just upstream of the upper end of the estuary could be expected to have some influence on dry-season conditions within the estuary. Aquatic habitat within a 447 m. (1,467 ft) reach of Salmon Creek adjacent to the well site (Figure 3.4.1) was characterized, and fish and other aquatic animals were sampled throughout the reach at the beginning of July 2004, and again in August 2004, after surface flow had ceased and most of the water in pools had disappeared.

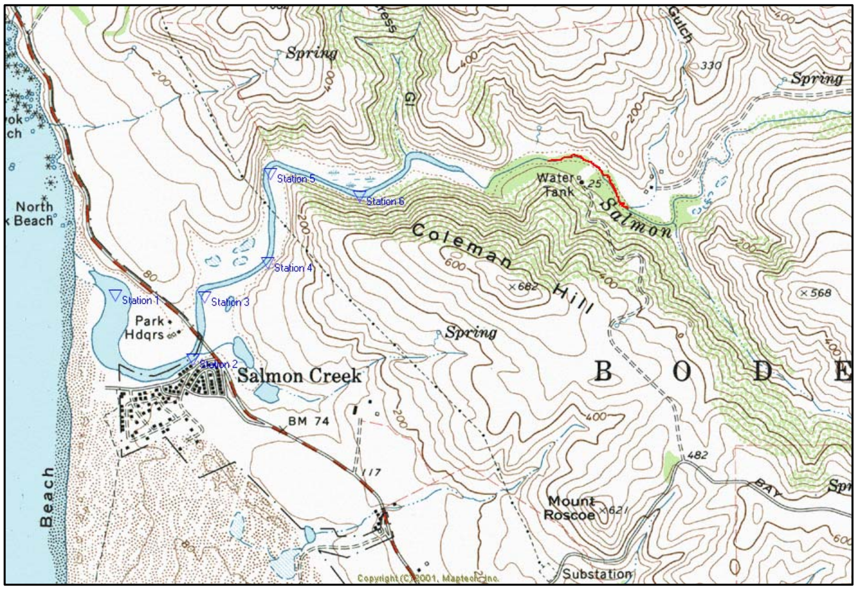


Figure 3.4.1 *Study area with sampling stations indicated by blue triangles. Red track indicates the freshwater study reach near the off-channel well.*

It was expected that the estuary study, in combination with the study of the rest of the Salmon Creek watershed, would lead to identification of processes or habitat conditions in the watershed that may have contributed to historic declines in populations of coho salmon, *Oncorhynchus kisutch* (now extirpated in the watershed) and steelhead (i.e., sea-run rainbow trout), *Oncorhynchus mykiss* (still spawning and rearing in the watershed, but in greatly reduced numbers from those reported in historical times). Coho (Central California Coast ESU) are listed as an endangered species under the federal Endangered Species Act (ESA) and California Endangered Species Act (CESA), and Steelhead (Central California Coast ESU) as a threatened species under the ESA. Salmon Creek, its tributaries, and the estuary are included in critical habitat for both coho and steelhead (NMFS 1999, 2005).

There are two additional listed aquatic species that currently occupy the estuary: the tidewater goby (*Eucyclogobius newberryi*), and the California freshwater shrimp (*Syncaris pacifica*) are both listed as endangered species under the ESA. The California freshwater shrimp is also an endangered species under CESA. The tidewater goby has been reported throughout the estuary (including this study), and the freshwater shrimp is routinely found near the well site just upstream of the estuary, and occurs seasonally in shallow, freshwater areas within the upper zone of the estuary (Fawcett, *unpublished data*). Biotic sampling conducted for this study was authorized by federal and state *Scientific Collector's* Permits issued to Michael Fawcett (NOAA Recovery Permit No. 1045; USFWS Recovery Permit No. TE027296-

3; DFG Scientific Collector's Permit No. SC-000806) and Jim Roth (DFG Scientific Collector's Permit No. 801036-01).

Methods

Estuary Monitoring

The U.S. Fish and Wildlife Service does not allow active sampling (use of nets or other devices) within habitat known to be occupied by tidewater goby during the months of May and June, so only visual observations were made (by snorkeling) during those months (i.e., if visibility was not obscured by turbidity). Beginning in July 2004, we attempted to use a variety of small beach seines (4-mm delta mesh, 1.2 m deep, 1.2 to 15 m long) and a small otter trawl (2.4 m wide at the mouth, 2 mm mesh) to sample fish and epibenthic (i.e., residing on or above the bottom) invertebrates in the estuary. The smallest seines (1.2 m length) are operated by a single person, who pulls the seine along the bottom by means of a wooden rod attached to each end, then guides the seine onto the shore or lifts it out of the water. Longer seines (5 to 15 m length, with a bag in the center) are pulled by two people along some pre-determined route, and then are pulled up onto a beach (or to the edge of the beach, such that the bag containing the catch remains in the water). We also used a larger seine (9.5-mm mesh, 2.4 m deep, 30 m long), which is deployed in an arc by boat while one person holds onto one end of the net, then both people pull the seine up onto the beach, leaving the bag (which contains most of the trapped fish) in the water; fish are then transferred from the bag to a live car or tub of aerated water for processing. Beach seines can effectively capture a variety of fish, including juvenile and adult salmonids, but are generally limited to use in wadeable depths (i.e., waist- to chest-deep water), and are difficult or impossible to use in situations where the bottom sediments are very soft, making wading difficult.

The otter trawl used in this study is towed at low speed (2-3 mph) behind a boat. Weighted wooden doors attached to a bridle hold the mouth of the net open while it is being towed along the bottom. The trawl can be used in a variety of depths, and is effective at capturing relatively slow-moving fish and macro-invertebrates (crabs, shrimp, etc.) on or near the bottom, but is not effective at capturing fast swimmers such as juvenile or adult salmonids, which simply move out of the way of the net. At the end of a short period (1-2 minutes) of towing, the net is hauled aboard, and animals are quickly transferred from the cod end of the net to an aerated tub of water.

Both trawl sampling and seine sampling disturb benthic habitat each time sampling is conducted. In an estuary as small and narrow as that of Salmon Creek, it is not feasible to conduct a statistically rigorous sampling program effectively covering a variety of species and habitats (with well-replicated sampling among stations and habitats, etc.), without damaging the habitat, harming protected species such as tidewater goby, and/or violating model assumptions such as independence of the samples. Therefore, we did not attempt to design such a program, and the available funding would not support one. Instead, our program was focused on using a variety of techniques to elucidate what species are present in the estuary in different seasons and locations within the estuary, and what is their relative abundance from one season or location to another, and to the physical parameters (water quality, hydrology, channel morphology) simultaneously being studied, all of this subject to the limitations imposed by conducting the study within a single one-year period. Rainfall amount and timing, air temperatures, ocean conditions, and other factors vary hugely from one year to another, and can have enormous impacts on aquatic life—several years of study encompassing a wide range of seasonal variation is usually necessary before one can make reasonable inferences about typical or average conditions affecting fish populations in a particular watershed.

An additional restriction is that, under the rules applicable to our federal recovery permit for tidewater goby, cumulative incidental mortality of five or more gobies caused by our sampling would lead to immediate suspension of further sampling, followed by a lengthy formal review, and possible revocation of, the permit. Because tidewater gobies were very abundant throughout the estuary during the study period (see Results section), were unavoidably captured during efforts to capture other species (e.g., steelhead), and are small and easily harmed by trampling, tumbling within a net, etc., we had to limit the number of attempts at seining or trawling, thereby limiting our ability to effectively characterize steelhead and other species' use of the estuary, in order to avoid harming excessive numbers of gobies.

Stream Monitoring Near the Off-Channel Well

Stream habitat near the well site was characterized in June 2004 by wading through the entire study reach, with one biologist (J. Michaud) sketching diagrams of habitat units (discrete pools, riffles, or glides, and locations of trees and their rootwads, large boulders, and other habitat features, and recording notes, while the other team members measured the lengths, widths, and depths of the units, and described the stream bed, presence of woody debris, riparian canopy, and other habitat features. All the units from a point approximately 217 meters downstream from the well site (i.e., measured along the stream channel from a point adjacent to the well site) to 230 meters upstream of the well site were thus characterized. The reach selected for study was based on previous observations made during the period from 1996-2003 of typical annual summer dewatering of some of the stream habitat adjacent to, and downstream of the well (*personal observation*). For convenience, the study reach was arbitrarily divided into lower, middle, and upper reaches, with 5-7 units lying within each reach. The units were numbered consecutively, from No. 1 (a long pool at the downstream end of the lower reach) to No. 18 (a riffle at the upstream end of the upper reach).

Some sampling by dipnet was conducted in most of the units on 4 June 2004; seining was not attempted on that date, because it was judged that many of the steelhead fry present were too small (ca. 40 mm or less) to effectively capture and safely handle. We returned on 2 July 2004 and seined every unit, attempting through repeated passes to capture all, or nearly all, of the fish within each unit. Captured fish, newts and their larvae, and other animals were temporarily held in aerated, shaded 5-gallon buckets of stream water at ambient stream temperature before processing and while seining continued. California freshwater shrimp were held in a separate bucket, to avoid predation or damage from other captured animals. All captured vertebrates, freshwater shrimp, and crayfish were identified and enumerated. Identification was to the level of species, except for lamprey larvae (known as *ammocetes*), which are difficult to identify in the field (i.e., difficult to distinguish among the three local species). Juvenile steelhead were anesthetized (or, more accurately, calmed) with dissolved carbon dioxide, then measured (fork length), and allowed to recover before being released back into the unit from which they were taken. Each habitat unit was measured again, and seining was repeated on 12 August 2004, by which time considerable dewatering had already occurred (several units were dry). An additional walk-through of the study reach was conducted on 31 August 2004, by which time most of the units were dry or reduced to shallow, exposed puddles, and few aquatic animals remained alive. An additional habitat survey (visual inspection only) and seining of the study reach was conducted at the end of the summer of 2005 (10 October 2005).

Results

Estuary Monitoring

Aquatic habitat

Our assessment of habitat conditions in the estuary was developed through a combination of bathymetry, water quality, and fish surveys conducted throughout the study period at different water-level stages (from bar-open, low tide to high tide and bar-closed conditions). Bathymetry and water quality in the estuary are described in detail in other sections of this report. The sampling stations identified in Figure 1 were selected (based on a bathymetry survey conducted in May 2004) to include the deepest areas in the estuary, because:

a) these were expected to be the locations where salinity stratification and its effects on water quality would be most evident, and
b) these would be locations to which steelhead and other fishes might be expected to retreat when threatened by avian predators such as pelicans, cormorants, and kingfishers, or when disturbed by human activities.

Steelhead, if not already hiding in the deepest water available, usually retreat to the deepest water immediately after being flushed from other shelter or instream cover, such as undercut ledges, rootwads, large woody debris, aquatic vegetation, or terrestrial vegetation trailing in the water (*personal observation)*. In the Salmon Creek estuary, cover is limited in the summer months to beds of ditch grass (*Ruppia* spp.) or floating algal mats in unshaded areas, and to other cover types associated with the few deep pools: bedrock ledges at Stations 3, 4, 5, and 6, trailing vegetation at Stations 3, 4, and 6, and large woody debris and old pier pilings at Station 2.

The deepest part of the estuary during the study period was at Station 3 (3.5 meters). The deepest part of the Station 1 area was only 2.0 m in June 2004, and 1.5 m by September 2004. However, we found that from July 2004 until early December 2004 (when rainfall runoff caused the sand bar at the mouth to open and the estuary was flushed) salinity stratification and the associated "solar pond effect" (the surface layer of freshwater acting as a lens to heat the underlying saltwater layer—see Water Quality report) resulted in all of the habitat in the estuary, with exception of the Station 1 area, below a depth of 1 meter below the water surface, being either too warm for salmonids (25.0-31.6 °C = 77.0-88.7 °F.), or anoxic (in which case it is unsuitable for all native fish and most invertebrates). Therefore, the only habitat available to steelhead and most other aquatic animals in the summer and fall was within the 1-m thick surface layer of freshwater or within the mixed water column at Station 1. The dense mats of *Ruppia* and floating algae present in most of the estuary contributed to the lack of mixing of water layers, and decaying *Ruppia* contributed to the oxygen depletion in the stagnant saltwater layer.

The streambed in most of the estuary, with exception of the bedrock outcrops mentioned above, consists mainly of small gravel, sand, and silt. Close to the mouth (Station 1), sand is the predominant feature. Some fairly large-diameter gravel and cobble bars occur at meanders or streambed-grade changes just downstream of Station 5, just upstream of Station 4, and between Station 4 and the Highway 1 Bridge (Figure 3.4.1). At Station 1 (the reach from the mouth to the base of the tall dunes), fine particles of silt and clay are flushed out of the area during bar-open conditions, leaving mostly sand behind. Thus, turbidity related to suspended fine sediment seldom occurs at Station 1 when the mouth is closed. Wind-driven turbulence apparently inhibits establishment of dense *Ruppia* beds at Station 1, and also inhibits growth of water clarity-reducing phytoplankton prevalent in the rest of the estuary. The result of these conditions is that the water column at Station 1 is usually clear from top to bottom whenever the mouth is closed, and fish have no place to hide from pelicans, cormorants, or other predators. The maximum depth at Station 1 was only 1.5 m in September 2004, making steelhead and other fish easily visible to pelicans and cormorants, which are frequently seen foraging or resting near Station1.

Aquatic Life
No biological sampling was conducted in the estuary during May and June in 2004 or 2005, because of the ban on disturbing habitat occupied by tidewater goby during those months (the main breeding period). Over the ensuing months we used a variety of sampling techniques to document fish and macro-invertebrate abundance and distribution (Table 3.4.1). These efforts resulted in the collection of ten fish species and a few invertebrates (Table 3.4.2) during the study period.

Table 3.4.1 Schedule of biological sampling in Salmon Creek estuary

Date	Location	Sampling methods	Comments
07/01/04	Sta. 1, 5	4-ft seines & direct observation	Confirmed that many tidewater gobies were present throughout estuary, decided against further sampling on this date
08/11/04	Sta. 1, 3-4	Otter trawl	2 tows at Sta. 1, one tow between Sta. 3 and 4
08/11/04	Sta. 1, 5	50-ft and 4-ft seines	50-ft seine used at Sta. 1, single tow
09/08/04	Sta. 1	100-ft seine	Single tow (400 steelhead captured)
09/10/04	Sta. 5, 6	Snorkel survey	
10/06/04	Sta. 1	100-ft seine	2 tows
11/02/04	Sta. 1-2	Otter trawl	1 tow
11/02/04	Sta. 1	100-ft seine	1 tow
11/02/04	Sta. 1, 4, 5, 6	Snorkel survey	
11/30/04	Sta. 1-2	Otter trawl	2 tows
11/30/04	Sta. 1	100-ft seine	1 tow
01/04/05	Sta.1-2	Otter trawl	1 tow
01/04/05	Sta. 1	100 ft seine	1 tow, aborted—water turbid, clogged with debris from recent stormwater runoff
02/02/05	Sta. 1	100-ft seine	3 tows
03/01/05	Sta. 1	100-ft seine	2 tows
04/07/05	Sta. 1	100-ft seine	3 tows
05/10/05	--------	None	No sampling because of tidewater goby restrictions; too windy and turbid for snorkeling
06/01/05	Sta. 1, 4, 5	Snorkel survey	Goby restriction on physical sampling in effect; water clarity poor
09/22/05	Sta. 1	100-ft seine	1 tow
09/22/05	Sta. 5-6	Snorkel survey	

Table 3.4.2 Aquatic species captured or observed in estuary during study period	
Common name	Scientific name
Fishes	
Tidewater goby	*Eucyclogobius newberryi*
Steelhead	*Oncorhynchus mykiss*
Threespine stickleback	*Gasterosteus aculeatus*
Prickly sculpin	*Cottus asper*
Pacific staghorn sculpin	*Leptocottus armatus*
Cabezon	*Scorpaenichthys marmorata*
Starry flounder	*Platichthys stellatus*
Pacific herring	*Clupea pallasii*
Topsmelt	*Atherinops affinis*
Shiner perch	*Cymatogaster aggregata*
Amphibians	
California red-legged frog	*Rana aurora draytonii*
Bullfrog	*Rana catesbeiana*
Reptiles	
Western pond turtle	*Clemmys (=Emys) marmorata*
Invertebrates	
Bay shrimp	*Crangon franciscorum*
Black-tailed shrimp	*Crangon nigrocauda*
Opossum shrimp	*Neomysis mercedis*
Amphipod	Class Crustacea, Order Amphipoda, Suborder Gammaridea (possibly several species)
Mammals	
River otter	*Lutra canadensis*

Because of the concern about causing excessive harm to tidewater goby, our sampling efforts were somewhat inhibited throughout 2004 and early 2005 by the presence of enormous numbers of tidewater goby every place we looked. We repeatedly tried brief tows of the otter trawl because it allowed sampling of bottom areas too soft or too deep for seining, but trawling often resulted in the capture of many gobies (Table 3.4.3), with the risk of some of them being entrained and crushed in the debris collected, or lost and stranded in the bottom of the boat during the process of removing the catch from the net (they are small fish, usually less than

50 mm long). We finally settled on the use of a 30 m long seine of fairly large mesh (9.5 mm) netting as a method that effectively captured steelhead (while allowing most of the gobies and invertebrates to pass through the net), but that particular seine could be used effectively only near Station 1 (Figure 3.4.1), where it could be pulled up onto the sandy beaches (and where net-clogging masses of filamentous algae and *Ruppia* were usually absent). Thus, the fish sampling effort during the study period was inconsistent and strongly biased toward the lower end of the estuary (Station 1). We attempted to compensate by conducting snorkel surveys elsewhere in the estuary, but this was frequently unsatisfactory because of poor water clarity.

Table 3.4.3 Total catch by otter trawl in Salmon Creek estuary

Species	Date (Sta. 1)	Date (Sta. 3-4)	Date (Sta. 1)	Date (Sta. 1)	Date (Sta. 1)
	8/11/04	8/11/04	11/2/04	11/30/04	1/4/05
Tidewater goby	158	167	265	31	18
Threespine stickleback	242	28	117	76	10
Starry flounder	1				2
Prickly sculpin	1		2		1
Bay shrimp	1				
Black-tailed shrimp	1				

Table 3.4.4 Total catch by seine at Station 1

Species	Date									
	7/1/04*	8/11/04**	9/8/04	10/6/04	11/2/04	11/30/04 ξ	1/5/04Φ	2/2/05	3/1/05	4/7/05	9/22/05
Tidewater goby	12	~300 ψ		24			1		4		
Steelhead	1	2	400	2	1				7		167
Threespine stickleback	30	~100	19	390			9		3	7	14
Pacific staghorn sculpin			3						1		
Prickly sculpin			1	1					2		
Pacific herring			46								
Shiner perch			2							5	
Starry flounder				1	1		3		8	6	2
Pacific herring				1							
Cabezon									1		
Topsmelt				1							
Black-tailed shrimp			2								
Bay shrimp				5							

* 25-ft seine, 2 tows
** 50-ft seine
ψ Gobies and stickleback allowed to swim out of net without further handling
ξ Net clogged with woody debris, no fish caught
Φ Net clogged with *Ruppia* and leaf litter, no fish caught

Table 3.4.5 Total catch by seine at Station 5		
Species	Date	
	7/1/04	8/11/04
Tidewater goby	~100	~190
Threespine stickleback		~350
Prickly sculpin		4
California red-legged frog		3

Ten species of fish were collected during the study period (Table 3.4.2); complete catch results by trawl and seine are provided in Tables 3.4.3-3.4.5, visual observations in Table 3.4.6. Steelhead and threespine stickleback are the only anadromous species captured in the estuary during this study. Cabezon are usually found in rocky, nearshore marine areas, but it is not unusual to find a few juveniles among collections made in estuaries, e.g., Estero Americano (Commins et al 1996) and the Russian River estuary (Roth et al 2000). The remaining species listed in Table 3.4.2 (with exception of tidewater goby) are common residents of estuaries along the Pacific Coast, either for all or part of their lives.

Table 3.4.6 Total numbers observed from boat or by snorkel surveys					
Species	Date	Date	Date	Date	Date
	7/2/04	9/8/04	9/10/04 (Snorkel)	11/2/04 (Snorkel)	6/1/05 (snorkel)
Tidewater goby		~350 (Sta. 1-5)	~250 (Sta.5-6)	~40 (Sta. 1) ~30 (Sta. 5-6)	
Steelhead		~50 (Sta. 1-5)	12 (Sta. 5-6)	1 (Sta. 5-6)	
Threespine stickleback		Hundreds		1 (Sta. 5-6)	Hundreds (Sta. 4, 5-6)
Prickly sculpin			1 (Sta. 5-6)		
California red-legged frog	1 (Sta. 5)				
Western pond turtle	1 (Sta. 2) 1 (Sta. 5)				
River Otter				2 (Sta. 3 – seen from boat)	

Few steelhead were captured in the estuary, except on two occasions: 399 juveniles (smolts) and 1 adult were captured at Station 1 on 8 September 2004 in a single tow of the 30-m seine, and 167 juveniles were caught at the same site on 22 September 2005, again in a single tow. In both cases, a large number of steelhead must have been present in the vicinity, because only a small fraction of the area was sampled in each pull of the seine. Only two steelhead were captured at Station 1 in two pulls of the seine in early October 2004, and none in a single attempt in early November 2004 (Table 3.4.4). On the first occasion, the water was too warm (20 °C at the surface at Station 1 — see Water Quality report) to safely subject the fish to the added stress of measurement, so the fish were quickly counted and released while I visually made rough estimates of how many belonged to each of three rough size groupings: 100-130 mm, 50 fish; 130-180mm, 249 fish; 180-260 mm, 100 fish. I assumed that the three size classes probably represented 1, 2, and 3-year old fish. The adult was approximately 450-500 mm long. All the steelhead were in good condition, i.e., fat and healthy-looking. On the second occasion (22 September 2005), we measured all the steelhead--the length-frequency distribution plotted in Figure 3.4.2 also suggests the presence of three size/year classes, with 2-year olds as the dominant class.

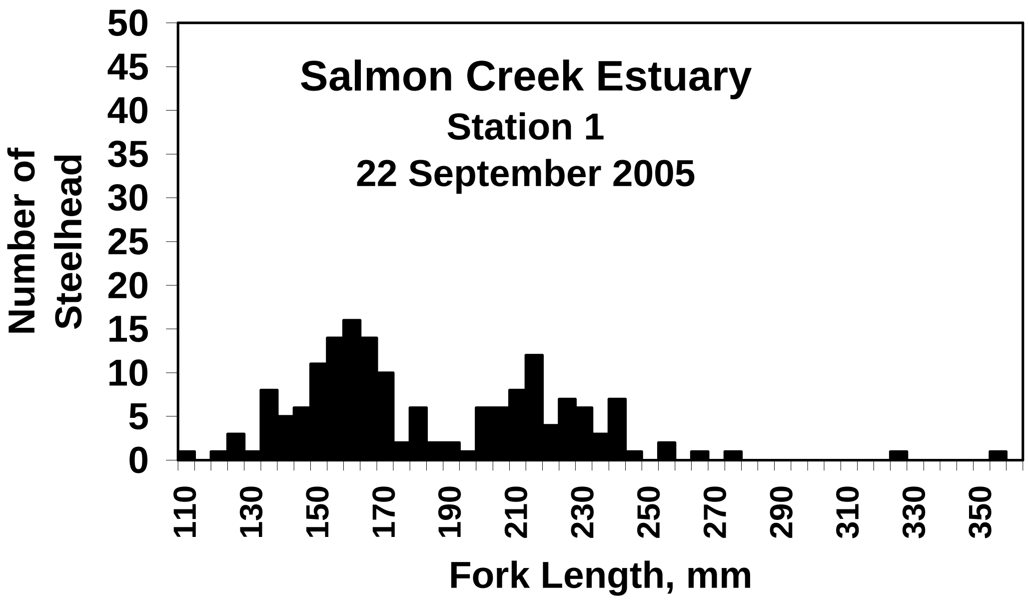


Figure 3.4.2 *Size distribution of steelhead captured by seine at Station 1 in September 2005*

The tidewater goby is currently known to occur in only two localities in Sonoma County (Salmon Creek and Estero Americano), but was historically present in Cheney Gulch as well--the Cheney Gulch population was apparently extirpated (USFWS 2005). Adults of this species rarely live longer than one year, and increases in population density generally occur in spring and summer, although some breeding occurs year-round (Swift, et al 1989; Moyle 2002; USFWS 2005). The tidewater goby can successfully breed at temperatures up to 25 °C (whereas temperatures above 24 °C for more than short intervals are lethal to both coho and steelhead--Moyle 2002). Tidewater gobies undergo "boom and bust" population cycles within occupied localities and do best in shallow coastal lagoons that are "often almost completely choked with aquatic vegetation", including *Ruppia maritima* and *Ruppia cirrhosa* (USFWS 2005), which are the two *Ruppia* species observed to be clogging the Salmon Creek estuary during most of the period of this study. *Ruppia* dies back and largely disappears from Salmon Creek (and other sluggish streams and ponds in the area) with the onset of cold weather in the fall, but the roots do not die, and re-growth begins from the roots in late winter-early spring (*personal observation*).

The Salmon Creek estuary appears to provide good habitat for tidewater goby, as this species has consistently been found there during periodic surveys conducted by Camm Swift and others (cited in Moyle 2002 and USFWS 2005). The Salmon Creek population is recommended as a potential source of tidewater gobies for introduction or re-introduction of the species to Cheney Gulch and Marshall Gulch (a few miles north of Salmon Creek) in the Recovery Plan for tidewater goby (USFWS 2005).

Stream Monitoring Near the Off-Channel Well

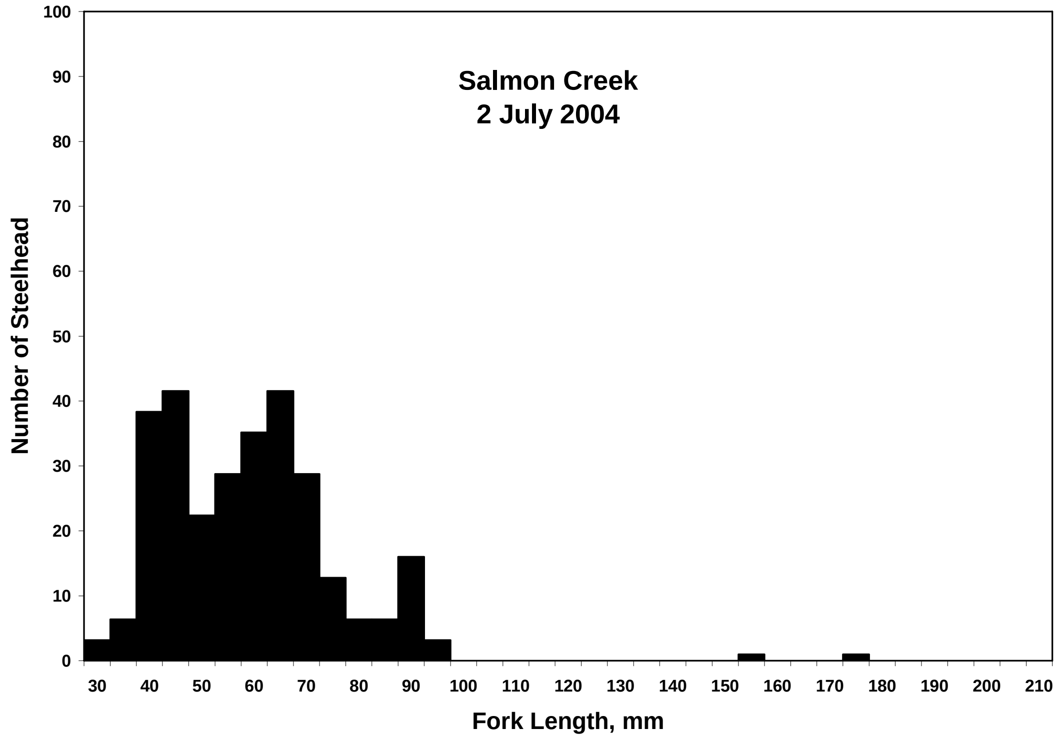
General characteristics of the habitat units surveyed on three dates in summer 2004 in the study reach near the well site are provided in Table 3.4.7. The initial habitat survey was conducted on 4 June 2004, prior to dewatering of the reach. Additional habitat surveys were conducted on 12 August and 31 August, by which time most of the units were dry or reduced to shallow puddles, as shown in two photographs of Unit 10 (Figures 3.4.3 & 3.4.4), which lies directly across the channel from the well site. Detailed analyses of hydrological events accompanying the visible dewatering of the stream during this period are presented in the main report.

Figure 3.4.3 *Unit 10 near well site, 12 August 2004 – considerable dewatering had already occurred since 2 July survey.*

Figure 3.4.4 *Unit 10 near well site, 31 Aug 04 – remaining pool only 4.4 cm. deep, no vertebrates left in the pool.*

Preliminary sampling by seine indicated that most of the steelhead present in the study reach on 4 June 2004 were fry too small (< 40 mm) to effectively capture by seine and safely handle for measurement, so we limited our sampling on that date to brief dipnetting in fewer than half of the units. The resulting catch totals for different species of aquatic animals on that date are included in Table 3.4.8, but should not be taken as quantitatively comparable to the totals presented for 2 July and 12 August 2004—on the latter dates we systematically seined every unit. Steelhead were measured during the 2 July survey; all but two of the 292 steelhead captured appeared to be young of the year (Figure 3.4.5). Considerable dewatering had occurred between the July and August sampling (Table 3.4.7), which meant that the remaining animals were more concentrated within the remaining units, thus more efficiently captured by seining, which partially explains why some species appeared to increase in number during the interval--the other part of the explanation is that increased individual body size (rapid growth rates during summer weather) makes more of the population of each species vulnerable to capture by seining than when the individuals are smaller in size earlier in the year.

All of the species listed in Table 3.4.2 are native to this region, except for bullfrogs (*Rana catesbeiana*), which are native to the eastern United States. Bullfrogs are introduced, invasive pests in the western U.S., implicated as contributing factors in the decline and disappearance of many native frogs and other vertebrates from their native geographic ranges in California (e.g., California red-legged frog, *Rana aurora draytonii*; and foothill yellow-legged frog, *Rana boylii*, both of which are found in the Salmon Creek watershed). Although California red-legged frog is a federally threatened species within most of its range in California, the listing range does not include coastal watersheds north of Walker Creek in Marin County (it is, however, a California species of special concern statewide, as is the foothill yellow-legged frog). Four adult California red-legged frogs were captured during sampling near the well site (Table 3.4.8). As mentioned earlier in this report, both steelhead and California freshwater shrimp are listed under the ESA: Steelhead is a *threatened species;* California freshwater shrimp is an *endangered species.* California freshwater shrimp is also listed as *endangered* under CESA.



Summary Statistics	
total count	293
YoY count	291
YoY m. L.	60.4 (based on 91 individuals measured)
YoY sd	15.1 (“)

Figure 3.4.5 *Size distribution of steelhead captured near the well site on 2 July 2004.*

Table 3.4.7 Stream habitat near well site

Reach	Unit No.	Length (m.) on Survey date			Width (m.) on Survey date			Max. Depth (cm.) on Survey date			Initial Description
		6/4/0	8/12/0	8/31/0	6/4/0	8/12/0	8/31/0	6/4/0	8/12/0	8/31/0	
Lower	1	22	22	~18	5.7	5.5	~5.0	90	90	~60	Pool with sand overlying b at base of rock bluff
	2	20	19	1.2	2.6	1.3	1.0	35	24	9.0	Sand-bottom riffle/glide
	3	12	7.8	0 (dry)	3.4	2.3	0	20	8.0	0	Sand-bottom pool
	4	6.1	0	0	2.5	0	0	6.0	0	0	Sandy riffle
	5	8.5	5.8	2.6	4.4	3.1	1.2	51	35	15	Sand-bottom pool
	6	36	19	2.6	13	6.6 *	1.2	48	35	12	Gravel bar at upstream end sandy elsewhere
Middle	7	24	23.5	4.0	3.8	2.5	1.9	55	46	18	Pool/glide with gravel-cob bottom, mostly unshaded
	8	6.3	0	0	1.4	0	0	20	0	0	Riffle, gravel-cobble bottom
	9	20	0	0	3.6	0	0	14	0	0	Glide/riffle
	10	62	44	3.0	5.1	2.3	0.9	32	31	4.4	Pool/glide
	11	17.1	10.5	0	6.6	~1.0	0	19	16	0	Pool, gravel-sand-silt botto
Upper	12	22.8	15.5	0	10	2.8	0	40	23	0	Glide/riffle, gravel bottom
	13	71	No dat	~4.0	9.3	9.0	2.5*	50	42	26	Pool/glide with woody del
	14	25	25	3.7	3.6	2.8	0.8	26	16	6.6	Glide
	15	4.7	0	0	3.8	0	0	10	0	0	Riffle
	16	72	70	~4.0	10	6.2	~3.0	68	55	26	Pool/glide with downed w and rootwads
	17	9.0	7.5	~6.0	4.9	4.7	~3.0	48	48	22	Pool, sand bottom
	18	13	13	0	2.0	0.5	0	12	1.0	0	Riffle

*Combined width of 2 smaller pools

Nearly all the animals remaining in the study reach on 12 August presumably died by the time I returned on 31 August, because the units they occupied were already isolated by lack of water between the units on 12 August – there was nowhere for them to go. During the 31 August survey, I found only a handful of sticklebacks still alive in a few of the units. No other fish were seen, and the mud within and around the remaining puddles of water was covered with tracks made by raccoons (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), and large wading birds (herons, egrets, etc.,) indicating that these predators probably ate most of the aquatic animals stranded in the shrinking pools.

Table 3.4.8 Total catch by seine and dipnet near well site

Common name	Scientific name	Date			
Fish		6/4/04*	7/2/04	8/12/04	10/10/05*
Steelhead	*Oncorhynchus mykiss*	24	292	60	34
Threespine stickleback	*Gasterosteus aculeatus*	>300	324	1260	429
Prickly sculpin	*Cottus asper*	4	45	87	21
California roach	*Lavinia symmetricus*	55	56	47	33
Lamprey (ammocetes)	*Lampetra spp.*			5	
Amphibians					
California red-legged frog	*Rana aurora draytonii*	1		3	
California (Coast Range) newt	*Taricha torosa torosa*	4			
Rough-skinned newt	*Taricha granulosa*	1	4	3	
Rough-skinned newt (larvae)	*Taricha granulosa*		1		
Red-bellied newt (larvae)	*Taricha rivularis*	4	51	68	
Bullfrog (larvae)	*Rana catesbeiana*				1
Invertebrates					
California freshwater shrimp	*Syncaris pacifica*	23	12	17	

* Dipnet sampling only
** Only 5 units sampled, all in lower reach

Discussion

Although coho salmon occurred in Salmon Creek in historical times, none were collected during this study, and none have been found in other surveys conducted in the Salmon Creek watershed in many years (Fawcett, unpublished data from occasional surveys from 1996 through 2004; Bill Cox, CDFG, personal communication; P. Adams, NMFS, personal communication). Steelhead still spawn and rear every year in Salmon Creek, although many local people feel that steelhead are no longer as abundant as they used to be. There are good reasons for believing that vast amounts of sediment has accumulated in mainstem Salmon Creek and in the estuary within recent decades, particularly during a couple of severe winters (1982-83 and 1986) when massive slope failures occurred on prominent coastal hillsides, sending vast quantities of material downhill and into nearby streams. In the case of Salmon Creek, it seems that something about the hydraulics near the mouth prevents significant amounts of sediment from completing the journey from headwaters to the sea (i.e., sediment accumulates in the estuary, but not much of it gets swept out to sea during the brief periods when the mouth is open). Depending on the tidal level when the berm at the mouth is breached, a deep and swift outlet channel may be rapidly formed. However, within a day after breaching, the outflow channel has largely filled up with sand again, so that a relatively minor flow of water (and entrained sediment) passes across the beach and out to sea. Questions have arisen about whether or not anthropogenic changes to the Salmon Creek estuary have caused or contributed to the extirpation of coho from the watershed. Information obtained during our brief period of study suggests at least three possible contributing factors:

1. The estuary has become smaller in surface area and volume of water held and shallower on average, than it once was, owing to massive sediment aggradation; much of the aggradation occurred during sporadic major storm events, e.g., the heavy rains, flooding, and landslides that occurred in early 1982 and 1986. Sediment aggradation in the estuary has altered the hydraulic properties of the estuary in ways that have reduced the frequency and magnitude of the tidal excursion, such that access to incoming adult coho on their spawning run is frequently not available (i.e., the bar at the mouth remains closed) until their normal peak entry time (October through December) in the region is passed or nearly so. As an example of this possibility, the mouth of the estuary did not open until the second week of December 8th in 2004, it then closed two days later and did not reopen again until December 27th (Chapters 3.1 and 3.3).
2. Excessive and increasing water diversions in the Salmon Creek watershed have reduced the freshwater input to the estuary, which has negatively affected the suitability of the estuary for salmonid rearing, especially during drought periods such as the area experienced in the nineteen-seventies, and during unusually dry summers, such as occurred in 2004. A dry summer occurs following a shortage of spring rainfall—other studies in the area (Fawcett et al 2003) have shown that the amount of rain that falls after the first of the year is far more important to summer stream conditions than the total amount of rain falling during the water year (July-June). Additionally, when a dry spring-summer occurs, water users tend to start diverting water earlier in the year, and use more water than during an average year, thus

exacerbating the effect of the shortage of spring rainfall. During the period of the present study, rainfall for the 2003-2004 water year was about average for the area, but very little rain fell in the spring of 2004 (Chapter 3.1, DWR and NOAA records). As a result, the berm at the mouth of the estuary closed in late May 2004 and remained closed until 8 December 2004; large areas of the estuary became isolated from the rest (e.g., surface water disappeared between Station 5 and Station 4), and the maximum depths of pools measured in September 2004 was substantially smaller than in the same pools measured in September 2005 (Chapter 3.3)—Spring and summer 2005 was unusually wet (Chapter 3.1), with significant rainfall events occurring throughout April, May, and June; no parts of the study area became dewatered in 2005 (*personal observation*), and the estuary mouth was breached several times during the dry season.

3. The estuary in its present condition lacks sufficient instream shelter to protect salmonid juveniles, smolts, or adults from predators. This shortage of cover became especially apparent in late summer-fall of 2004, when the only part of the estuary that had water quality conditions suitable to keep salmonids alive was at Station 1, where a large school of steelhead present in September in clear water only 1.0-1.5 m deep, was apparently decimated by predators (brown pelican, *Pelicanus occidentalis*, an endangered species) and double-crested cormorant, *Phalacrocorax auritis,* during the interval between the September survey (400 steelhead captured) and the 2 November survey, when only 1 steelhead was captured at Station 1 (Table 3.4.4) Flocks of both of these birds were observed foraging and consuming fish at Station 1 during the September 2004 survey and on other occasions. Throughout the late summer and fall of 2004, steelhead at Station 1 had nowhere to escape—they could not go out to sea because the estuary mouth was closed, and they could not go back upstream because of intolerable water quality conditions upstream of Station 1.

The three factors cited above lead to some obvious management or enhancement plans that could be undertaken, namely: reducing sediment input in the watershed through erosion control measures; reducing water diversions from the watershed during the summer months; and installing some log/rootwad structures in the estuary to improve available cover for fish. However, any attempts at active physical modification of the estuary (e.g., installing logs or channel modification) in the estuary will run into the problem of improving conditions for one group of listed species (steelhead and salmon) at the expense of another (tidewater goby). The estuary appears to be ideally suited for tidewater goby in its present condition, so enhancements made to benefit salmonids would be likely to negatively impact goby habitat. A compromise will require consultation with, and cooperation among several agencies: USFWS, NMFS, U.S. Army Corps of Engineers, and DFG.

CHAPTER 4: SUMMARY AND DISCUSSION

Estuaries and lagoons play a critical role in the life cycle of coho salmon and steelhead trout in the small coastal streams of Northern California. Good water quality, sufficient water quantity, habitat complexity, and ample food availability are the vital components necessary for salmonids to not only survive, but also to thrive. Water quality requirements include water temperatures in optimum ranges, adequate dissolved oxygen levels, and water clarity (turbidity) that does not inhibit feeding, territorial behavior, or physiologic functioning. Juvenile salmonid residence in the estuary or lagoon provides the necessary conditions for them to adjust physiologically from freshwater to saltwater. Estuaries also provide rich foraging opportunities that promote additional growth before heading out to the ocean. Food availability is dependent upon habitat complexity, water quality, and macro-invertebrate populations. Multiple studies on steelhead and other salmonids indicate that rapid growth and greater size upon ocean entry, resulting from estuary rearing, directly relates to higher rates of marine survival and return (Miller and Sadro, 2003).

The estuary and lagoon habitat is particularly important in systems that display absent or degraded summer upstream habitat. During drought years or in areas of poor summer rearing habitat juveniles will emigrate downstream seeking available habitat (Bjornn 1971). Under these conditions significant percentages of a watershed's juvenile population can end up rearing in the coastal lagoons and estuaries (Zedonis 1992, Shapavalov and Taft 1954). If the estuarine lagoon habitat is unavailable, or of poor quality, the annual production of steelhead (and coho) juveniles and smolts may perish. Important habitat features in estuaries for steelhead and coho include side channels, substrate complexity, and adequate woody debris for cover (DFG, 2004).

Elevated sediment delivery to coastal and estuarine habitats often adversely affects the biologic structure and functioning of the ecosystem, and reduces its ecologic, recreation, and aesthetic value (Thrush et al, 2004). In undisturbed coastal systems a dynamic balance occurs between the volume of terrestrial import of sediment to the estuary and export out. Increased rates and volumes of sediment delivered to the estuary from disturbances in the upper watershed (land use changes/practices, catastrophic fires, and extreme flood events) throws the dynamic out of balance and sedimentation of the estuary occurs. High sediment loading smothers macroinvertebrate and benthic faunal communities (Thrush et al, 2004)—an important food source for rearing juveniles. Excessive flood-borne sediments can fill tidal channels and aggrade tidal wetlands; permanently altering ecosystem structure and reducing critical habitat.

Dramatic reductions in the size and depth of the Salmon Creek estuary have occurred since European settlement of the area in the mid 1800s. Areas of open channel have filled in, side channels have disappeared, the channel has aggraded and coarsened, and tidal wetlands have transitioned to upland communities. Photos from the 1920s and 1940s show a wider, deeper estuary with extensive tidal wetlands and slough channels. Successive aerial photographs document the aforementioned physical changes over the next 60 years, many of which occurred by the late 1960s. Several large storm events in the 50s and 60s, combined with widespread channel clearing practices in the upper watershed, likely delivered large volumes of sediment to the estuary—filling in side channels and aggrading wetlands. New Highway 1 Bridges encroached on the tidal wetlands, altering the hydrodynamics of the system. The January 1982 storm mobilized sediment throughout the watershed, delivering coarse material to the mainstem from upper tributary storage. During the '82 storm further aggradation of the floodplains occurred, raising their elevations well above the tidal and lagoon water surfaces. In the subsequent 25 years pools have filled in and the overall bed elevation has aggraded up to 6 feet in some areas with excess sediment moving through the system.

The dynamic equilibrium of the Salmon Creek estuary is out of balance. More sediment is entering than can be transported out. This disequilibrium is likely to continue indefinitely, as large volumes of sediment are mobilized annually, and temporarily stored in the channels throughout the watershed. The incised, morphologically simplified channels of the upper watershed do not provide long-term storage for sediment, thus all the material is being transported to the estuary. This shift in the sediment regime, in conjunction with water quality and quantity issues, has significantly altered the hydrodynamics of the ecosystem and its habitat value.

Water quality and biotic data on the Salmon Creek estuary was collected from June 2004 through December 2005. Monthly profiles of temperature, salinity, and dissolved oxygen at six sampling stations between the estuary mouth and the upstream limit of tidal action near the Chanslor Ranch indicate that, during closed-bar conditions, the lower lagoon near the beach was well-mixed all summer and stations in the middle and upper zones were strongly stratified with near-bottom saline layers that remained anoxic and too hot for salmonid survival. Thus, fish habitat was limited to the shallow surface layer of freshwater in middle and upper zones, and to the well-mixed area near the mouth (which was also shallow and lacking in woody debris for cover).

Good quality rearing habitat in coastal estuaries is achieved in either bar-open conditions with full tidal mixing or if full conversion to a freshwater lagoon occurs after bar closure (Smith, 1990). Incomplete freshwater conversions, such as occurred in Salmon Creek in 2004 and 2005 and in other estuaries along the Northern California Coast (Smith, 1990; Cannata, 1998) produce stratified conditions, which result in limited, restricted habitat and reduced growth and survival. During the drought year of 2004, low flows in Salmon Creek permitted the encroachment of seawater into the upper estuary and were not sufficient to keep lagoon levels high enough for pool connectivity and vital habitat. The areas of adequate water quality were devoid of cover and shade. It is estimated that in 2004 very low, if no, steelhead smolts were produced by the estuary. High spring rainfall in 2005 led to better water quality and higher water levels in the lagoon. Stratification was still present, but limited to a smaller area and depth; resulting in a more benign habitat for fish in summer 2005. Correspondingly, smolt production was significantly greater.

Spring—but not winter—rainfall appears to be a major determinant of estuary habitat quality in the following summer. Late spring rainfall maintains the shallow aquifers and contributes to sustained, higher summer streamflows. Thus, summer streamflow directly correlates to lagoon habitat and juvenile production and survival. Domestic and agricultural water use in the watershed reduces the amount of streamflow available for upstream and estuarine habitat. Direct withdrawals and near-channel wells reduce the fresh water entering the estuary. The consequences of these system-wide withdrawals are more significant in low-water years.

Effects of reductions in streamflow upstream of a lagoon include slower velocities through riffles, diminished dissolved oxygen in pools immediately upstream of the lagoon, and lower water levels in the lagoon (Smith 1994). In nearby Redwood Creek lagoon, Smith (1994) reports that the lowered lagoon depths, shallowing of riffles and runs, and low pool dissolved oxygen resulting from the elimination of surface flow, as a result of daily withdrawals from near-channel wells, significantly reduced steelhead and coho numbers and growth in 1992 and 1993. Groundwater pumping from near-channel, public water supply wells in Salmon Creek during the summer of 2004 and 2005 lowered the water table elevation in the creek. In 2005 (wet year) the water levels recovered quickly and normalized to a stable base level. In 2004 (dry year) there was a slow recovery time after pumping periods and the water level decreased daily. It is unclear whether the steady decline in groundwater levels was due to the localized well pumping or to natural reductions in the groundwater volumes during the drought year; it is likely a combination of factors. During 2004 the stream channel in the vicinity of the wells went completely dry, while in other areas of the watershed flow was unusually low and in some areas pools were disconnected and shallow.

Adult salmonids use estuaries as a resting and feeding place before beginning their upstream spawning migration. Once the estuary mouth is open, movement into the river system is typically timed to high stream flows and high tides. It is critical that the barrier bar breaches in time to allow the adults entrance to the estuary and watershed during their spawning periods. Coho salmon migrate and spawn during the late summer and fall, whereas steelhead spawn in the winter (January- March). The Salmon Creek lagoon breaches on average in late November, with a range from early October to mid February.

Late summer lagoon volume governs the quality and extent of rearing habitat for juvenile salmonids, as well as the rainfall necessary to breach the barrier bar in the fall. The quantity of streamflow entering the estuary after bar closure determines whether there is sufficient freshwater to provide quality habitat. Low lagoon water depths, in combination with a lack of structure for cover and protection, lead to high predation losses in the late summer. High rates of sediment delivery to the estuary are contributing to depth and volume reductions. Without significant increases in summer freshwater flows, channel depths, and side channels and large woody debris for cover and predation protection the Salmon Creek estuary/lagoon will continue to be marginal salmonid habitat.

CHAPTER 5: ENHANCEMENT RECOMMENDATIONS

The following recommendations are based on the study results and are intended to improve aquatic habitat conditions in the Salmon Creek estuary. Short-term actions that would implement components of these recommendations are listed in the following chapter.

1. **Enhance habitat diversity in the estuary to provide cooler temperatures, more foraging areas and cover for young steelhead.**

   Historic maps and photographs show that the estuary included a network of small side channels and ponds that would have created excellent rearing conditions for salmonid fish, especially steelhead trout. In addition, the water quality and fisheries reports (Section 5.3 and 5.4) describe that when the mouth is closed, salinity stratification, oxygen depletion in the saline layer and the "solar pond effect" (in which the surface lens of freshwater heats the underlying saltwater layer) combine to restrict fish either to the top 1 meter freshwater or to the 1.5-2.0 m. deep, well-mixed reach directly behind the sandbar at the estuary mouth. In the well-mixed area, the fish are very vulnerable to predation from pelicans, cormorants and other birds because this area lacks ditch or wigeon weed (*Ruppia spp.)* or other cover, and water clarity is usually good. Installation of large woody debris structures, similar to those used in the Mattole River estuary, would provide instant cover. We recommend using an adaptive management process in which a small number (3-5) structures would be installed and then monitored for steelhead use as well as impacts to other species before a larger scale effort is undertaken.

   Longer term solutions would include re-creating side channels and reconnecting existing ponds. Significant additional assessment is needed before pursuing these alternatives. One important question to be answered is their effect on the tidewater goby population which appears to be thriving under current conditions.

2. **Maintain sufficient freshwater flows to provide upstream rearing habitat, keep the sandbar open longer, and moderate salinity, temperature and dissolved oxygen.**

   The amount of freshwater flow is a critical factor in determining when the sandbar will form and how long it will last. Low flows also result in shallower pools and isolation of large areas of the estuary. In fall of 2004, surface water completely disappeared between Stations 4 and 5. Low summer flows also reduce habitat available to steelhead in the upper watershed, and drive them into the estuary where they encounter poor water quality and hungry pelicans.

An action essential for sustaining beneficial flows is to reduce the reliance of local domestic water providers on summer withdrawals from Salmon Creek through increasing storage capacity, developing offstream water sources, and encouraging conservation. Salmon Creek Watershed Council, other local organizations and residents, and agencies can affect this change through helping the suppliers secure grants and educate their customers, and by developing and rigorously promoting a water conservation program.

Domestic water providers are not the only users of summer flow. Agricultural and private domestic users also divert stream water throughout the watershed. Attempts were made in this study to assess diversions, but little official data is available on how much water is being taken and where the withdrawals occur. Completion of a water budget would allow predictions on how varying water years would impact stream conditions, and provide an important tool for managing the timing and amount of water withdrawn from the Salmon Creek system by all users. It would also provide information on water availability that is essential for sound planning and growth decisions.

We strongly recommend that USGS install a stream gage at the upstream end of the estuary and that additional flow meters be installed at 2-3 stations in the upper watershed. Without ongoing monitoring, it is very difficult to assess when additional water is being withdrawn and when conservation measures are making a difference.

Other actions include encouraging the use of practices to increase infiltration and reduce stormwater runoff, particularly in new residential and agricultural development, and supporting projects that demonstrate rainwater catchment and other alternatives to ground or surface water withdrawals.

3. **Reduce the amount of sediment entering estuary.**
The estuary has become smaller because of sediment deposited from major storm events, such as the one in January 1982, and land use changes in the watershed over the past 150 years. Sediment volumes and sizes delivered from the watershed on an annual basis have increased dramatically from pre-European levels, altering the hydrodynamics of the estuary. As the volume of water held by the estuary decreases, the force of the outgoing water is reduced and the sandbar at the mouth forms earlier and remains in place longer. The length of the estuary closure is a significant factor in the loss of the Salmon Creek's coho salmon run. With the bar frequently remaining closed well into December, coho who usually enter streams from October through December, have little chance of

getting into Salmon Creek. The increased sediment also affects habitat for steelhead and other aquatic wildlife by filling in pools and gravels, and increasing turbidity.

Implementation of Best Management Practices (BMPs) for vineyards and livestock operations, repair of accelerated channel and upstream erosion, and sound management of unsurfaced roads and driveways will help reduce sediment entering the estuary. A thorough geomorphic assessment is needed to determine which erosion sites are having the most impact on instream and estuarine conditions, and how best to address them to achieve lasting, cost-effective repairs.

The recent exponential rise in numbers of dead tanoaks and other trees, victims of Sudden Oak Death (SOD), has created dangerous fire conditions in many parts of the watershed. Management to reduce this risk could help avert significant erosion.

4. **Maintain high quality of incoming freshwater.**
   Turbidity and high temperature are the greatest water quality issues in Salmon Creek. Turbidity, or fine sediment suspended in the water, is addressed above under sediment reduction. Temperature in the estuary is largely controlled by the amount of entering freshwater, but high water temperatures upstream can also affect estuary temperature. Most of Salmon Creek is well vegetated, but efforts should continue to protect and replant grazed riparian areas. Riparian pastures with carefully managed seasonal grazing have been effective where complete, year-round livestock exclusion is not feasible.

5. **Continue monitoring programs.**
   This study allowed for one year of monthly biological and water quality sampling plus continuous datasonde monitoring, and an additional one-day survey in fall 2005. That duration is barely enough to establish workable protocols, and certainly insufficient to detect trends in salmonid use of the estuary and how they adapt to changing conditions. At a minimum, an additional five years of biological and water quality monitoring in the estuary is needed. Securing assistance from area colleges and universities could help sustain the monitoring and incorporate it into more comprehensive studies.

6. **Enhance upstream salmonid rearing habitat**
   Although this recommendation does not directly impact estuarine habitat, providing better rearing habitat upstream could allow some steelhead to stay in the upper watershed longer before migrating into the estuary. A healthy estuary can provide excellent rearing conditions; however current conditions in the Salmon Creek estuary as described above can imperil fish. Maintaining

beneficial flows, as described in Recommendation 2 will help sustain pools and high water quality. Instream structures, such as carefully placed large woody debris, can trap sediment, create or enhance pools and provide shade and cover.

7. **Implement compelling education and outreach programs.**
With nearly the entire Salmon Creek watershed in private ownership, education is a primary means of implementing changes in how people manage their property and their water use. Opportunities for synergy and cooperation among the many active groups in the watershed abound. The Salmon Creek Watershed Council, the Occidental Arts and Ecology Center and the Bodega Land Trust are well suited for developing and delivering community-based education programs. Gold Ridge RCD and UC Cooperative Extension have already successfully offered workshops and demonstration programs and have ready access to many of the larger landowners in the watershed. Salmon Creek School is in the process of building an environmental education center that will serve the entire community, not just area students.

Community education is particularly needed in the following areas:
- water conservation
- BMPs for sediment control on ranches, horse facilities, vineyards and rural homes
- reduction of stormwater runoff from roofs and other hard surfaces
- stream dynamics—how stream channels adapt over time and how landowners can anticipate changes in the shape and location of their creeks
- habitat needs for steelhead and coho salmon
- Sudden Oak Death and land management to reduce fire danger
- a primer on the Salmon Creek watershed for new residents

Community members also have plenty to teach researchers and land managers. Oral history was a part of this project and of Gold Ridge RCD's planning work in the upper watershed. As little previous scientific study or monitoring has been conducted on Salmon Creek and the estuary, memories and inherited stories provide critical information to understanding how the Salmon Creek system has reacted to weather conditions and changes in land use. Although extensive and invaluable information was collected in the two efforts, there is much more to gather and to collate into usable documents.

8. **Integrate watershed planning and restoration efforts.**
This effort, the Gold Ridge RCD/Salmon Creek Watershed Council assessment and planning work in the upper watershed, UC Cooperative extension research into how pathogens are transported and stored by sediment and the estuary, and

other studies and planning efforts should be integrated into an overall strategy for managing the Salmon Creek watershed and guiding salmonid restoration.

A watershed GIS (Geographical Information System) was initiated as part of this project. A GIS allows land managers to correlate layers of information, such as an erosion inventory with instream habitat conditions, to better understand and predict how changes in the watershed will impact habitat. Continuing to update it with new information will provide an excellent tool for ongoing assessment and management.

CHAPTER 6: ACTION PLAN

Short Term Action Plan.

The following actions can be completed or well-underway within the next one to three years. Since most will require funding, an action common to each category is the ongoing submittal of grant proposals to agencies and foundations.

ACTION	INITIATING ORGANIZATIONS AND/OR AGENCIES	STATUS AND COMMENTS
Enhance Estuary Habitat		
Install large woody debris structures in the lower estuary to enhance cover for out-migrating steelhead.	Salmon Creek Watershed Council, State Parks	Agency coordination and initial planning underway.
Continue biological monitoring in the estuary for at least five more years to gather better information on how salmonids are using estuary. Include effectiveness monitoring of enhancement projects.	Salmon Creek Watershed Council, area colleges and universities, State Parks	
Organize volunteer events to remove and manage exotic invasive plants on State Park estuary property.	State Parks, Salmon Creek Watershed Council, Bodega Land Trust	
Maintain Beneficial Streamflow		
Support local domestic water providers in securing off-stream water storage and/or new water sources to reduce summer withdrawals from Salmon Creek.	Local water providers, Salmon Creek Watershed Council	Request assistance from the Regional Water Quality Control Board and NOAA to find and secure funding.
Continue to monitor streamflow entering the estuary. Include monitoring stations at several upstream sites.	Salmon Creek Watershed Council, area colleges and universities	

Install USGS stream gage upstream of estuary.	USGS, Salmon Creek Watershed Council with support from all involved agencies	
Support the Bodega Volunteer Fire Department and other community projects in developing effective strategies to increase infiltration and reduce stormwater runoff from new construction or expansion projects.	Salmon Creek Watershed Council, Bodega Land Trust	
Develop a water budget to better manage water diversions in order to maintain sufficient baseflow in Salmon Creek and its estuary to support an anadromous fishery.	Salmon Creek Watershed Council, area colleges and universities	
Manage Sediment		
Repair priority sediment sources as identified in Gold Ridge RCD Erosion Site Inventory.	Gold Ridge RCD	RCD and partners are seeking grant funding.
Complete geomorphic and additional sediment source assessment to better target and appropriately repair those erosion sites that are most impacting salmonid habitat.	Gold Ridge RCD	RCD is submitting a proposal under the SWRCB Consolidated Grant Program.
Continue the road assessment and improvement program. Include long driveways. Assess impact of raised private roads and driveways in floodplain.	Gold Ridge RCD, Salmon Creek Watershed Council	
Encourage the use of Best Management Practices (BMPs) on vineyards and ranches. Demonstrate appropriate BMPs in Salmon Creek and neighboring watersheds.	Gold Ridge RCD, Bodega Land Trust, UC Cooperative Extension, NRCS	Bodega Land Trust is submitting a proposal under the SWRCB Consolidated Grant Program for demonstration of agricultural BMPs.

Maintain High Water Quality		
Continue to fund and coordinate volunteer water quality monitoring.	Gold Ridge RCD, Salmon Creek Watershed Council, Community Clean Water Initiative, Bodega Land Trust	Sonoma County Fish and Wildlife Commission recently granted funding for monitoring equipment and supplies.
Promote the fencing and management of riparian areas in grazing lands to reduce stream temperature and turbidity.	Landowners, Gold Ridge RCD, NRCS	
Enhance Upstream Salmonid Rearing Habitat as Alternative to Estuary		
Continue large woody debris (LWD) placement projects to trap sediment, create pools and provide cover for rearing steelhead.	Landowners, Gold Ridge RCD, Bodega Land Trust, DFG	
Remove barriers or impediments to upstream salmonid migration.	Landowners, Gold Ridge RCD, Bodega Land Trust	
Provide Community Education and Outreach		
Develop a watershed information packet for local real estate agents to distribute to new residents.	Salmon Creek Watershed Council, Occidental Arts and Ecology Center, Bodega Land Trust, Salmon Creek School	
Implement a Water Conservation Campaign.	Salmon Creek Watershed Council, Occidental Arts and Ecology Center, Bodega Land Trust, Salmon Creek School	

Implement a Fuel Management/Sudden Oak Death Awareness Program.	West County Fire Safe Council, Salmon Creek Watershed Council, Occidental Arts and Ecology Center, local fire departments, CDF	
Continue to collect and document oral history.	Salmon Creek Watershed Council, Gold Ridge RCD, Bodega Land Trust	
Develop an educational trail system around estuary.	State Parks, Salmon Creek Watershed Council, Bodega Land Trust	
Coordinate Watershed Planning and Restoration Efforts		
Incorporate various assessments and studies into an Integrated Watershed Management Plan	Salmon Creek Watershed Council, Gold Ridge RCD, Bodega Land Trust	Included in the Gold Ridge RCD and Bodega Land Trust proposals to the SWRCB Consolidated Grant Program.
Continue to develop a Watershed GIS (Geographic Information Service).	Salmon Creek Watershed Council, Gold Ridge RCD	Included in the Gold Ridge RCD proposal to the SWRCB Consolidated Grant Program.

REFERENCES

Anderson, M. Kat. *Tending the Wild: Native American Knowledge and the Management of California's Natural Resources*. University of California Press, Berkeley, 2005.

Barnhart, R.A. 1986. Species profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest) – steelhead. U.S. Fish and Wildlife Service Biological Report. 82 (11.60) U.S. Army Corps of Engineers, TR EL-82-4. 21 pp.

Bjornn, T.C. 1971. Trout and salmon movements in two Idaho streams as related to temperature, food, stream flow, cover, and population density. Trans. Amer. Fish. Soc. 100(3): 423-438.

Boreta, Rade G. 1967. Letter to California State Department of Fish and Game. October 26, 1967.

California Coastal Commission. 1985. Letter to Margaret Mantua of the Bodega Bay Public Utilities District from Mark Delaplaine, Coastal Planner. December 3, 1985.

California Department of Fish and Game (CDFG). 1929. Memorandum. April 10, 1929.

California Department of Fish and Game (CDFG). 1933. Field Correspondence. May 4, 1933.

California Department of Fish and Game (CDFG). 1938. Memorandum to Henry Lencioni. June 8, 1938.

California Department of Fish and Game (CDFG). 1938. Memorandum. June 10, 1938.

California Department of Fish and Game (CDFG). 1947. Field Correspondence. August 1, 1947.

California Department of Fish and Game (CDFG). 1947. Letter to L.M. Abraham from Brian Curtis, Supervising Fisheries Biologist. August 20, 1947.

California Department of Fish and Game (CDFG). 1947. Field notes. August 28, 1947.

California Department of Fish and Game (CDFG). 1950. Field notes, Letter to Captain Lee Shea. June 21, 1950.

California Department of Fish and Game (CDFG). 1950. Field Correspondence. August 24, 1950.

California Department of Fish and Game (CDFG). 1953. Field note. June 16, 1953.

California Department of Fish and Game (CDFG). 1953. Field notes. November 15, 1953.

California Department of Fish and Game (CDFG). 1958. Field note. May 8, 1958.

California Department of Fish and Game (CDFG). 1958. Field note. October 27, 1958.

California Department of Fish and Game (CDFG). 1961. Stream Flow Measurement. August 14, 1961.

California Department of Fish and Game (CDFG). 1961. Intraoffice Correspondence. November 21, 1961.

California Department of Fish and Game (CDFG). 1961. Stream Survey: Salmon Creek. December 28, 29, 1961.

California Department of Fish and Game (CDFG). 1964. Stream Survey: Salmon Creek. April 29, 1964.

California Department of Fish and Game (CDFG). 1965. Stream Survey: Finley Creek. August 2, 1965.

California Department of Fish and Game (CDFG). 1965. Stream Survey: Coleman Valley Creek. August 3, 1965.

California Department of Fish and Game (CDFG). 1965. Stream Survey: Fay Creek. August 4, 1965.

California Department of Fish and Game (CDFG). 1966. Stream Survey: Fay Creek. June 14, 1966.

California Department of Fish and Game (CDFG). 1967. Letter to Robert G. Ballachey from Willard Greenwald, Regional Manager. November 30, 1967.

California Department of Fish and Game (CDFG). 1970. Stream Survey: Fay Creek. December 31, 1970.

California Department of Fish and Game (CDFG). 1973. Field note. September 20, 1973.

California Department of Fish and Game (CDFG). 1977. Field note. August 26, 1977.

California Department of Fish and Game (CDFG). 1977. Field note. September 14, 1977.

California Department of Fish and Game (CDFG). 1977. Field note. September 19, 1977.

California Department of Fish and Game (CDFG). 1977. Field note. October 14, 1977.

California Department of Fish and Game (CDFG). 1977. Field note. November 7, 1977.

California Department of Fish and Game (CDFG). 1982. Letter to Brian Hunter of the Fisherman's Marketing Association Inc. of Bodega Bay from Michael Gold, Regional Manager. October 15, 1982.

California Department of Fish and Game (CDFG). 1982. Letter to Brian Hunter of the Fisherman's Marketing Association Inc. of Bodega Bay from Michael Gold, Regional Manager. October 29, 1982.

California Department of Fish and Game (CDFG). 1983. Letter to Brian Hunter of the Fisherman's Marketing Association Inc. of Bodega Bay from Michael Gold, Regional Manager. April 11, 1983.

California Department of Fish and Game (CDFG). 1988. Letter to Don Head of the Department of Public Works from Michael Gold, Regional Manager. June 1, 1988.

California Department of Fish and Game (CDFG). 1996. Initial Report of Fish and Wildlife Loss. April 17, 1996.

California Department of Fish and Game (CDFG). 2001. Memorandum. September 17, 2001.

California Department of Fish and Game (CDFG). 2003. *Stream Inventory Report Fay Creek.*

California Department of Fish and Game (CDFG). 2004. *Stream Inventory Report Coleman Valley Creek.*

California Department of Fish and Game (CDFG). 2004. *Stream Inventory Report Finley Creek.*

California Department of Fish and Game (CDFG). 2004. *Stream Inventory Report Nolan Creek.*

California Department of Fish and Game (CDFG). 2004. *Stream Inventory Report Salmon Creek.*

California Department of Fish and Game (CDFG). 2004. *Stream Inventory Report Thurston Creek.*

California Department of Fish and Game (CDFG). 2004. Recovery Strategy for California Coho Salmon: Report to the California Fish and Game Commission. Species Recovery Strategy 2004-1. February 2004.

California Natural Diversity Database 2005. State and federally listed endangered and threatened animals of California. List prepared October 2005.

Cannata, Stephen, P. 1998. Observations of Salmonid Use, Water Quality, and Channel Morphology of the Navarro River Estuary/Lagoon May, 1996 to December, 1997.Humboldt State Foundation. February 16, 1998.

Circuit Rider Productions. 1985. Fish Habitat Improvement Completion Form for fencing and revegetation work completed by Circuit Rider Productions. December 9, 1985.

Commins, M.L., M.H. Fawcett, and J.C. Roth. 1996. Environmental conditions in West County waterways. Prepared by Merritt Smith Consulting for Harland Bartholomew and Associates, Inc., the City of Santa Rosa and the U.S. Army Corps of Engineers. April 1996. 32 pp. + appendices

Drierchman, F.R. 1932. Letter to Fish and Game Commission. April 22, 1932.

Fawcett, M.H., J.C. Roth, and D.W. Smith. 2003. Salmonid juvenile density monitoring in Sonoma County streams, synthesis of a ten-year study (1993-2002). Prepared by Merritt Smith Consulting for the City of Santa Rosa. 52 pp.

Grady, Rex. *Let Ocean Seethe and Terra Slide: A History of the Sonoma Coast and the State Park That Shares Its Name*. Lilburne Press, Occidental.1996.

Hill, Amie. *An Historical and Anecdotal Walking Tour of the Small (but Fascinating) Village of Occidental*. n.p., 1997 (10th ed., 2005)

Miller, Bruce A. and Steve Sadro. 2003. "Residence Time and Seasonal Movements of Juvenille Coho Salmon in the Ecotone and Lower Estuary of Winchester Creek, South Slough, Oregon." Transactions of the American Fisheries Society 132: 546-559.

Moyle, P.B. 2002. Inland Fishes of California. Revised and expanded. U.C. Press. 502 pp.

National Marine Fisheries Service. 1999. Designated critical habitat: Central California Coast and Southern Oregon/Northern California Coasts coho salmon. Federal Register, Vol. 64, No. 86: 24049-24062. May 5, 1999.

National Marine Fisheries Service 2005. Endangered and Threatened Species; designation of critical habitat for seven evolutionarily significant units of Pacific salmon and steelhead in California. Federal Register Vol. 70, No. 170: 52487-52627. September 2, 2005.

Rancho Bodega History Society Newsletters, 1991-2006.

Roth, J.C., M.H. Fawcett, D.W. Smith, J. Martini, J. Mortenson, and J. Hall. 2000. Biological and water quality monitoring in the Russian River estuary, 1999. Fourth annual report. Prepared by Merritt Smith Consulting for the Sonoma County Water Agency. 38 pp. + appendices.

Shapovalov, L. and A.C. Taft. 1954. The life histories of the steelhead (Salmo gairdneri gairdneri) and silver salmon (Oncohynchus kisutch) with special reference to Waddell Creek, California, and recommendations regarding their management. Fish Bulletin 98. 303 pp + apps.

Smith, Dr. Jerry. 1990. The Effects of Sandbar Formation and Inflows of Aquatic Habitat and Fish Utilization in Pescadero, San Gregorio, Waddell and Pomponio

Creek Estuary/Lagoon Systems, 1985-1989. Department of Biological Sciences, San Jose State University. December 21, 1990.

Smith, Dr. Jerry. 1994. Effects of Streamflow Reductions on Fish Habitat Quality in Redwood Creek and Lagoon. Department of Biological Sciences, San Jose State University. February 18, 1994.

Smith, Dr. Jerry. 2003. Water Quality Concerts and Central Coast Steelhead and Coho. Department of Biological Sciences, San Jose State University. August 5, 2003.

Sonoma County Historical Library, Santa Rosa, many historical periodicals consulted

Sundermeyer, Ruth. California Coastal Lagoons: Effects of Sandbar Breaching. Institute for Fisheries Resources.

Swift, C. C., J. L. Nelson, C. Maslow, and T. Stein. 1989. Biology and distribution of the tidewater goby, Eucyclogobius newberryi (Pisces: Gobiidae) of California. Contributions in Science, Number 404. Natural History Museum of Los Angeles County. 19 pp.

Thrush, S.F., J.E. Hewitt, V.J. Cummings, J.I. Ellis, C. Hatton, A. Lohrer, A. Norkko. 2004. "Muddy waters: elevating sediment input to coastal and estuarine habitats." Front Ecol Environ 2(6): 299-306

Tuomey, Honoria. History of Sonoma County, vols. I and II. n.p., 1926.

U.S. Fish and Wildlife Service 2005. Recovery plan for the tidewater goby (Eucyclogobius newberryi). Portland, Oregon. 199 pp.

Wilson, Simone. Sonoma County: A River of Time. American Historical Press, Sun Valley, California, 1999.

Zedonis, P.A. 1992. The biology of the juvenile steelhead (Oncorhynchus mykiss) in the Mattole River estuary/lagoon, California. M.S. Thesis, Humboldt State University, Arcata, California.

Websites:
http://www.sonomamarinrcds.org/district-ssr/Newsletters/summer2002/summer2002.htm. 2002. Sotoyome Resource Conservation District Newsletter. Gualala River Estuary Study Begins.

www.krisweb.com. 2004. Klamath Resource Information System (KRIS) Project; KRIS Russian River. Prepared for the Sonoma County Water Agency.

http://www3.csc.noaa.gov/salmonid/. 2006. Salmonid Habitat Restoration Planning Resource for San Mateo and Santa Cruz Counties. Estuarine and Lagoon Conditions.

http://www.dpla2.water.ca.gov/publications/groundwater/bulletin118/basins/pdfs_desc/1-57.pdf. 2006. California Department of Water Resources, Division of Planning and Local Assistance. Bodega Bay Area Groundwater Basin.

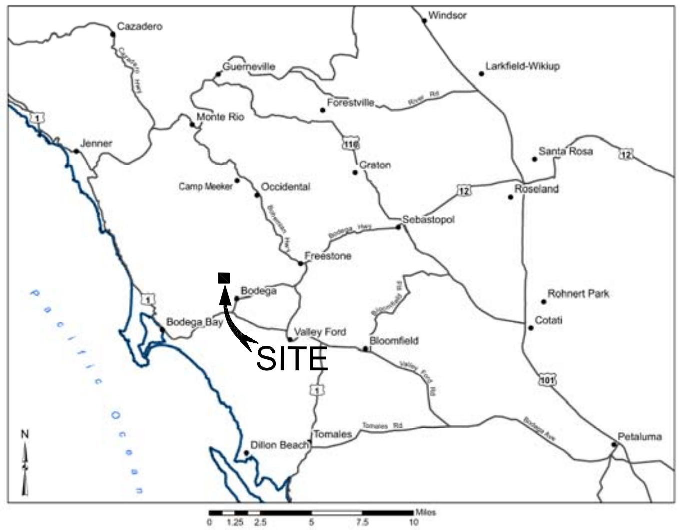
http://www.navarro-by-the-sea-center.org/salmon.html. 2006. Navarro-by-the-Sea Center for Riparian and Estuarine Research. Stephen P. Cannata. Observations of Salmonid Use, Water Quality, and Channel Morphology of the Navarro River Estuary/Lagoon, May 1996 to December 1997.

Newspaper Articles:
Bodega Bay Navigator. 2005. Logbook. Sonoma Coast State Beach Rangers Salmon Creek Mouth. May 15-21, 2005.

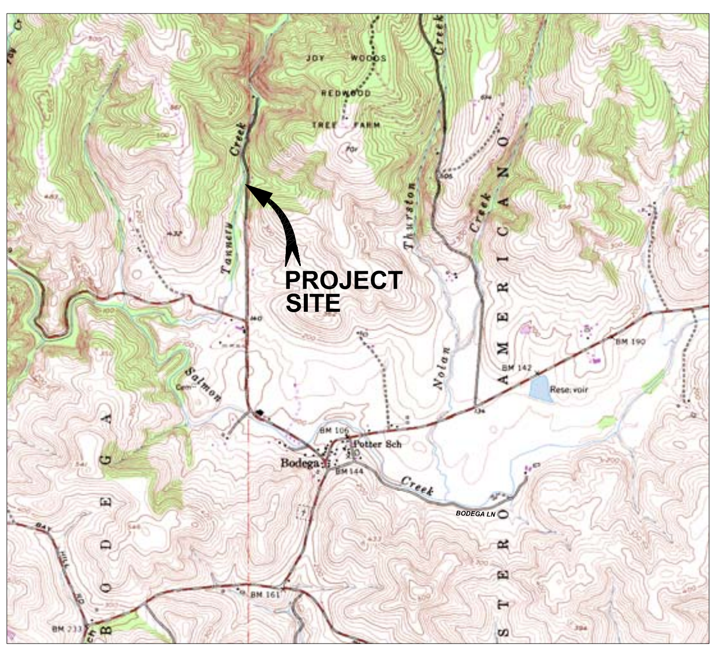
APPENDICES

Appendices include historical background and oral histories by Kat Harrison, water quality graphs by James C. Roth, and data files. These files may be viewed electronically on the supplemental CD.

SAVE OUR SALMON:
SALMON CREEK INSTREAM HABITAT ENHANCEMENT PROJECT
TANNERY CREEK LARGE WOOD STRUCTURES
CONCEPTUAL PLANS FOR ECOLOGICAL PERMITTING



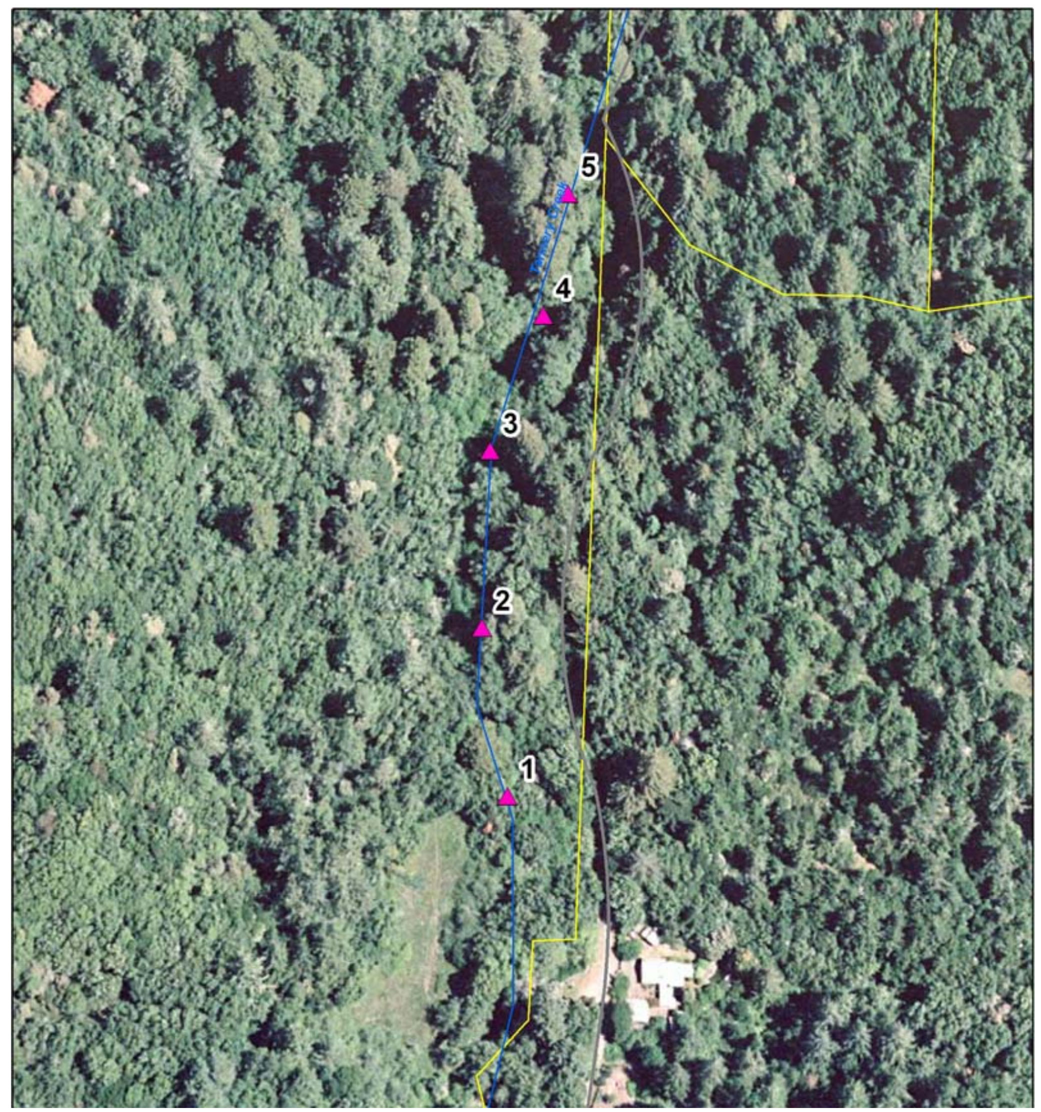
VICINITY MAP



LOCATION MAP
SCALE: 1" = 1000'

SHEET INDEX

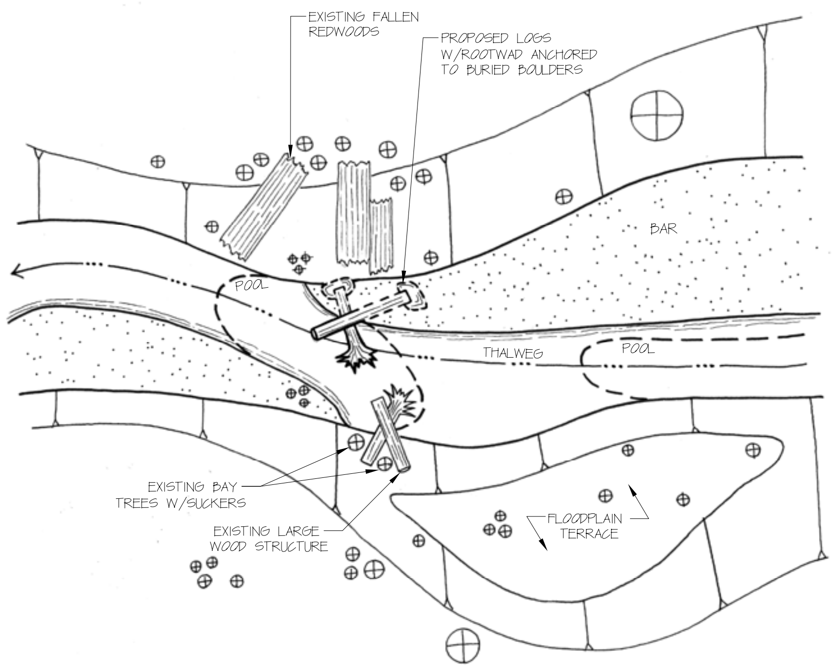
SHEET NO.	TITLE
1	TITLE SHEET
2	LARGE WOOD STRUCTURES CONCEPTUAL PLAN



LAYOUT
1" = 100'

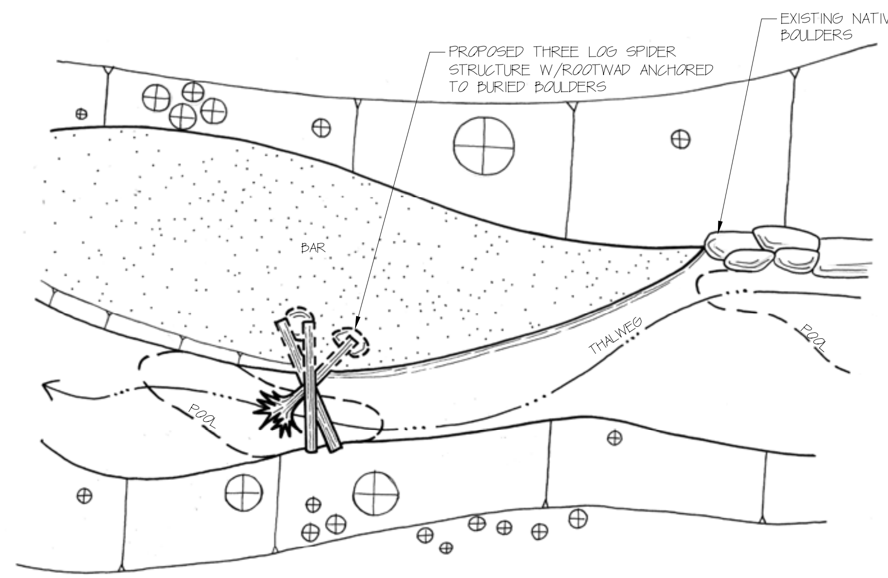
NOTE:
DRAWING SCALE HAS BEEN REDUCED FROM ITS ORIGINAL SIZE.

DATE: 09-02-09 SCALE: AS SHOWN DESIGNED BY: DG DRAFTED BY: MY CHECKED BY: DG	REVISIONS | DATE | BY	PREPARED FOR: GOLD RIDGE RESOURCE CONSERVATION DISTRICT P.O. BOX 1064 OCCIDENTAL, CA 95465	SAVE OUR SALMON: SALMON CREEK INSTREAM HABITAT ENHANCEMENT PROJECT TANNERY CREEK LARGE WOOD STRUCTURES TITLE SHEET	SHEET 1 OF 2	



SITE 1

GOAL: NEW STRUCTURE TO ENHANCE FUNCTION OF EXISTING STRUCTURE TO FOCUS FLOWS, SCOUR DEEPER POOL AND INCREASE COVER



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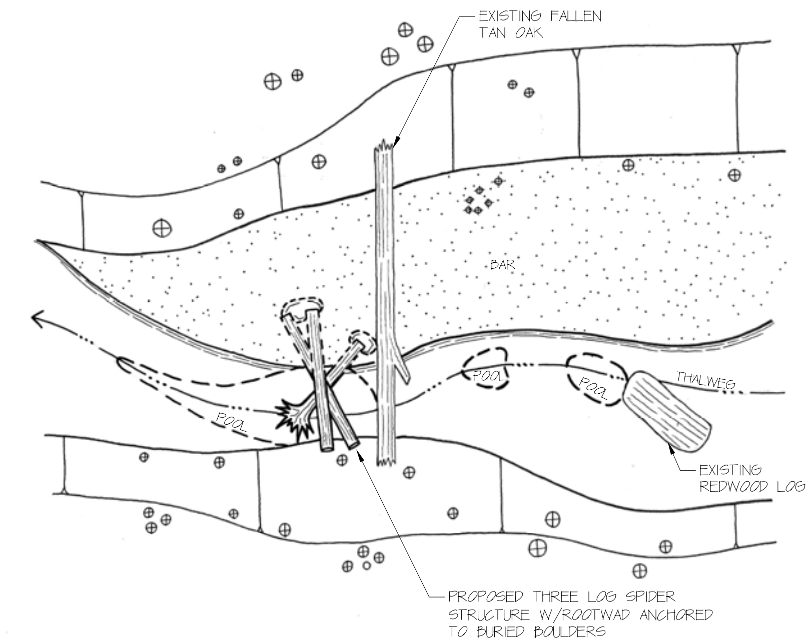

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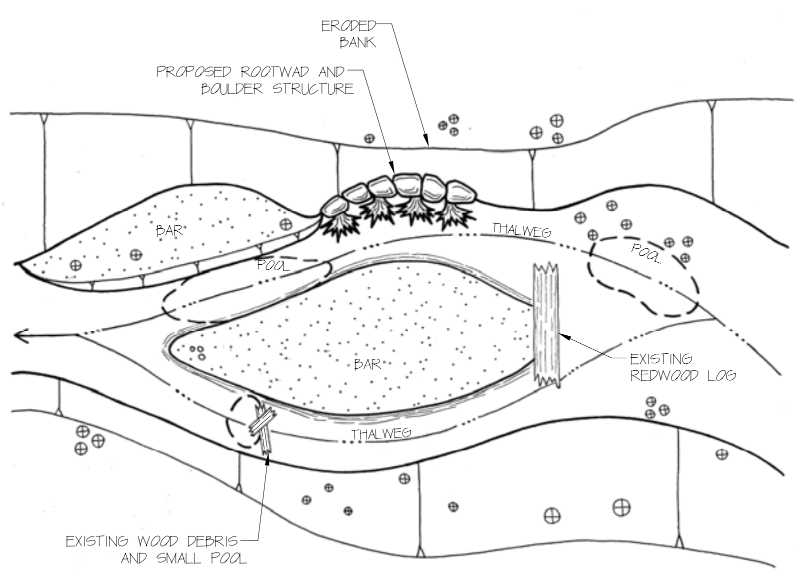

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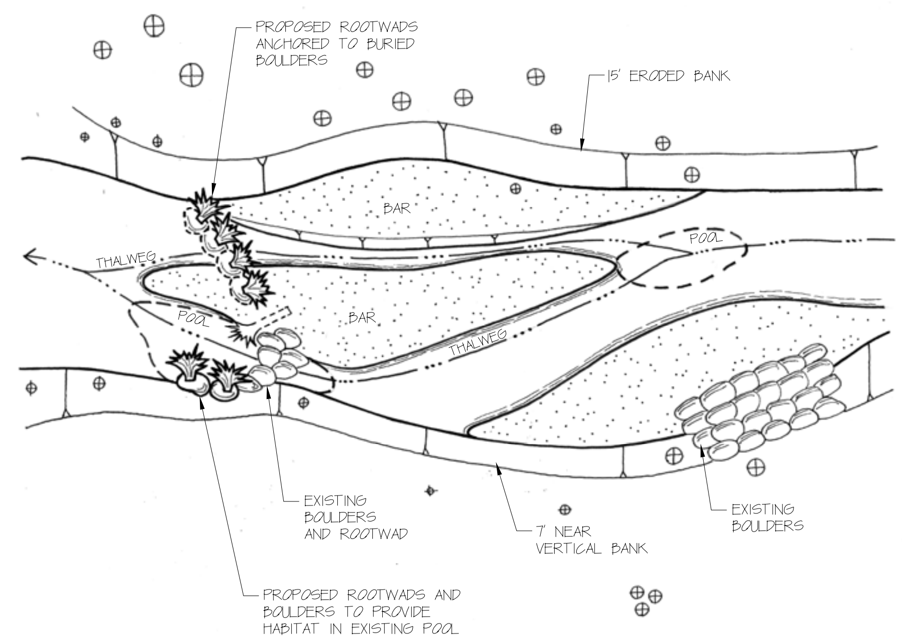
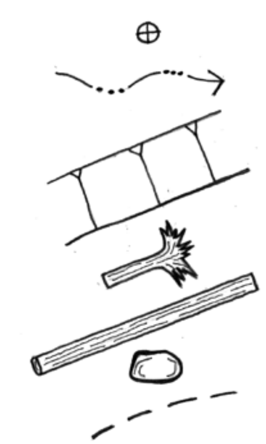


SITE 5

GOAL: NEW STRUCTURE TO FOCUS FLOWS, ENHANCE POOL AND INCREASE COVER

LEGEND



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DATE: 09-02-09
SCALE: NTS
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CHECKED BY: DG

REVISIONS	DATE	BY

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