2012 STATE OF THE BASIN REPORT;
AMARGOSA RIVER BASIN

Inyo and San Bernardino Counties,
California & Nye County, Nevada

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EXECUTIVE SUMMARY

This 2012 State of the Basin Report (SOBR) was prepared by The Source Group, Inc. (SGI) on behalf of the Amargosa Conservancy (AC) as part of a much larger effort that is anticipated to be conducted cooperatively between the AC and the U.S. Geological Survey (USGS). The goal of the overall project is to improve the understanding of the water that sustains the Amargosa River and the desert ecosystems that flourish along the river and its adjoining springs, and to equip the AC with the knowledge necessary to identify and avert impacts to those water sources. The purpose of the work conducted as part of the current scope is to provide important new information and conduct continuing baseline spring and groundwater-level monitoring, and prepare a "State of the Basin" report (SOBR).

In 2009, the Amargosa River between Shoshone and the terminus of the Amargosa Canyon received Wild and Scenic status through an act of Congress. As a result, the U.S. Bureau of Land Management (BLM) is charged with developing a management plan for the Wild and Scenic portion of the River. It is essential that hydrogeologic characterization of the California portion of the basin take place in order for that management plan, and its associated management recommendations, to have a firm basis, and to assure that monitoring is conducted in a meaningful way to identify potential impacts to the river and its feeder springs before potential irreversible impacts from future groundwater development occur.

The Amargosa River Basin covers an area of 3,124 square miles in east-central California and west-central Nevada. The Amargosa River Basin can be subdivided into three basin areas from upstream to downstream:

- Northern Amargosa Groundwater Basin (Nevada portion of the Basin);
- Middle Amargosa Valley Groundwater Basin (California); and
- Death Valley Groundwater Basin (California – Nevada).

In the Amargosa River Basin, the principal hydrogeologic units consist of the unconsolidated basin fill materials, volcanic rocks (primarily in Nevada), and a regionally-extensive carbonate rock aquifer. The Death Valley regional groundwater flow system is considerably more extensive than the Amargosa River Basin watershed. The reason for this is the extensive area beyond the watershed boundary underlain by the carbonate rock aquifer that drains toward Death Valley. In this large flow system, groundwater recharge results from precipitation in the form of snowmelt and rainfall that falls within the mountains of southern and central Nevada, and reaches the Amargosa River Basin where it is discharged.

The principal surface water body in the region is the Amargosa River, an intermittent river with headwaters issuing from springs northeast of Beatty, Nevada, and extending approximately 180 miles to the river's terminus at the playa in Death Valley. Except for portions of the river in the Amargosa Canyon area in California, and near Beatty, Nevada, the Amargosa River typically flows only after periodic storms. In those areas where the river is usually dry, the flow of water is in the subsurface. The perennial reach of the Amargosa River between Shoshone and Dumont Dunes was designated as a National Wild and Scenic River in 2009. Except during runoff events from rainstorms, the perennial flow in the Wild and Scenic section of the river is completely supplied by groundwater.

The principal task during this project was the geochemical sampling of springs, the Amargosa River and groundwater wells, along with continued monitoring of spring flow, river flow and groundwater levels in the Middle Amargosa River Basin, an area encompassing nearly 1,000 square miles. The results of these activities form the foundation for all future more detailed hydrogeologic investigations that are likely to include additional detailed geochemical analyses of springs and future groundwater monitoring wells to evaluate provenance of the spring water present. Those detailed analyses will continue to serve to assist in the identification of regional and local groundwater flow paths, and enable the development of an efficient, focused groundwater monitoring effort that will be protective of the environmental and cultural resources of the basin.

Among the results of the geochemical work was evidence that spring sources within the study area are complex and from multiple sources. Currently, there is insufficient information to develop a groundwater budget for the portion of the basin between the California – Nevada state line and Salt Creek (the Middle Amargosa River Basin). Attempting to evaluate groundwater recharge and groundwater underflow into the Basin will be difficult both from a technical standpoint and in funding what would be such a major investigative endeavor. Therefore, the most logical means to evaluate the groundwater budget for the California portion of the basin will be to develop a firm understanding of the various groundwater discharge components including evapotranspiration (including spring flow), and subsurface underflow beyond Salt Creek. In order to accomplish these goals, a number of recommendations are provided to address these data deficiencies.

1.0 INTRODUCTION

This SOBR was prepared by SGI on behalf of the AC as part of a much larger effort that is being conducted between the AC, BLM, The Nature Conservancy, and the U.S. Geological Survey (USGS). The goal of the overall project is to improve the understanding of the water that sustains the Amargosa River and the desert ecosystems that flourish along the river and its adjoining springs and to equip the AC with the knowledge necessary to identify and avert impacts to those water sources. The purpose of the work conducted as part of the current scope is to improve on our understanding of the groundwater flow paths to the Amargosa River and surrounding springs, continue to develop baseline spring, river flow, and groundwater-level monitoring, and prepare a SOBR.

In 2009, the Amargosa River between Shoshone and the terminus of the Amargosa Canyon received Wild and Scenic status through an act of Congress. As a result, the BLM is charged with developing a management plan for the Wild and Scenic portion of the River. It is essential that hydrogeologic characterization of the California portion of the basin take place in order for that management plan, and its associated management recommendations, to have firm basis, and to assure that monitoring is conducted in a meaningful way to identify potential impacts to the river and its feeder springs before potential irreversible impacts from future groundwater development occur.

This project is an important starting point into the investigation of the hydrogeology of the Amargosa Basin south of the Nevada state line. Prior to the initial reconnaissance work conducted by SGI during 2010-2011 (SGI, 2011), regional hydrogeologic investigations in the California portion of the basin have been virtually non-existent. The discussions regarding the California portion of the basin therefore are more conceptual in nature than those regarding the Nevada portion of the basin.

The objectives of the project described in this report were to:

- Develop initial groundwater geochemical analyses to evaluate potential groundwater flow paths;
- Enhance previous reconnaissance-level information on the springs of the southern half of the Amargosa Basin, generally between Death Valley Junction and Saratoga Springs;
- Continue to develop an understanding of Amargosa River conditions in the southern half of the basin;
- Describe the results of groundwater-level monitoring and evaluate potential future monitoring locations; and,
- Continue to enhance the conceptual model of the Amargosa Basin with an emphasis on the southern half of the basin.

1.1 Scope of Work

The scope of work included the following tasks:

- Task 1 – Sampling and analysis of water samples collected from springs, the Amargosa River, and selected wells;
- Task 2 – Continued periodic groundwater level, spring flow and river flow monitoring; and
- Task 3 – Analysis and preparation of this SOBR.

1.1.1 Water Chemistry Data Collection

Water samples from springs, two wells and the Amargosa River were collected and analyzed for a specific suite of constituents, including field parameters, general chemistry, a comprehensive suite of trace metals, and stable/non-stable isotopes. The general chemistry and trace metal samples were analyzed by ATL laboratory at their Las Vegas, Nevada facility. Isotope analyses were conducted by outside labs including the Massachusetts Institute of Technology (MIT, for uranium and strontium isotopes), and University of Arizona (deuterium/oxygen/tritium). Hurst & Associates (Hurst) was retained to provide high-level expert analysis and interpretation. Additional samples were collected for quality assurance/quality control (QA/QC) purposes.

1.1.2 Discharge, Water Level and Seepage Run Monitoring

Flow discharge and groundwater elevation measurements were collected on a periodic basis from a select group of springs and wells within the southern Amargosa River area. Seepage run monitoring was conducted periodically on the stretch of River from Tecopa to the Dumont Dunes area and consisted of five distinct monitoring locations (including the two USGS gauges, and three manual monitoring points). Basic water quality data were also collected at all discharge, elevation and seepage run monitoring points.

1.1.3 Data Assessment and Reporting

This task included the time required to analyze the chemical data obtained from the springs and wells, and to compare it to data collected in the Pahrump, Amargosa Valley, and Nevada Test Site areas. The chemical data, along with the discharge, water level and seepage run data will be compiled in this updated 'State of the Basin' report, modifying the previous report that was be presented to the Amargosa Conservancy (SGI, 2011).

1.2 Location and Physiographic Setting

The Amargosa River Basin covers an area of 3,124 square miles in east-central California and west-central Nevada (Figure 1-1). The Amargosa River Basin can be subdivided into three basin areas:

- Northern Amargosa Groundwater Basin (Nevada portion of the Basin also referred to as the Amargosa Desert Hydrographic Basin by the Nevada Department of Water Resources);

- Middle Amargosa Valley Groundwater Basin (California); and
- Death Valley Groundwater Basin (California –Nevada).

The Northern Amargosa Valley Groundwater Basin is comprised of the Amargosa River Valley from the river's headwaters northwest of Beatty, Nevada, to the California-Nevada state line. Elevations in this portion of the Amargosa River Basin range from 6,317 feet above mean sea level (ft msl) at Bare Mountain south of Beatty and east of the Amargosa River, to about 2,300 ft msl at the California-Nevada state line near Death Valley Junction, California. The basin is bounded by consolidated rocks of the Yucca Mountain/Pahute Mesa area to the northeast, Bare Mountain on the east, and the Funeral Range to the west. The Northern Amargosa River Basin as defined covers 896 square miles.

The Middle Amargosa Valley Groundwater Basin (groundwater basin #6-20 as designated by the California Department of Water Resources) is comprised of the Amargosa River Valley along with Chicago Valley and parts of Greenwater Valley within Inyo and San Bernardino Counties, California. The California-Nevada state line is considered the northern boundary of the Middle Amargosa Valley Groundwater Basin. The elevation of the valley floor generally ranges from about 400 feet near Salt Creek in the southern portion of the valley to about 2,300 feet at the California-Nevada state line near Death Valley Junction. The basin is bounded by consolidated rocks of the Resting Springs and Nopah Ranges on the east, the Dumont Hills on the south, and the Greenwater Range and Ibex, Black, and Funeral Mountains (collectively known as the Amargosa Range) on the west. The surrounding mountains range in elevation up to 7,335 feet above mean sea level (ft msl) at Kingston Peak (within San Bernardino County along the southeast edge of the Basin) and up to 6,725 ft msl at Pyramid Peak, the high point of the Funeral Range to the west. The Middle Amargosa River Basin covers an area of 609 square miles.

The Death Valley Groundwater Basin (groundwater basin #6-18 as designated by the California Department of Water Resources) is comprised of the Amargosa River Valley from the Salt Creek area to the sink at Badwater in Death Valley, and northward to the northern physical terminus of Death Valley in Nevada (Oriental Wash Area of the Death Valley Basin as designated by the Nevada State Engineer). Elevations in this portion of the Amargosa River Basin range from 282 feet below mean sea level at Badwater, to 11,049 ft msl at Telescope Peak, the highpoint of the Panamint Range along the west side of Death Valley. The combined area of the California and Nevada portions of this lower part of the Amargosa River basin is 1,622 square miles.

1.3 Climate

The climate of the area is arid with low precipitation and high mean annual temperatures and evaporation rates. Summer temperatures can exceed 120 degrees Fahrenheit while winter temperatures can fall below freezing. The average annual precipitation at Shoshone, California is 4.81 inches based on a record from 1972 through 2010 (Western Regional Climate Center, 2011). The average maximum high temperature is 83.2 degrees Fahrenheit and the average minimum is 56.3 degrees Fahrenheit. Mean monthly high temperatures at Shoshone range from 58.8 degrees

Fahrenheit in December to 108.7 degrees Fahrenheit in July. Mean monthly low temperatures in Shoshone range from 38.0 degrees Fahrenheit in December to 78.3 degrees Fahrenheit in July.

1.4 Land Use

The principal land uses (not including open space / wild lands) in the project area are agricultural, recreational, wildlife, livestock and domestic/municipal uses. With increasing solar development, industrial use is expected to increase in the future. Domestic water is generally supplied with groundwater from private domestic wells. Water for the town of Shoshone, California is supplied by Shoshone Spring. The town of Beatty, Nevada derives its water from groundwater wells. However, some residents obtain their water solely from spring water. Sewage is generally treated by individual septic systems with the exception of at the communities of Beatty, Nevada, and Shoshone and Tecopa (both in California) where sewage systems are present. Agricultural land use is primarily crops such as alfalfa (Nevada) and to a much lesser extent dates (California). Recreational uses include the use of spring water at the hot springs in Tecopa, California, and until recently the hot springs northeast of Beatty, Nevada along U.S. Highway 95.

1.4.1 Water Rights

Water rights summaries for California and Nevada are provided in Appendices C and D, respectively. Additional discussion regarding permitted rights, water usage, and estimated recharge for the Amargosa Basin are provided in Section 3.0.

1.5 Groundwater Management

Groundwater quality issues in the California portion of the basin are regulated by the California State Water Resources Control Board (California Regional Water Quality Control Board – Lahontan Region). Within the Inyo County, California portion of the Amargosa River Basin, the county conducts water-related activities such as issuing well permits through the Inyo County Environmental Health Department, and water-quality functions such as monitoring groundwater conditions and quality at the Tecopa and Shoshone landfills through the Inyo County Public Works Department. Other community planning and environmental review activities are conducted through the Inyo County Planning Department. Currently, there is little to no development in the San Bernardino County, California portion of the basin, however similar functions within San Bernardino County's departments exist should development occur in the future.

In Nevada, the Nevada Division of Water Resources (NDWR) manages Nevada's water resources through the appropriation and reallocation of the public waters. In addition, the NDWR is responsible for quantifying existing water rights; monitoring water use; distributing water in accordance with court decrees; licensing and regulating well drillers and water rights surveyors; reviewing flood control projects; monitoring water resource data and records; and providing technical assistance to the public and governmental agencies. The Nevada State Engineer determines the limit and extent of water rights and establishes conditions regarding those rights. The Nevada Department of Environmental Protection manages Nevada's stormwater pollution program. Within Nye County, Nevada, the Nye County Water District was established in 2007 to develop sustainable water development planning, characterize the groundwater resource, and to evaluate and mitigate impacts caused by groundwater use. Nye County's Water Resources Plan (2004) provides guidance for ensuring adequate supplies of water remain available in Nye County for the benefit of the county's residents and environment.

Death Valley National Park oversees water-related issues within the Death Valley National Park inclusive of the Devil's Hole section of the park in Nevada. Currently, Death Valley National Park staff monitor selected springs throughout the park, with an emphasis on Saratoga Spring at the south end of Death Valley adjacent to the Amargosa River. Likewise, the BLM oversees water-related issues on BLM lands. As part of those responsibilities, the BLM is also charged with developing a management plan for the wild and scenic portion of the Amargosa River.

1.6 Sources of Information

Information gathered by SGI and used in this report were from the archives and reports by the of the USGS, NDWR, California State Water Resources Control Board, Nye County Water District, Nevada Bureau of Mines and Geology, AC, Death Valley National Park, BLM, California Department of Water Resources, and groundwater level and spring data collected by SGI and within SGI's water resources library.

1.6.1 Death Valley Regional Flow System Report

A key foundational document for this effort is the report "Death Valley Regional Ground-Water Flow System, Nevada and California – Hydrogeologic Framework and Transient Ground-Water Flow Model" (Belcher, 2004). This comprehensive volume describes the conceptual model, and numerical modeling of, the Amargosa Groundwater Flow System in its entirety, however with a focus on the Northern Amargosa River Basin. The description of the conceptual model for the Amargosa Basin in this report is largely distilled from this extensive report. The USGS conducted the modeling and prepared the associated report bringing together data collected over decades for the U.S. Department of Energy programs at the Nevada Test Site and at Yucca Mountain. The purposes of the USGS work described in the report were to:

- Provide boundary conditions for site scale models at the Yucca Mountain and Underground Test Area Corrective Action Units on the Nevada Test Site;
- Evaluate the impacts of changes in groundwater flux;
- Provide a decision-making tool with respect to groundwater for defense and economic development on the Nevada Test Site;
- Evaluate potential effects to the Nevada Test Site due to off-site groundwater development;
- Provide a framework for identifying an effective groundwater quality monitoring network; and

- Facilitate the development of a cooperative, regional Death Valley groundwater management district.

2.0 FIELD ACTIVITIES

The field activities performed during this project were designed following the reconnaissance and cataloging of all of the known springs and wells in and beyond the Middle Amargosa River Basin, an area encompassing nearly 1,000 square miles. The results of the initial reconnaissance published in the 2011 State of the Basin Report (SGI, 2011), were used as the foundation for the design and implementation of a more detailed hydrogeologic investigation. The field work for this more detailed hydrogeologic investigation was conducted between April and December 2011 and included the collection of water chemistry samples, flow volumes, water levels, and ongoing general water quality monitoring for a select group of springs, wells and points along the Amargosa River. The results from this investigation as described in the following sections, will serve to assist in the identification of regional and local groundwater flow paths, and enable the development of an efficient, focused groundwater monitoring effort that will be protective of the environmental and cultural resources of the basin.

2.1 Spring Discharge, Groundwater Level and River Surface Flow Monitoring

Spring flow discharge and groundwater elevation measurements were collected across a single year on a seasonal basis from a select group of springs and wells within the Middle Amargosa River Basin. Seepage run monitoring (i.e. the measurement of flow at several distinct locations) was conducted along the stretch of river from Tecopa to below the Dumont Dunes area where the River crosses California Route 127. The seepage runs were conducted at five distinct monitoring locations along the Amargosa River, including two USGS gauge locations and three manual monitoring points. Additional monitoring included following the movement (progression and regression) of the leading edge of the River near the Dumont Dunes area and seepage run monitoring of Willow Creek just upstream of the confluence with the Amargosa River.

The three goals of the discharge, water level and seepage run monitoring are as follows:

- To quantify spring discharge rates, groundwater elevations, and river surface flow which will provide estimates of seasonal variations;
- To establish a record of discharge from the springs and wells selected for monitoring, including seasonal trend information in order to provide a more robust baseline for future comparisons, and
- To establish flow gains and losses along the perennially flowing portion of the Amargosa River, including seasonal trend information in order to provide a more robust baseline for future comparisons.

The measurement events of discharge rates, groundwater elevation and river surface flow occurred in spring/early summer (April/May), late summer/fall (September) and winter (December) of 2011.

2.1.1 Spring Discharge Monitoring

The springs designated for ongoing quantifiable discharge measurement include Amargosa Canyon Spring 1, Amargosa Canyon Spring 4, Borax Spring, Bore Hole Spring, Crystal Spring, Horse Thief Spring, Tecopa Hot Spring (as measured near the Amargosa Conservancy trailer), and Willow Spring. Data from other springs were collected as practical, including Resting Spring, Shoshone Spring, Thom Spring and Five Springs. The primary method used to quantify spring discharge was measuring the time it takes for spring flow to fill a bucket of a known volume. In some cases, such as Borax Spring and Tecopa Hot Spring, the spring discharged over a lip or out a pipe which enabled direct measurement of spring flow. In others, such as Crystal Spring and Amargosa Canyon Spring 4, spring discharge was temporarily captured and channeled into a pipe or a flume to facilitate direct measurement using the bucket filling technique. A secondary method used to quantify spring discharge was direct measurement using a Marsh-McBirney Flo-Mate solid-state flow meter placed in a flowing channel of water. Measurements from the flow meter are combined with cross-sectional dimensions of the flow channel to yield spring discharge. This measurement technique was used at Amargosa Canyon Spring 1 and Bore Hole Spring. All of the spring flow measurements recorded starting with the initial spring survey (including visual estimations of flow) are summarized on Table 2-1. Spring flow measurements are also found in the individual spring data sheets included in the Catalog of Springs (Appendix A).

There are compromises in the use of both spring flow measurement options that can result in under-estimation or over-estimation of free-flowing discharge. Ideally, all the flow from a spring would be fully captured and channeled into a pipe of flume, which allows for much greater accuracy in measurement of flow. This is the case for Borax Spring and Tecopa Hot Spring at the Amargosa Conservancy trailer. Temporarily channeling the spring using a pipe and other non-permanent materials such as mud and rocks can capture most of the flow, but not all, which can lead to inaccuracies in measurement. Measurement of flow using the solid-state flow meter requires estimates of cross-sectional area and the use of one to two flow measurement points as the meter is often large relative to the width of the channel. Ultimately, all of the spring flow measurements within this report should be seen as an estimate for the range of flows emanating from each spring. Significant alteration to spring discharge locations would be required to achieve the accuracy needed to resolve fine, seasonal changes in spring discharge.

2.1.2 Groundwater Level Monitoring

The wells designated for ongoing groundwater elevation measurement include the Eagle Mountain well and Cynthia's Well. Neither of these wells have a surveyed mark for ground level, thus surface elevation was estimated using USGS contour maps. Depth to water was measured from the same point during each monitoring event so accurate comparisons between events can be made. All of the depth to water measurements recorded starting with the initial well survey are summarized on Table 2-1. Depth to water measurements are also found in the individual well data sheets included in Appendix A

2.1.3 River Surface Flow Monitoring

Surface flow was measured at five locations along the Amargosa River from the town of Tecopa south to the California Route 127 undercrossing near Dumont Dunes. Two of the measurement points were flow gauges established by the USGS. The first is the USGS gauging station located in the town of Tecopa, California (station no. 10251300) and the second is located near China Ranch, just above to confluence with Willow Creek (station no. 10251330). The three manual flow measurement stations were located at the intersection with Sperry Wash, the crossing of Dumont Dunes Road and the undercrossing of California Route 127. As the project progressed, additional measurements were obtained from the Amargosa River just below the confluence with Willow Creek, and along Willow Creek just upstream of the Amargosa River.

A Marsh-McBirney Flo-Mate electromagnetic velocity meter and associated equipment was used to gauge river flow at each measurement location along the Amargosa River. Surface water flow velocity was measured and recorded at 0.5-foot intervals across the width of the River along a measurement transect oriented perpendicular to the direction of river flow. Concurrent with each velocity measurement, depth to river bottom was recorded. The full profile of river velocities and depths for the complete cross-section of the river could then be aggregated to determine total river volumetric flow at the measurement location. Each measurement transect location was recorded using a hand held GPS receiver so subsequent measurements were performed approximately along the same river cross-section.

The study was designed to make use of the two USGS flow gauges located along the Amargosa River. However, during the course of the study, the USGS gauge below China Ranch was not recording flow due to ongoing attempts to establish a rating curve. In August 2011, the gauging station was moved several hundred feet upstream to an area better suited to establish an acceptable rating curve. Several manual measurements were performed at the location of this USGS gauge. The USGS gauge located in Tecopa yielded flow during the April/May time period. However, no flow data were available during the period in September when SGI was collecting data. Data from this new USGS gauge location only became available on December 1, 2011. Comparisons of flow derived from this study and the USGS gauge will be discussed in future SOBRs as more data are gathered.

During the spring reconnaissance field activities conducted during November 2010 and January 2011, the leading edge of the Amargosa River extended to an indeterminate point downstream of the California Route 127 undercrossing. The initial visit to this section of the River in late April 2011 showed that the leading edge had retreated to a point between the California Route 127 undercrossing and the crossing of Dumont Dunes Road. A subsequent visit a week later (early May, 2011) showed the retreat of the River continued such that the leading edge was approximately 1,000 feet upstream of the Dumont Dunes Road crossing. The visit in September 2011 showed the leading edge of the River in approximately the same place. During the December visit, the leading edge of the River had advanced beyond the Dumont Dunes Road crossing, but did not extend as far as the California Route 127 undercrossing. This data, along with visual observations by long-time residents, provides strong indications that flow in the Amargosa River is primarily controlled by evapotranspiration. The increase in evapotranspiration that occurs during the longer, hotter summer days reduces water availability for surface flow resulting in the retreat of the River. The reduction in evapotransipration that occurs during the shorter and cooler winter days increases the water available for surface flow, thus the leading edge of the River advances independent of precipitation. The management of non-native vegetation along the Amargosa River (i.e. tamarisk removal) will likely have a significant effect on the flow of water in the River.

2.2 Water Sample Data Collection

As a next step to determining relationships between waters found in the Middle Amargosa River Basin, water samples were collected from a select group of spring and wells, including the following:

Ibex Spring	Sheep Creek Spring	Amargosa Canyon Spring 1
Amargosa Canyon Spring 4	Crystal Spring	Willow Spring
Shoshone Spring	Borax Spring*	Wild Bath Spring
Tecopa Hot Spring*	Thom Spring	Five Springs
Eagle Mountain Well	Chappo Spring	Bore Hole Spring*
Salt Spring	Cynthia's Well	Saratoga Spring
Amargosa River at Sperry Wash	Resting Spring	

* indicates duplicate sample collected

Water samples were analyzed for both general chemistry and select stable isotopes. The general chemistry samples were sent to ATL Laboratory in Las Vegas, Nevada and analyzed for the following constituents:

- Metals (Sb, As, Be, B, Cd, Cr, Cu, Fe, Pb, Li, Mn, Se, Si, Ag, Sr, Tl, Zn);
- Cations (Ca, Mg, Na, K);
- Anions (SO_4, NO_3, Cl, F); and
- Alkalinity, Hardness, Total Dissolved Solids, Specific Conductance.

Samples were also sent to the Massachusetts Institute of Technology for strontium and uranium isotope analysis and to the University of Arizona for tritium and oxygen/hydrogen isotope analysis.

2.2.1 General Chemistry Analytical Results

The general chemistry results were used to identify potential relationships between the sampled waters. The primary tool used was the Stiff Diagram, which is a graphical representation of the major ion composition of a water sample. A polygonal shape is created from three parallel horizontal axes extending on either side of a vertical axis. They show the relative ratios of cations (positively charged ions, plotted on the left hand side) and anions (negatively charged ions, plotted on the right hand side) plotted in milliequivalents per liter. These diagrams are useful in making visual comparisons between water samples. In order to geographically compare the resulting Stiff Diagrams from all the water samples, the plots were included on a series of maps of the Middle Amargosa River Basin as shown on Figures 2-1 through 2-6. A summary table of the analytical results is provided in Appendix E.

Looking at the morphology of the Stiff Diagrams across all six figures of note is that none of the samples collected were of a calcium bicarbonate water type typical of waters sourced in carbonate rock terrains and as seen in Pahrump Valley (Figure 2-7, Malmberg, 1967). Most of the waters can be placed within two primary groups. The first is the ‘Amargosa River’ group, distinguished by overall higher ionic concentrations, especially sodium and chloride. The sample locations that are included within this group cluster around the Amargosa River and include Tecopa Hot Spring, Bore Hole Spring, the Amargosa River at both Tecopa and Sperry Wash, Salt Spring and Saratoga Spring. The second is the ‘Eastern Water’ group, characterized by overall lower ionic concentrations, with sodium continuing to be the dominant cation. The sample locations that are included within this group include Willow Spring, Chappo Spring, Resting Spring, the Amargosa Canyon Springs, and Cynthia’s Well. The exact relationships between the waters within each group and between the groups are likely very complex, but the geographic relationships are obvious. Within the Amargosa River group, Bore Hole Spring and Tecopa Hot Spring both feed Grimshaw Lake, which in turn is the perennial source of water for the Amargosa River. The sample locations within the Eastern Water group are all located east of the Amargosa River along the base of the Resting Spring, Kingston and Nopah Ranges. The Stiff Diagrams for Thom Spring and Wild Bath Spring appear to be a hybrid between the two groups, especially when comparing ionic concentrations of sodium suggesting that waters from the two groups are mixing. The Stiff Diagrams for Ibex Spring, Shoshone Spring and water from Eagle Mountain Well are similar to those of Thom Spring and Wild Bath Spring, but in geographically disparate locations so their connection, if any, to the two groups is unknown. Five Springs, Crystal Spring and Sheep Creek are similar in that they all have the lowest overall ionic concentrations and are generally isolated and found at the edge of the study area. Borax Spring has its own unique Stiff Diagram signature likely due to its source of water interacting with borate deposits. With the exception of Salt Spring, all of the sampled waters contain little to no calcium or magnesium.

Also of note is the consistency of elevated arsenic concentrations among the water samples with the exception of those water samples collected east of the fault running between Tecopa and Shoshone. Water samples at locations such as Willow Creek, Crystal Spring, and Amargosa Canyon Spring #4, Resting Spring and Cynthia’s Well all had arsenic concentrations at or below the maximum contaminant level of 10 µg/L. This is suggestive of a water source to the east that is lacking a thermal or otherwise volcanic rock source along with the lack of a typical carbonate-rock signature, and is suggestive of the Kingston Range as a source, or partial source, of these springs.

2.2.2 Isotope Analytical Results

An analysis of the isotope data was conducted by Dr. Richard Hurst of Hurst and Associates, Inc. (HAI). His write-up titled 'A Multiple Isotopic Investigation of the Amargosa River: Inyo-San Bernardino Counties, Ca and Nye County, NV' is attached to this report as Appendix B. In the report, Dr. Hurst uses the results from the various isotopic analyses to approximate age and to evaluate mixing relationships of the waters that were sampled. The important findings are as follows:

- The majority of the waters sampled were derived from pre-1952 recharge (i.e. more than 60 years old);
- The isotope results do not support the Spring Mountains as the source of the water issuing from springs in the Middle Amargosa River Basin;
- There is no indication that drainage from Yucca Mountain is impacting groundwater in the Middle Amargosa River Basin;
- Flow within the Middle Amargosa River Basin is complicated and may be controlled by preferential pathways such as faults; and
- Additional data collection is required to clarify potential relationships between springs and the River.

Within the report, Dr. Hurst proposes a multi-component mixing diagram based on the combined strontium and uranium isotope data and draws relationships between the sampling locations along mixing lines (note that a mixing line simply suggests a relationship based on similarities in isotopic signatures). These mixing line relationships include:

- Sheep Creek Spring – Chappo Spring – Ibex/Crystal Springs;
- Salt Spring – Saratoga Spring – Amargosa River (Sperry Wash) – Borax Spring;
- Eagle Mountain Well – Cynthia's Well – Tecopa Hot Spring – Bore Hole Spring – Wild Bath Spring;
- Five Springs – Thom Spring – Amargosa Canyon Spring 1 – Willow Spring; and
- Resting Spring – Shoshone Spring – Amargosa Canyon Spring 4.

Dr. Hurst notes that springs could have similar isotopic signatures through interaction with similar rock types while varying significantly in geography (e.g. Ibex Spring and Crystal Spring have similarities in isotopic signatures though are separated by a significant distance making actual interaction unlikely).

2.3 Ongoing Spring Reconnaissance

The ongoing spring reconnaissance and well canvassing activities conducted within the Middle Amargosa River Basin has yielded information on 39 springs, five wells and three locations along the Amargosa River itself. The data collection activities included monitoring standard field water quality parameters and estimating the flow of water from the spring. Visual observations included a general description of the spring and the surrounding environment, notation of diversions or modifications to the spring, a description of vegetation present and photographic (stills and video) documentation of the spring. The well reconnaissance included gauging for groundwater level and total well depth, and collecting groundwater quality field parameters if practical. The study area covered for the spring and well reconnaissance activities included the area from (but not inclusive of) Ash Meadows in the north to the Avawatz Mountains in the south. Chicago Valley and the Amargosa Range formed the eastern and western boundaries of the study area, respectively. This excluded areas such as Pahrump Valley, the Yucca Mountain Test site and all military installations. The results of the spring reconnaissance and well canvassing were individually summarized in a series of detailed write-ups which included a synopsis of all the collected information including photos and video. The full collection of spring and well summaries were cataloged as Appendix A of the 2011 State of the Basin Report.

Subsequent to the publication of the 2011 State of the Basin Report, the ongoing data collection activities allowed for the expansion of the data set presented in the individual spring and well summaries. The collection of water chemistry and isotope samples, and the ongoing measurements of surface water flow, spring discharge and groundwater elevations has resulting in many of the springs initially surveyed have been visited several additional times. For each of these visits, standard field water quality parameters were measured along with observations of changes to the environment surrounding the spring. The summary write-up for each spring and well has been updated to include all additionally collected data and observations and are included in this Report as Appendix A.

3.0 GROUNDWATER SYSTEM – CONCEPTUAL MODEL

The conceptual model of a groundwater system is the foundation of any analysis of a groundwater basin. The conceptual model describes groundwater occurrence, groundwater movement, hydraulic properties of aquifer materials, and groundwater inflow and outflow components. As described in the previous SOBR, as new data are gathered in the Middle Amargosa Basin, the conceptual model for the area would be updated as appropriate to reflect those data. This section of the SOBR, provides an updated overview of the conceptual model reflecting the results of new geochemical data, groundwater level data, and river gauging results.

3.1 Regional Setting and Geologic Conditions

The Amargosa River Basin is located in Inyo and San Bernardino Counties, California, and Nye County, Nevada within the Basin and Range geomorphic province. The Basin and Range region is characterized by basins of internal drainage with considerable topographic relief, alternating between narrow faulted mountain chains and flat arid valleys or basins. The ranges generally trend north-northwest parallel to the regional structural regime. The geology of the Amargosa Basin is very diverse generally ranging from Precambrian, Paleozoic and Mesozoic metamorphic and sedimentary rocks, Mesozoic-aged igneous rocks, Tertiary and Quaternary-aged volcanic rocks, and playa, fluvial and alluvial deposits (Planert and Williams, 1995). A regional geologic map is provided on Figure 3-1.

The valley areas are covered by coalescing alluvial fans forming broad slopes between the surrounding mountains and the valley floors. The regional gradient of the Northern Amargosa River Basin is generally to the south-southeast with gradients that typically range from five to 15 feet per mile. The basin fill deposits are interpreted to be underlain primarily by Paleozoic sediments although in the central portion of the basin floors, the basin fill sediments have not been fully penetrated by drilling. Generally, the Middle Amargosa Basin is marked by several unique features including the badland-type topography of the Tecopa lakebed deposits and the Amargosa River Canyon. Between Shoshone and Tecopa the slope of the valley floor flattens among the lakebed deposits, and then steepens as the river flows through the Amargosa River Canyon. Downstream of the canyon, the topography reverts to an area of broad, coalescing alluvial fans, eventually reaching the flat playa in Death Valley.

3.2 Hydrogeologic Units

In the Amargosa River Basin, the principal hydrogeologic units consist of unconsolidated basin fill materials, volcanic rocks (primarily in Nevada), and the carbonate rock aquifer. The following provides a summary of these three hydrogeologic units.

3.2.1 Basin Fill

Tertiary and Quaternary-aged basin fill deposits are present throughout the basin as alluvial, fluvial and lacustrine (lakebed) deposits. Coarse-grained deposits (primarily sand and gravel) within the basin fill are responsible for transmitting the greatest quantities of groundwater and are most relied upon for groundwater production in the region. The basin fill is generally unconsolidated, moderately to well-sorted sand, gravel, silt and clay, and wells completed in the basin fill can yield several hundred gallons per minute (Walker and Eakin, 1963). As the axes of the valleys are reached, the sorting of the sediments will increase which can serve to significantly increase the permeability of the sediments. With increasing depth, groundwater production can be expected to decrease in these deposits as increasing lithostatic pressure and infilling of pores coincident with their greater age may occur reducing permeability.

Within the basin fill, the fine-grained (clay and silt) deposits that largely comprise the lakebed deposits (for example in the Shoshone – Tecopa area) serve as aquitards. Aquitards are low permeability geologic units that inhibit groundwater flow and can serve as confining units. Wells and boreholes that are completed in aquifer materials underlying these aquitards may exhibit artesian conditions such as those observed from flowing wells and borings such as at Borehole Spring and Borax Spring in the Shoshone-Tecopa area.

3.2.2 Volcanic Rocks

Tertiary and Quaternary-aged volcanic rocks are present within the Amargosa River Basin particularly in the area of the headwaters of the Amargosa River in the Beatty area of Nevada, and in the Greenwater Mountains immediately west of Shoshone, California. In the California portion of the basin, the volcanic rocks are generally of lesser importance to the overall groundwater system as opposed to the northern portion of the basin in Nevada.

3.2.3 Bedrock Units

Bedrock units underlying the alluvial valleys and generally comprising ranges such as the Nopah and Resting Spring Ranges, and portions of the Amargosa Range, consist of Precambrian to Mesozoic-aged metamorphic and sedimentary rocks. These geologic units consist of Paleozoic-age carbonate rocks (the “carbonate rock aquifer”); quartzite, and shale which have been folded and faulted (Figure 3-1). Generally, bedrock units such as these produce little water except where they are fractured and faulted, providing pathways for groundwater movement. Other bedrock units consist of the Mesozoic-aged granitic rocks as found in the Kingston Range. Within the granitic rocks, groundwater flow can be assumed to be negligible except where fracturing is present yielding modest quantities of groundwater.

Where carbonate rocks are present, greater movement of groundwater can occur due to the unique depositional and erosional characteristics of those rocks. Fractures and secondary solution openings along bedding planes can transmit considerable quantities of groundwater. Groundwater that discharges from the springs at Ash Meadows largely involves groundwater moving through these secondary openings in the carbonate rocks. Within the basin, significant groundwater flow through the carbonate rock aquifer occurs within the lower to middle Paleozoic-age carbonate rocks that comprise a package of rocks approximately 26,000 feet thick (Sweetkind, Belcher, et.al., 2004).

Groundwater flow in carbonate rocks can be very complex. Carbonate rocks with extensive solution channels or fractures primarily developed in one direction will have permeabilities that are highly oriented in specific directions. Therefore, the groundwater flow may not be predictable simply by drawing flow lines perpendicular to regional groundwater surface contours representative of the regional carbonate aquifer (Davis & DeWiest, 1966). Although the carbonate rock aquifer likely transmits large volumes of groundwater in the region, permeability is limited to areas of fracturing which proportionally makes up a small portion of the carbonate rock volume. Therefore, despite the potential for wells to obtain large yields from the carbonate rocks, that success is dependent on intersecting those fractured zones.

3.2.4 Geologic Structure

The rocks in the Amargosa River Basin have been extensively deformed by a variety of fault types that have occurred in the distant past as well as the present. These fault types include:

- Normal faulting typical to the Basin and Range with vertical displacement being dominant;
- Strike-slip faulting (lateral displacement dominant) typical of larger-scale regional fault systems such as the Furnace Creek – Fish Lake Valley Fault and Las Vegas Valley Shear Zones; and
- Thrust faults (low angle faults) that during the Paleozoic and Mesozoic resulted in displacing rock units in a manner that can affect groundwater movement in the present.

Springs may issue from the locations of faults due to either the lower fracture permeability of the fault in rock, or the displacement of permeable basin fill or rock adjacent to relatively impermeable materials. For example, The Tecopa Hot Springs rise along a fault (Waring, 1915) that runs north-northwest through the basin (Figure 3-2). Shoshone Spring also rises along the northward extension of the same fault that passes through Tecopa, part of the Furnace Creek Fault Zone (California Division of Mines, 1954). The Death Valley – Furnace Creek Fault System (inclusive of the Furnace Creek Fault Zone) is part of a large, currently active, northwest directed pull-apart zone. Movement along the Furnace Creek Fault Zone is primarily strike-slip (Brogan, Kellog, Slemmons and Terhune, 1991). The Death Valley – Furnace Creek Fault System is the second longest fault system in California (the San Andreas Fault System being the longest).

Thrust faults are present throughout the region, however given their age, in many areas their presence is concealed by overlying volcanic or basin fill deposits. Fracture permeabilities along thrust faults are insignificant due to the age of the structures and fracture filling and the low angle nature of the faulting not supporting fractures with significant apertures. However, in areas where impermeable rocks are thrust against more permeable rock in the subsurface (e.g., quartzite thrust against carbonate rocks), those faults may also serve as a barrier to groundwater flow.

3.3 Surface Water

The principal surface water body in the region is the Amargosa River, an intermittent river with headwaters issuing from springs northeast of Beatty, Nevada, and extending approximately 180 miles to the river's terminus at the playa in Death Valley. Except for portions of the river in the Amargosa Canyon area in California, and near Beatty, Nevada, the Amargosa River typically flows only after periodic storms. In those areas where the river is usually dry, the flow of water is in the subsurface. The perennial reach of the Amargosa River between Shoshone and Dumont Dunes was designated as a National Wild and Scenic River in 2009. Except during runoff events from rainstorms, the perennial flow in the Wild and Scenic section of the river is completely supplied by groundwater.

The Amargosa River rises as spring flow from the southwest side of Pahute Mesa in Nevada. From here, the river flows generally southwest toward Beatty, Nevada, and after passing through the Amargosa Narrows, enters the Amargosa Desert. After crossing the border into California, the river generally runs southward along a valley that follows the trend of the Furnace Creek Fault Zone, adjacent to California State Highway 127 near Death Valley Junction. Here, the river meets with Carson Slough (which drains Ash Meadows and is the chief tributary to the Amargosa River in Nevada), and continues its southward route passing to the east of the community of Shoshone and on to Tecopa. South of Tecopa, the river enters the Amargosa Canyon, being augmented by spring flow on its course. South of the Amargosa Canyon, the river flows by Dumont Dunes, and then heads west and then northward, rounding the Amargosa Range on the south and flowing into Death Valley.

The USGS monitors the flow of the Amargosa River (USGS, 2011) at a gage 0.2 miles west (Gauge no. 10251300) of Tecopa The USGS has monitored Amargosa River flow intermittently at other locations along the river over the past 50 years, but given the spotty nature of those records, they are of limited utility. The average flow of the river at this station based on 36 full years of data between 1962 and 2010- (some years missing) is 3.55 cubic feet per second (cfs). The maximum mean annual flow recorded there was 14.9 cfs in 1983 when the record peak flow of 10,600 cfs was recorded on August 16, 1983. At times the river has been dry at this station. Mean annual flows at the Tecopa station along with the other stations mentioned are summarized on Table 3-1.

Additionally, SGI conducted flow measurements at three locations along the river which are provided on the Field Activities Data Summary table (Table 2-1). Field water quality parameters collected by SGI indicated that Amargosa River waters are somewhat intermediate in chemistry between the more saline hot spring waters at Tecopa, and the fresh water springs identified in the area.

Other surface water bodies in the area consist of spring-fed ponds in the Ash Meadows area (Nevada), spring-fed Grimshaw Lake in the Tecopa area, and streams that issue from springs only to end where either that flow is utilized by vegetation, or it percolates back into the subsurface. One exception to this is Willow Creek, a significant spring-fed stream that rises northeast of China Ranch (south of Tecopa), and flows into the Amargosa River within the Amargosa River Canyon. Flow at Willow Creek is ungaged.

3.4 Regional Groundwater System

The regional groundwater flow system is considerably more extensive than the Amargosa River Basin watershed (Figure 3-3). The reason for this is the extensive area beyond the watershed boundary underlain by the carbonate rock aquifer that drains toward Death Valley. In this large flow system, groundwater recharge results from precipitation in the form of snowmelt and rainfall that falls within the mountains of southern and central Nevada, and reaches the Amargosa River Basin where it is discharged (Planert and Williams, 1995).

The Northern Amargosa River Basin appears to receive much of its carbonate-rock aquifer underflow from central Nevada. As shown on Figure 3-4, groundwater moves southward through Lincoln County, Nevada where it splits with a portion of that flow heading southwest toward the Amargosa Desert and Ash Meadows. The remainder of the flow moves southeast toward Muddy Spring and the Colorado River area.

Within the Middle Amargosa River Basin (between the California-Nevada state line and Salt Creek), it has been long postulated that groundwater moves through the carbonate aquifer southwest from the Spring Mountains and beneath Pahrump Valley (Figure 3-5) toward the Tecopa – Shoshone – Chicago Valley – California Valley areas (Faunt, D'Agnese and O'Brien, 2004). Figure 3-6 presents a conceptual cross-section based on this concept demonstrating flow paths that could be expected as groundwater moves from the Spring Mountains to the Shoshone-Tecopa area under this conceptual model. As shown, a westward groundwater gradient across the region, combined with the presence of a continuous package of lower Paleozoic carbonate rocks could allow groundwater to pass beneath the drainage divides.

However, based on the results of the current geochemical analyses and more recent detailed mapping by the USGS (Workman, et.al., 2002), it appears that in the Shoshone – Tecopa area, the carbonate rock aquifer as a conduit for groundwater to move directly from the Spring Mountains/Pahrump Valley area toward the Shoshone-Tecopa area may be of little direct influence. Flowpaths from the Pahrump Valley area toward the Middle Amargosa Basin may follow a more circuitous route. Figure 3-7 presents a portion of the 2002 geologic map indicating that Precambrian to Cambrian bedrock units underlying the carbonate rock units outcrop along the western base of the Resting Spring Range and the portion of the Nopah Range south of the Nopah Peak Thrust. This would indicate that the saturated rocks beneath these ranges are primarily comprised of quartizite, shale, siltstone and dolomite of lesser permeability than would be expected of the Paleozoic-age carbonate rocks. An alternative flowpath for groundwater flowing from

Pahrump Valley then may be toward the northwest beneath Stewart Valley and toward the Northern Amargosa Basin in the Ash Meadows area, and then southward toward the Middle Amargosa Basin. Additionally, some underflow may flow into Chicago Valley by passing beneath and around the north of the Nopah Range (north of the Nopah Peak Thrust). Groundwater in Chicago Valley would encounter a barrier caused by the submerged bedrock units of the Resting Spring Range, and flow southward toward the Amargosa River. Resting Spring may be at least a partial result of this flow. With respect to the lack of a calcium bicarbonate signature at Resting Spring, it should be noted that within the alluvium in Pahrump Valley and Stewart Valley, groundwater in the playa areas has a strong sodium chloride signature (Figure 2-7). The dominance of sodium over calcium in Resting Spring waters may partially be indicative of a more shallow connection (if one exists) of waters between the northern end of Pahrump Valley and Stewart Valley as opposed to deep circulation of groundwater. The absence of groundwater quality data in Chicago Valley leads to this conceptual alternative flow path having great uncertainty associated both in its very presence, and if it does exist, its importance to the overall system. Further work is needed in this area.

There has been insufficient information to develop a strong groundwater budget for the Middle Amargosa River Basin. Recommendations for additional hydrogeologic characterization to address this deficiency are provided in Section 4.0. Beyond the Middle Amargosa River Basin, groundwater moves west in the Death Valley Basin, then north augmented by underflow from the Owlshead Mountains area, to the Death Valley Playa (Faunt, D'Agnese and O'Brien, 2004).

The regional groundwater flow system covers an area of nearly 40,000 square miles. The following sections describe the occurrence and movement of groundwater, the aquifer characteristics of the basin fill and carbonate rock aquifers, and groundwater basin inflow and outflow components.

3.4.1 Groundwater Occurrence and Movement

Within the Amargosa River Basin, groundwater occurs primarily within the basin fill deposits and carbonate rock aquifer. Although groundwater occurs with significance in the volcanic rocks in the northern portion of the basin, the focus of this report is the basin south of the Death Valley Junction area (Middle Amargosa River Basin), and therefore is not discussed here. The only materials from which groundwater can be extracted for significant use is within the coarse-grained deposits of the unconsolidated basin fill and within the fractured carbonate rocks (Walker and Eakin, 1963). Volcanic rocks and other bedrock units can generally be assumed to be relatively impermeable except where locally fractured and minor yields can be achieved.

In the Northern Amargosa River Basin, groundwater is generally found within the basin fill from which most of the groundwater pumping in the Amargosa River Basin is concentrated. In the Ash Meadows area, the primary aquifer is the carbonate rock aquifer system. Groundwater within the carbonate rocks flows laterally across basins as interbasinal flow as described earlier. Although the direction of groundwater movement in the carbonate rocks toward Ash Meadows has been considered to be generally from the east (Spring Mountains), recent work (Bushman, et.al., 2010) suggests that at least a portion of that water may be derived from flow from the north.

The direction of groundwater movement usually parallels the slope of the ground surface, from points of recharge in the higher elevations to points of discharge such as springs or the Amargosa River in the valley. Within the basin fill aquifer, groundwater movement is from north to south from the northern portion of the basin toward Shoshone and Tecopa. A potentiometric surface map of the shallow basin fill aquifer based on the groundwater levels (Table 3-2) collected by the USGS, SGI, AC, Nye County and Inyo County (by TEAM Engineering & Management, Inc.) during the 4th Quarter of 2010 is provided on Figure 3-8. This is the same map that was provided in the 2011 SOBR. At the time of this report, groundwater level data were still not available for the 4th quarter of 2011 from Nye County. Therefore, an updated groundwater surface map, and change in groundwater surface map will be provided as an addendum to this report when those detail become available. The relatively consistent hydraulic gradient (slope of the groundwater surface) in this area is primarily an artifact of the spacing and lack of monitoring wells between Eagle Mountain and Shoshone, California. Additional monitoring wells would be needed to evaluate local variations in that gradient.

It has been postulated that the carbonate rock aquifer discharges groundwater into the Shoshone – Tecopa area is from the Spring Mountains nearly 30 miles to the east (Malmberg, 1967 and Belcher, 2004). As described earlier, the specific sources of water discharged from the springs and to the Amargosa River cannot be currently identified. However, the results of our recent isotopic sampling efforts indicate that water flowing westward directly from Pahrump Valley through the carbonate aquifer does not make up a significant component of the waters found within the Middle Amargosa River Basin. Therefore, it is likely that the primary source of water is flow through alluvium, recharged via precipitation runoff from the surrounding mountains, or fed from deeper aquifer units through faulting.

Precipitation and snowmelt runoff from the mountains surrounding the Middle Amargosa River Basin collect in the thick packages of alluvium that fill the valleys. The water percolates through the alluvium under the force of gravity, flowing downhill towards the lowest point in the Basin, the Amargosa River. Figure 3-9 shows the conceptualized flow paths of groundwater flowing In the alluvial valleys within the Middle Amargosa River Basin. North of Shoshone, groundwater flows south around Eagle Mountain in the alluvium that forms the floor of the valley through which runs the Amargosa River.

The valley and the River are additionally fed from water runoff from the east slope of the Amargosa Range and the west slope of the Resting Spring Range. Water from the east slope of the Resting Spring Range and the west slope of the Nopah Range flow into Chicago Valley, following the slope of the valley floor to the south. At the south end of the Resting Spring Range, the alluvial valley turns southwest towards Tecopa and the Amargosa River. Right at this bend is Resting Spring, which likely exists as a result of the change in valley direction and the constriction in the width of the alluvium in the valley between the Resting Spring Range and the Nopah Range, forcing groundwater to the surface at the spring location. Water from the southeastern slope of the Nopah Range and the western slope of the Kingston Range flows into California Valley and west around the southern tip of the Nopah Range. Some of this water likely flows down China Ranch Wash, which in turn is the source of the water from Willow Spring and Willow Creek.

Runoff from the eastern Ibex Hills flows into Greenwater Valley toward the Amargosa River. South of the Sperry Hills, runoff from the north facing slope of the Avawatz Mountains, along with the Salt Spring Hills, Saddle Peak Hills and the Ibex Hills flows into the basin fill of Southern Death Valley, down the middle of which runs the Amargosa River.

Based on the results of SGI's spring reconnaissance, it is clear that a number of distinct spring sources are represented in this concentrated part of the Amargosa River Basin. The elevated temperatures of the hot springs around Tecopa indicate that the spring water has either been at great depth or the presence of a geothermal anomaly. Either of these conditions would be needed to influence the water temperatures to reach values significantly greater than the long-term mean annual temperature. This is similar to warm springs in the Furnace Creek area of Death Valley National Park (Pistrang and Kunkel, 1964). The Furnace Creek area warm springs are also present along the Furnace Creek Fault Zone where deep circulation is postulated. This indicates that absent shallow heated igneous rocks, those waters moved at considerable depth (in the 1,000's of feet below ground surface) only to move upward along fractures or faults to the surface where it is discharged. In other springs, field water quality parameters are suggestive of groundwater flow of a more local nature.

3.4.2 Aquifer Characteristics

Groundwater within the basin is held within the sand, gravel, silt and clay that make up the valley fill aquifer. Within the Northern Amargosa River Basin, hydraulic conductivity (the ability for a geologic material to transmit water) in the basin fill can range from 0.02 feet per day (f/d) in the low permeability clayey deposits, to 140 f/d in the coarse-grained sands and gravels (Belcher, 2004). SGI is unaware of any aquifer testing that has occurred within the basin fill in the Middle Amargosa River Basin or the Death Valley Basin, but it is likely that hydraulic conductivities generally fall within the same range as those described above.

The aquifer characteristics of the carbonate rock aquifer can be highly variable. Where fractures and solution openings exist, these rocks can be the most permeable materials in the basin. Absent fracturing, hydraulic conductivities can be extremely low. Carbonate rock hydraulic conductivities can range from 30 f/d or greater to much less than 0.001 f/d (Spitz & Moreno, 1996).

3.4.3 Groundwater Basin Inflow Components

Groundwater inflow components within the Amargosa River Basin include recharge from precipitation that falls within the drainage basin and groundwater underflow into the basin, primarily through the carbonate rock aquifer. In this area, large uncertainties exist regarding recharge rates, and currently, groundwater pathways for underflow into the basin. Therefore, best estimates of recharge are probably most available by evaluating groundwater discharge and changes in storage/changing groundwater levels in the area.

3.4.3.1 Recharge

Walker & Eakin (1963) estimated recharge to the Northern Amargosa River Basin from precipitation within the basin plus recharge from precipitation on the northern and western slopes of the Spring Mountains to be approximately 5,000 acre-feet per year (AFY). Within the California portion of the basin, the Middle Amargosa Basin and Death Valley Basins do not have specific recharge estimates associated with them (California Department of Water Resources, 2003).

3.4.3.2 Groundwater Underflow

Walker & Eakin (1963) estimated that of the 17,000 AFY discharged from the springs at Ash Meadows on an annual basis; approximately 13,000 AFY might be the result of groundwater underflow through the carbonate rocks from the Spring Mountains to the east. The remaining 4,000 AFY being supplied by underflow from areas to the northeast in central Nevada. South of Death Valley Junction, the general absence of previous hydrogeologic investigations in the Shoshone – Tecopa region results in more generalized assumptions regarding underflow. As shown in Figure 3-5, regional groundwater flow enters the California portion of the basin from Pahrump Valley to the northeast and from the Northern Amargosa River Basin. Additional underflow from the south from the Silurian Valley area enters the system between the Amargosa River Canyon and Saratoga Springs (Faunt, D'Agnese and O'Brien, 2004).

The existing Death Valley Regional Flow System model could be used to evaluate the groundwater budgets for specific zones in this part of the groundwater system, therefore extracting underflow estimates for each of these areas. However, given the current lack of understanding regarding the flow system, those estimates while interesting to consider and providing a starting point from which to evaluate the groundwater flow system, would have considerable uncertainty associated with them. With additional data collection and analysis, greater refinement to that groundwater model, or a new groundwater flow model focused on the Middle Amargosa River Basin, could provide more reliable estimates.

3.4.4 Groundwater Basin Outflow Components

3.4.4.1 Spring Flow & Evapotranspiration

Spring flow and evapotranspiration have been combined as a basin outflow component in this basin as in this area as they are unavoidably linked. Groundwater-dependent vegetation (phreatophytes) are present along the Amargosa River and in spring areas. Springs discharge water from the groundwater system, but in nearly all cases within the basin, that flow either evaporates, is used by plants, or percolates back to the groundwater system in a relatively short distance. One of the few exceptions to this is Willow Creek south of Tecopa which rises from spring flow within China Ranch, and generally maintains surface flow to its confluence with the

Amargosa River. In the Nevada portion of the basin, the discharge from spring flow and evapotranspiration has been estimated at 23,500 AFY (Walker & Eakin, 1963).

In the Shoshone - Tecopa - Chicago Valley - California Valley area, the combined spring flow and evapotranspiration has been estimated at approximately 8,900 AFY. In the Death Valley Basin, combined spring flow and evapotranspiration has been estimated at approximately 35,000 AFY (San Juan, Belcher, et.al., 2004).

Based on the field reconnaissance activities, it is clear that the springs in the California portion of the basin emanate from a variety of sources. These sources appear to range from those with deep circulation paths (such as Tecopa Hot Springs), those with shallow and potentially more local circulation paths (such as at Thom Spring near Tecopa) and those in which mixing or other influences of multiple sources may be present (such as at Wild Bath Spring near Tecopa). The Wild Bath Spring is of particular interest in that while it is a warm spring, it has pH and TDS characteristics typical of the cool, fresh water springs nearby. Its location suggests an area of mixing between flow paths of hot and cool springs, or warming of the fresh water through conduction of heat from the nearby hot water source. With respect to specific spring flow (not including evapotranspiration or Amargosa River flow), SGI's total field estimated spring flow during the spring reconnaissance was 1.8 cfs (approximately 1,300 AFY).

3.4.4.2 Pumpage

Within the Amargosa River Basin, pumpage is primarily within the Northern Amargosa River Basin. This water is largely used for irrigation. Table 3-3 summarizes groundwater pumping from the Northern Amargosa River Basin since 1983 (NDWR, 2011a). Total pumping over time is also represented on Figure 3-10. Average annual pumping since 1983 has been 11,788 AFY; however 2010 saw a total of 15,393 AFY pumped from the basin, a reduction of 987 AFY from 2009. However, as can be seen, over the 27 years of pumping records, the Northern Amargosa River Basin has seen a steady increase in pumping. For comparison purposes the annual duty for the Northern Amargosa River Basin (Figure 3-11, referred to as Amargosa Desert in the State of Nevada report) is 27,336.86 AFY (includes certificate, permit, and ready for action) as of February 21, 2012 compared to the estimated annual perennial yield of the basin of 24,000 AFY (Walker and Eakin, 1963). This updated annual duty is a reduction of approximately 1,700 AFY since first reported in the 2011 SOBR (SGI, 2011).

In the Middle Amargosa River Basin and Death Valley Basin, water supplies are more reliant on spring flow, and groundwater pumping is relatively insignificant in comparison to the Nevada portion of the basin. Groundwater pumpage for domestic or public use is probably on the order of less than 100 AFY (San Juan, Belcher, et.al., in Belcher, 2004). Water used for irrigation of date palms is supplied by spring water.

Outside of the Amargosa River Basin, pumpage in the Pahrump Valley is of most significance to the Amargosa groundwater system. Pumping records available since 1959 (NDWR, 2011b) indicate that beginning with initial groundwater usage of 1,159 AFY in 1959, groundwater pumping in the Pahrump Valley rapidly increased to a maximum pumpage of 47,950 AFY in 1968 (Figure 3-12. During the period of 1964 through 1978, pumping in the Pahrump Valley averaged more than 37,000 AFY. Since that time, groundwater pumping in the Pahrump Valley has gradually decreased to the point that in 2010, total groundwater pumping in the Pahrump Valley was 15,229 AFY, the lowest pumpage since the initial record in 1959. The 2010 pumping rate (which also represents an 862 AFY reduction in pumping since 2009) is likely attributable to economic conditions and may represent a temporary decrease from the 20,000 to 25,000 AFY of pumping that has been characteristic of the Pahrump Valley since 1980.

Groundwater levels in the Pahrump Valley were noted to have declined steadily over the period of record, but of note is that impacts to springs in the Middle Amargosa Basin, particularly in the Shoshone – Tecopa area have not been noticeable. It should be noted that there currently is no spring monitoring program that would identify relatively small changes in the flow regime. This would be consistent with the conceptual model of limited direct communication with the springs in the Shoshone-Tecopa area. As previously reported this could also indicate that either:

- The result of the excessive pumping in Pahrump Valley has been a decrease in storage, and that induced seepage from the carbonate rock aquifer underlying the valley has not been significant due to the buffering effect of the thousands of feet of alluvium overlying the carbonate rock aquifer; or
- The effect of the pumping in the Pahrump Valley has not had sufficient time to propagate through the carbonate rock aquifer and to be seen in the Middle Amargosa Basin (however this is appears unlikely based on the results of the current field work).

Given the current understanding regarding spring sources, and regional groundwater underflow into the Middle Amargosa Basin, particularly in the Shoshone – Tecopa area, either of the conditions described above, or a combination of the two, are reasonable assumptions. Another less likely assumption is that groundwater underflow emanating from the Spring Mountains does not enter the Middle Amargosa River Basin in the Shoshone-Tecopa area, and the source of spring water in that area is derived from another unidentified regional source.

3.4.5 Groundwater Quality

Groundwater quality in the Amargosa River Basin is highly variable. In recharge areas, the concentrations of dissolved solids in groundwater are low. However dissolved solids will increase as the groundwater moves through the groundwater system and is in contact with the rock materials present. For example, in the area of Willow Creek, dissolved solids may be high due to the presence of gypsum deposits in the geologic materials through which groundwater in that area is flowing. In the Northern Amargosa River Basin where groundwater pumping is focused, much of the water present is suitable for irrigation (not all of which is suitable for domestic use), however water of medium to high salinity is locally present. Existing groundwater quality data are provided in Appendix E.

3.5 Groundwater in Storage

The volume of groundwater in storage within the basin fill is a function of the area of the aquifer material, a selected saturated thickness, and specific yield (ratio of the volume of water that the aquifer will yield due to gravity to the aquifer's volume) of aquifer material. For the purposes of this report, estimates of groundwater in storage are based on the existing literature. In the Amargosa Basin, the volume of groundwater in storage is orders of magnitude greater than the volume of recharge that occurs on an annual basis representing a groundwater accumulation over thousands of years. Storage calculations are rough estimates as the parameters described above are subject to significant variation.

In the Northern Amargosa River Basin, the volume of groundwater in storage for the Amargosa Desert has been estimated at 1.4 million acre-feet within the upper 100 feet of the saturated basin fill (Walker & Eakin, 1963). Estimates of the volume of groundwater in storage within the Middle Amargosa and Death Valley Basins have not been developed by the State of California.

3.6 Groundwater Levels and Discussion of Inflow and Outflow Components

The volume of groundwater in storage is an important aspect of the groundwater system. Changes in storage are identified in the field by changes in groundwater levels. A fundamental groundwater equation and the basis for evaluations of groundwater budgets (inflow vs. outflow estimates) is:

Inflow – Outflow = Change in Storage

When outflow exceeds inflow, there is a negative change in groundwater in storage and groundwater levels can be expect to decline. When inflow exceeds outflow, the reverse is true. When the system is in equilibrium, water levels will generally remain relatively constant despite short-term fluctuations. Long-term groundwater level declines are a clear indication that outflow has been exceeding inflow for an extended period of time. It should also be noted that in many areas, the recovery of groundwater levels due to groundwater being removed from storage can take longer than the period to remove it depending on the volume removed from storage, precipitation trends and the geology of the basin.

Taking this one step further, under predevelopment conditions, a groundwater system is in equilibrium, a condition where inflow equals outflow. Groundwater pumping causes a disruption in this equilibrium, and recharge amounts and patterns can change. More often, discharge amounts and patterns are impacted. This includes the loss of phreatophytic vegetation (vegetation whose water requirements are met by roots tapping groundwater such as in the area of springs) and reduction or elimination of spring flow. All pumped water must be supplied by one or more of the following:

- Decreases in groundwater storage;
- Increased or induced recharge; and
- Decreased discharge either in the form of reduced subsurface outflow or decreases in natural forms of discharge such as evapotranspiration, spring flow or river base flow.

Regardless of the amount of groundwater pumped, the system will undergo some drawdown in groundwater levels in pumping wells to induce the flow of groundwater to these wells, which means some water initially is removed from storage. For most groundwater systems, the change in storage in response to pumping is a transient phenomenon that occurs as the system readjusts to the pumping stress. The relative contributions of changes in storage, increases in recharge, and decreases in natural discharges evolve over time. As an example, upward leakage from the carbonate rock aquifer to the basin fill aquifer has been postulated as early as the 1960's (Walker & Eakin, 1963). Elevated pumping in the basin fill aquifer could induce greater upward leakage from the carbonate rock aquifer that correspondingly could result in reduced spring flow from those carbonate rocks.

If the system can come to a new equilibrium (i.e., a combination of increased recharge and/or decreased discharge), the storage decreases will stop, and inflow will again equal outflow. The amount of groundwater "available" for a future groundwater development project is therefore dependent on what these long-term changes are, and how these changes affect the environmental resources of the area. Numerical models are ideal tools to evaluate these issues in that the complexities of the groundwater system can be evaluated in detail, and assumptions of how the groundwater system works can be tested for internal consistency. Further, with advances in software available to the groundwater professional, the efficiency and associated costs of groundwater modeling have significantly decreased over the last two decades.

Groundwater inflow, outflow and storage estimates were provided where available in the previous sections. Based on a review of limited shallow groundwater levels in the Shoshone – Tecopa area, the groundwater system in the Shoshone and Tecopa area appears stable.

3.7 Future Groundwater Use and Discussion of Groundwater Availability

As shown in Table 3-3 and Figure 3-9, there has been an increased use of groundwater in the Nevada portion of the Amargosa Basin over the past 25 years. The potential for future development will be limited by both quantity and quality. However, as can be seen by the active duty for the Northern Amargosa River Basin, there is significant potential for pumping to increase considerably should water rights holders fully exercise their water rights. Given the over-allocated nature of the Northern Amargosa River Basin, significant impacts to the groundwater resource could result if that condition occurred. These uses are anticipated to increase due to future population growth, and the likely future addition of groundwater usage for solar energy development. Although wet cooling solar projects are not anticipated, groundwater usage for processes such as mirror washing will still be needed.

For example, it is anticipated that the new Solar Millenium solar energy facility in the Northern Amargosa River Basin will require the use of 400 AFY of groundwater for a project covering 4,350 acres (a usage rate of approximately 1 AFY per 10 acres) (EPG, 2010). As can be seen, the incremental increase of solar projects within the region could result in a significant steepening of the increased trend in groundwater usage. Additionally, the proposed Hidden Hills project located in the Pahrump Valley immediately northwest of California Valley (part of the Amargosa River watershed) would use an estimated 140 AFY during its lifetime in a groundwater basin that is already significantly over-appropriated. The competing demands for renewable energy and protection of the Amargosa River point to the need for increased knowledge and baseline hydrologic data in the Middle Amargosa River Basin. Recommendations for future investigation are provided in Section 4.0 of this report.

4.0 DISCUSSION AND RECOMMENDATIONS

The Amargosa River Basin, which spans two states, three counties and one National Park, exists as one of the most important desert waterways in the southwestern United States. Both the groundwater and surface water in the basin support a unique and diverse ecosystem, while also supporting human needs through domestic, agricultural, wildlife, stock-watering, mining and other industrial uses. As the river is a groundwater-fed surface water body, relatively small variations in the groundwater surface elevation can have considerable effects on the ability for the river to maintain surface flow. While the Nevada portion of the basin has been well-studied, primarily as a result of hydrologic studies centered on the Nevada Test Site and the Yucca Mountain Project, the California portion of the basin has seen little in the way of regional hydrogeologic investigations.

In the Northern Amargosa River Basin groundwater is already over-allocated. Although pumping does not currently take place at the full amount entitled to by groundwater-rights holders, considerable impacts to the groundwater reservoir and associated springs could occur should those water rights holders eventually fully exercise their water rights. Groundwater usage within the Northern Amargosa River Basin has steadily increased over the past 25 years, and the addition of a new industry to the area (solar) will likely provide some additional pressure on the groundwater resource. Also as groundwater usage increases in the Northern Amargosa River Basin, it is conceivable then that groundwater flow into the Middle Amargosa River Basin could decrease. Given the importance of the alluvial aquifer to many of the springs in the Middle Amargosa River Basin, this issue is of key importance to sustaining the Amargosa River.

In 2009, the Amargosa River between Shoshone and the terminus of the Amargosa Canyon received Wild and Scenic status through an act of Congress. As a result, the BLM is charged with developing a management plan for the Wild and Scenic portion of the River. It is essential that hydrogeologic characterization of the California portion of the basin continue to take place in order for that management plan, and its associated management recommendations, to have a firm basis, and to assure that monitoring is conducted in a meaningful way to identify potential impacts to the river and its feeder springs before irreversible impacts from future groundwater development occur.

The principal task during this project was the geochemical sampling of springs, selected wells and river flow in the Middle Amargosa River Basin. The results of these investigative activities provide valuable starting points for all future more detailed hydrogeologic investigations. Those detailed analyses will serve to assist in the refinement of regional and local groundwater flow paths, and enable the development of an efficient, focused groundwater monitoring effort that will be protective of the environmental and cultural resources of the basin.

Currently, there is insufficient information to develop a groundwater budget for the Middle Amargosa River Basin. Attempting to evaluate groundwater recharge and groundwater underflow into the basin will be difficult both from a technical standpoint and in funding what would be such a major investigative endeavor. Therefore, the most logical means to evaluate the groundwater budget for the Middle Amargosa River Basin will be to develop a firm understanding of the various groundwater discharge components including evapotranspiration (including spring flow), and subsurface underflow beyond Salt Creek and analyzing associated groundwater level trends.

Based in the results of current investigative work, and in order to accomplish the larger goals of the project, the following lines of investigation to refine the conceptual model for the Middle Amargosa Basin should be considered:

- **Additional Piezometer/Monitoring Well Installation** – 13 piezometers/monitoring wells (wells) should be installed to further evaluate the conceptual model of this part of the Amargosa Basin with an emphasis on understanding groundwater flow paths; and for supplemental monitoring to evaluate baseline groundwater conditions and identification of impacts to groundwater levels in the future should they occur. SGI anticipates the wells would consist of both shallow (assumed depth of 25 feet below ground surface (ft bgs)) and deep (assumed depth of 100 ft bgs) wells. We are not recommending monitoring wells in the carbonate rock aquifer at this time due to the costs of such a venture and the need to accomplish the work described herein prior to undertaking that level of effort. We anticipate wells in the following general locations:
    - Two deep wells in the alluvial aquifer between Eagle Mountain and Shoshone (anticipated depth to groundwater in this area is approximately 50 ft bgs);
    - Two shallow wells along the Amargosa River between Shoshone and Tecopa;
    - Two shallow wells along the Amargosa River south of the Amargosa River Canyon (one near the site of Sperry and the other at the end of the graded dirt road north of Dumont Dunes);
    - One shallow well at Willow Spring;
    - One shallow well at Twelvemile Spring (to evaluate conditions in Chicago Valley);
    - One shallow well along the Amargosa River near Tecopa and the USGS Amargosa River gaging station there; and
    - Four deep wells in the area northeast, east and southeast of Tecopa to evaluate flow coming from Chicago Valley and the Kingston Range.

This list should be considered a beginning effort for future well locations. Additional wells should also be considered for the California Valley and other locations along the Amargosa River and selected springs to support both protective spring and groundwater level monitoring but also to assist in evapotranspiration investigations.

- **Discharge, Water Level, Precipitation and Seepage Run Monitoring** - Flow discharge and groundwater elevation measurements should continue and collected on a regular basis from the existing suite of springs and wells being monitored in additional to new wells. Seepage run monitoring should continue to be conducted periodically (at least three times per year) on the stretch of River from Tecopa to the Dumont Dunes area and should continue to consist of the existing five distinct monitoring locations (including the two USGS gauges, and three manual monitoring points). Basic water quality data should be collected at all discharge, elevation and seepage run monitoring points. Recently, the USGS moved its flow gage to a new location just above the confluence of the Amargosa River and Willow Creek. Continued monitoring of the River at that location should be conducted until it is established that the new flow monitoring set up is calibrated. Additionally, downloading data from the newly installed precipitation stations if applicable;

- **Geochemical Sampling of New Piezometers/Monitoring Wells** - Water samples should be collected from new wells and analyzed for a specific suite of constituents, including field parameters, general chemistry, a comprehensive suite of trace metals, and selected stable/non-stable isotopes as presently being conducted with the exception of tritium which would no longer be analyzed. **Installation of Four Precipitation Stations** – To evaluate areal and elevation variations in precipitation in the area (for greater understanding of the water budget of the area and to provide information useful in distributing recharge in the numerical groundwater flow model) and to refine our understanding of the effects of precipitation events on groundwater-level fluctuations, four precipitation stations should be installed at the following locations:
    - The northernmost newly-installed well south of Eagle Mountain;
    - Twelvemile Spring;
    - Saratoga Spring; and
    - Horsethief Spring (in the Kingston Range).

  These locations (along with the existing station in Tecopa) provide good coverage areally, and spanning a wide elevation range (from approximately 200 ft msl to 4,600 ft msl). Permitting would be required by the BLM and Death Valley National Park (for Saratoga Spring). At this time, it is planned that data downloading would be accomplished during quarterly events as part of Task 2. It is anticipated that NOAA-II precipitation gages would be installed, manually serviced, and fitted with data loggers and flash memory data collection modules. The stations would be able to account for snow water content which would be of particular importance at the Kingston Range location (Horsethief Spring area). Precipitation stations would be secured by fencing.

In each case, the specific means for accomplishing each of these tasks will build on the foundation by previous work. For example, the locations of the piezometers/monitoring wells are based on the foundational geochemical and flow monitoring work described in this report. Beyond the scope items described above, the development of a refined numerical groundwater flow model for the Middle Amargosa Basin area should be developed as a management tool upon which to base future water management decisions. Ideally, the model would be created using the industry standard program MODFLOW originally developed by the USGS. The model should be developed in a means (e.g., using standard format files) that allows such a tool to be used efficiently and cost-effectively by groundwater professionals fluent in groundwater flow modeling representing governmental, and non-profit and for profit private sector constituents and stakeholders.

5.0 CONDITIONS AND LIMITATIONS

This report has been prepared according to generally accepted standards of hydrogeologic practice in California at the time this report was prepared. Findings, conclusions, and recommendations contained in this report represent our professional opinion and are based, in part, on information developed by other individuals, corporations, and government agencies. The opinions presented herein are based on currently available information and developed according to the accepted standards of hydrogeologic practice in California. Other than this, no warranty is implied or intended.

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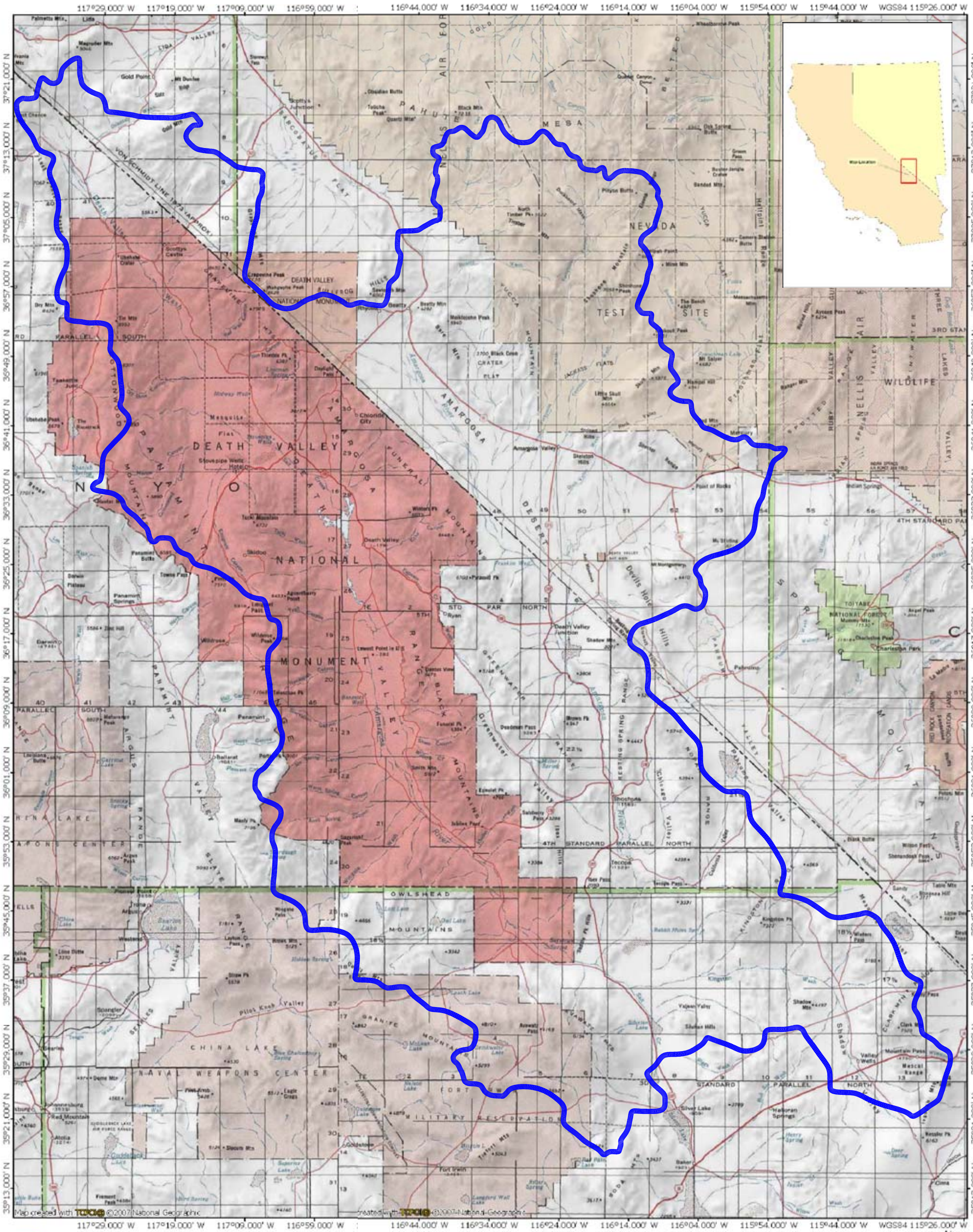
FIGURES



NATIONAL GEOGRAPHIC

0 5 10 15 20 miles
0 5 10 15 20 25 30 km

TN MN 13°
02/22/11

WATERSHED BOUNDARY

SGI environmental THE SOURCE GROUP, INC.
3478 BUSKIRK AVE, STE 100
PLEASANT HILL, CA 94523

AMARGOSA BASIN
CALIFORNIA-NEVADA

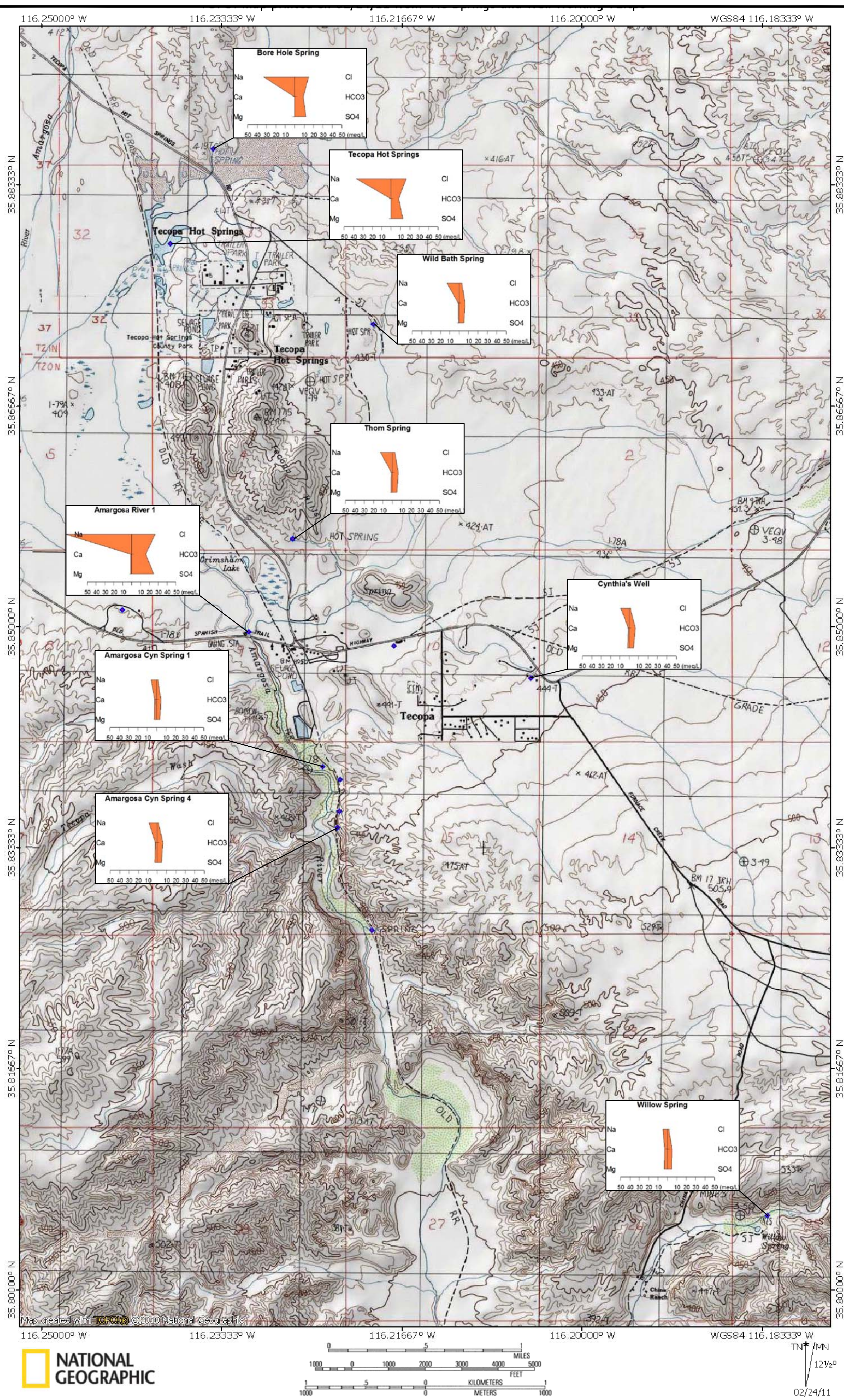
LOCATION OF AMARGOSA RIVER DRAINAGE BASIN

PROJECT NO.	DATE	DR.BY:	APP. BY:
01-AC-001	02/14/11	SD	AZ

0 20 40
HORIZONTAL SCALE IN MILES

N

FIGURE 1-1



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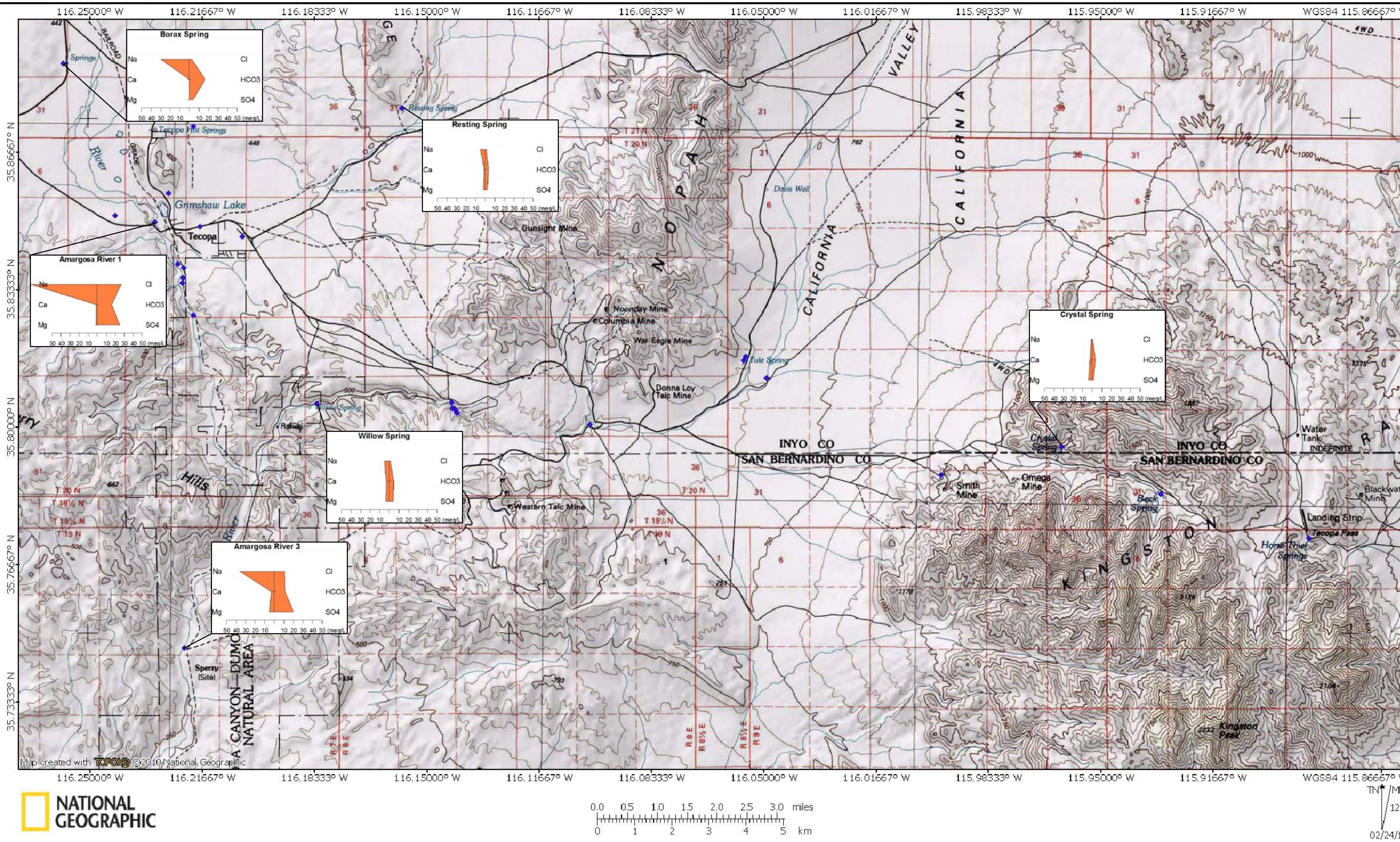
AMARGOSA BASIN
CALIFORNIA - NEVADA

PROJECT NO.	DATE	DR.BY:	APP. BY:
01-AC-001	02/24/11	JP	AZ

TECOPA AREA DATA COLLECTION LOCATIONS AND RESULTS

FIGURE 2-1



NATIONAL GEOGRAPHIC

LEGEND

AMARGOSA BASIN
CALIFORNIA - NEVADA

TECOPA AND KINGSTON RANGE DATA COLLECTION LOCATIONS AND RESULTS

PROJECT NO.	DATE	DRAWN BY:	APP. BY:
01-AC-001	02/24/11	JP	AZ

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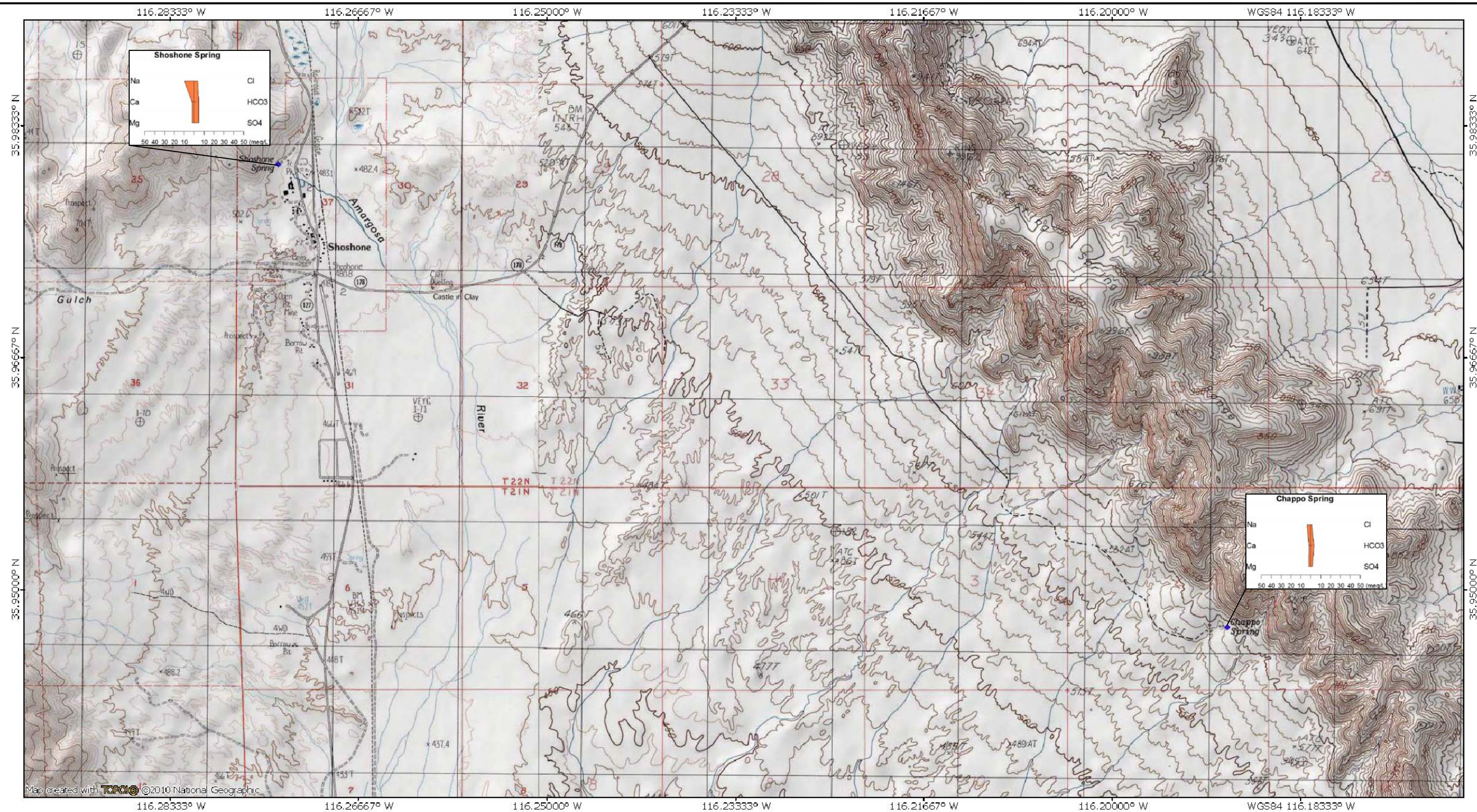
FIGURE 2-2



NATIONAL GEOGRAPHIC

MILES
FEET
KILOMETERS
METERS

TN MN 12½°
02/24/11

LEGEND

AMARGOSA BASIN
CALIFORNIA - NEVADA

SHOSHONE AREA DATA COLLECTION LOCATIONS AND RESULTS

PROJECT NO.	DATE	DRAWN BY:	APP. BY:
01-AC-001	02/24/11	JP	AZ

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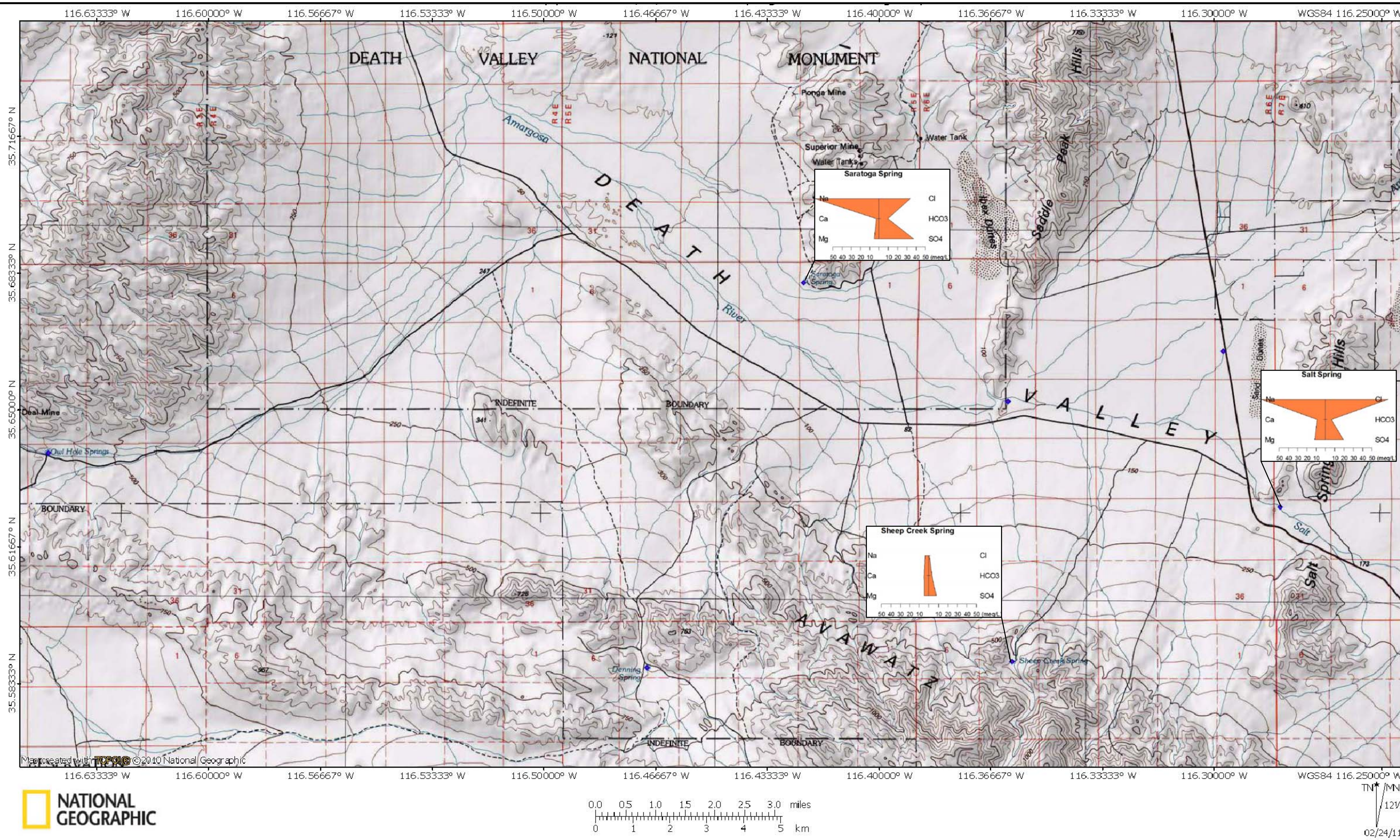
PLEASANT HILL, CA 94523

FIGURE
2-3



LEGEND

AMARGOSA BASIN
CALIFORNIA - NEVADA

AVAWATZ AREA DATA COLLECTION LOCATIONS AND RESULTS

PROJECT NO.	DATE	DRAWN BY:	APP. BY:
01-AC-001	02/24/11	JP	AZ

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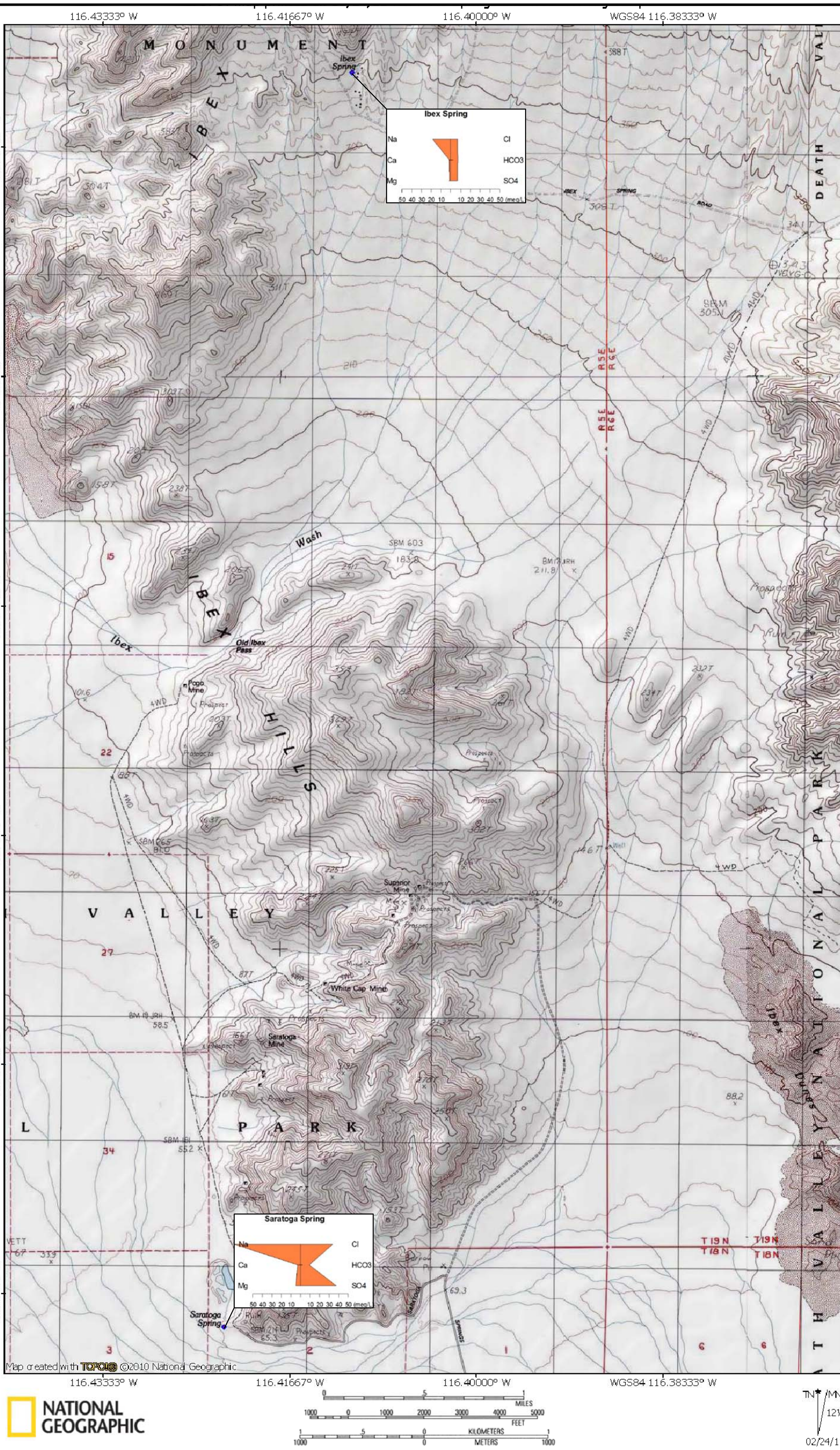
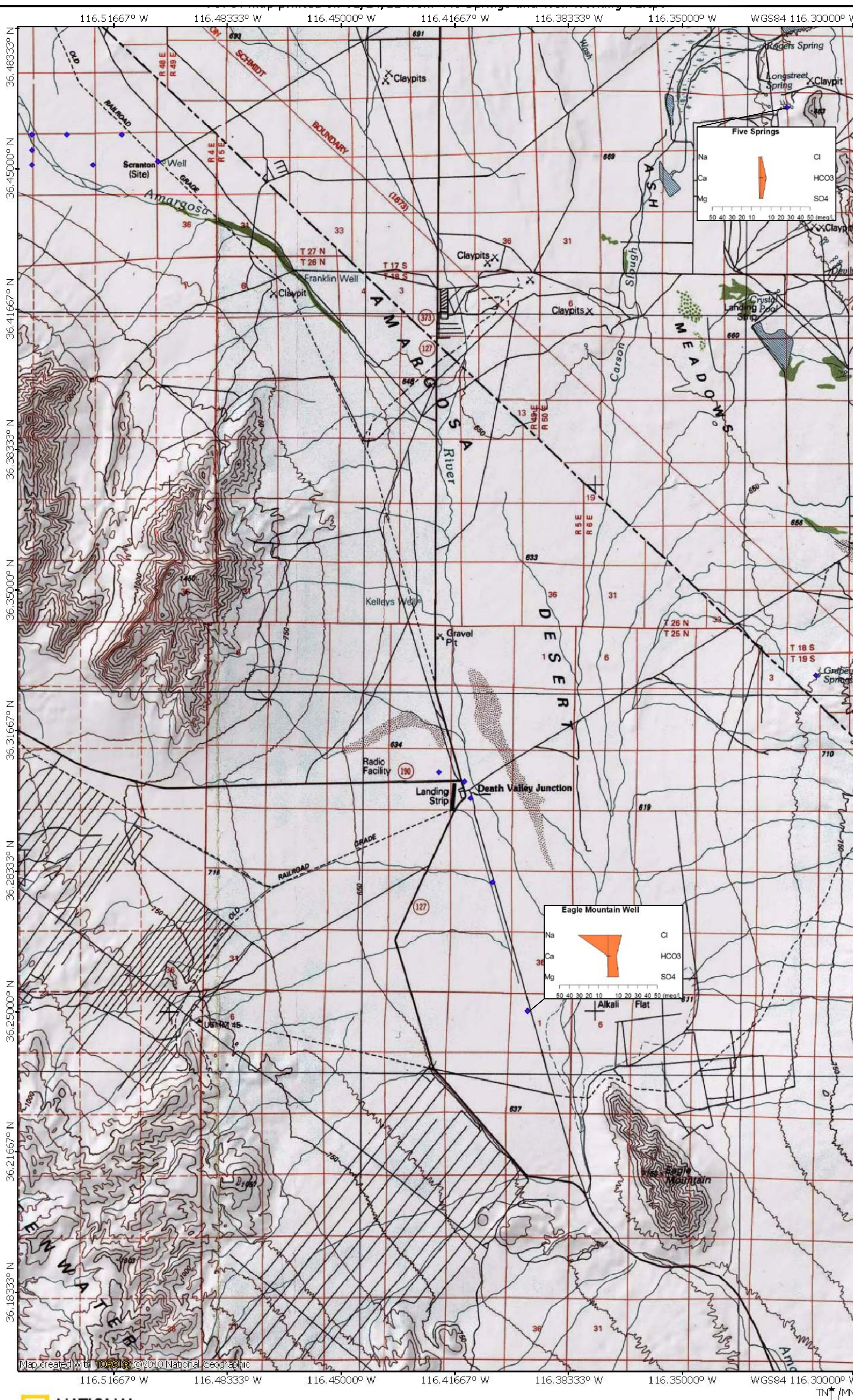
PLEASANT HILL, CA 94523

FIGURE 2-4



SGI environmental **THE SOURCE GROUP, INC.** 3451-C VINCENT ROAD PLEASANT HILL, CA 94523	AMARGOSA BASIN CALIFORNIA - NEVADA			**IBEX HILLS AREA DATA COLLECTION LOCATIONS AND RESULTS**	**FIGURE** **2-5**
	PROJECT NO. 01-AC-001	DATE 02/24/11	DR.BY: JP / APP. BY: AZ		



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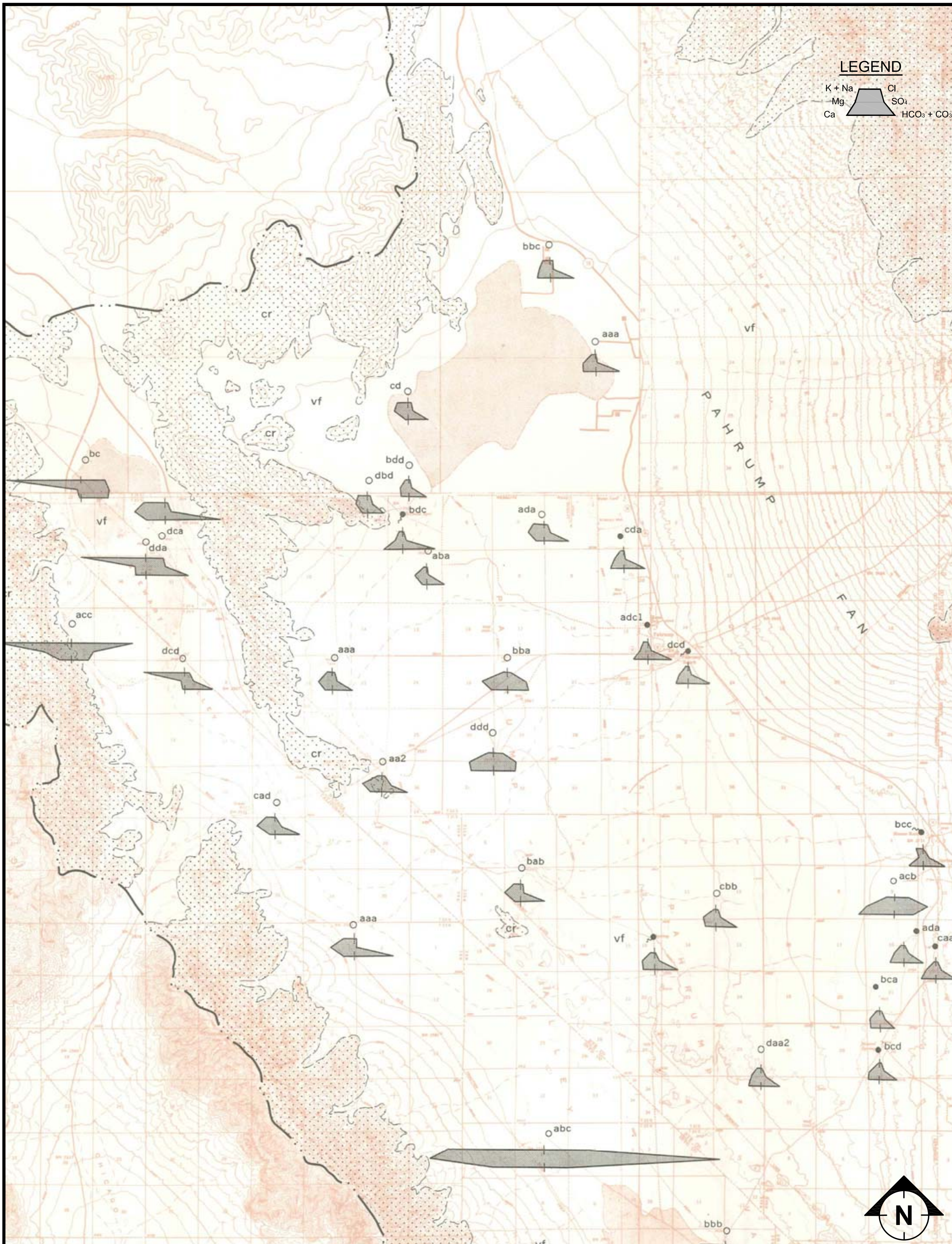
AMARGOSA BASIN
CALIFORNIA - NEVADA

PROJECT NO.	DATE	DR.BY:	APP. BY:
01-AC-001	02/24/11	JP	AZ

EAGLE MOUNTAIN AREA DATA COLLECTION LOCATIONS AND RESULTS

FIGURE

2-6



THE SOURCE GROUP, INC. 3478 BUSKIRK AVE, STE 100 PLEASANT HILL, CA 94523	AMARGOSA VALLEY CALIFORNIA - NEVADA				GROUNDWATER CHEMISTRY, PAHRUMP VALLEY (MALMBERG 1972)	FIGURE 2-7
	PROJECT NO.	DATE	DR.BY:	APP. BY:		
	01-AC-003	03/11/12	JP	JP		

EXPLANATION

Basin-fill deposits

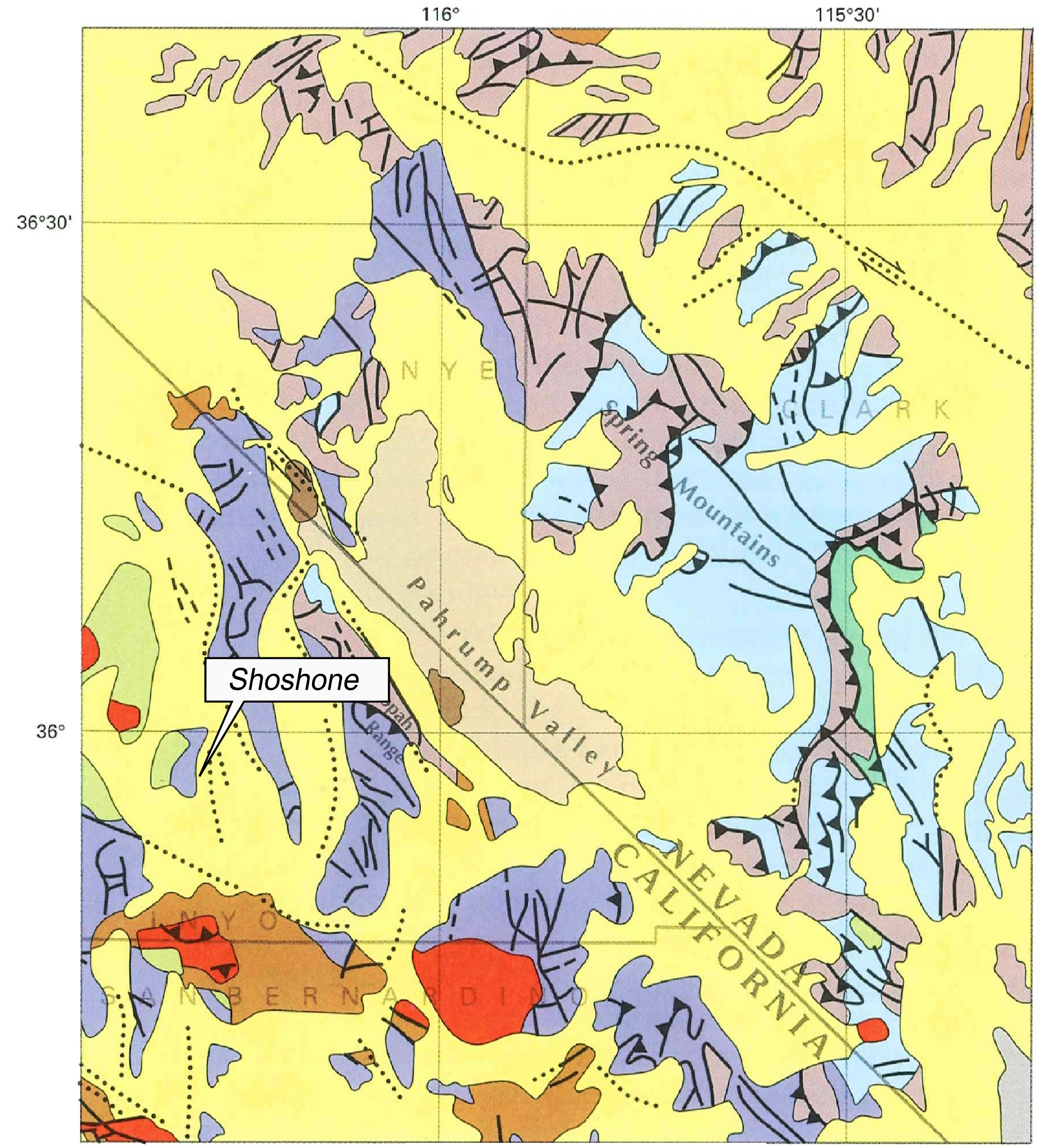
- Quaternary playa deposits
- Quaternary and Tertiary unconsolidated coarse-grained deposits
- Quaternary and Tertiary lacustrine and associated fine-grained deposits

Consolidated rocks

- Tertiary consolidated deposits
- Tertiary to Triassic marine and continental rocks
- Triassic to Mississippian carbonate rocks
- Devonian to Cambrian carbonate and clastic rocks
- Cambrian and Precambrian clastic rocks
- Quaternary and Tertiary volcanic rocks
- Miocene to Triassic intrusive rocks
- Precambrian basement rocks

Fault—Dashed where approximately located. Dotted where concealed Arrows show relative movement

Thrust fault—Sawteeth on upper plate



Base modified from U.S. Bureau of the Census TIGER/Line files, 1:100,000, 1990

Modified from Plume and Carlton, 1988 and Harrill, 1986

Source: Planert and Williams, 1995

AMARGOSA BASIN
CALIFORNIA-NEVADA

REGIONAL GEOLOGIC MAP

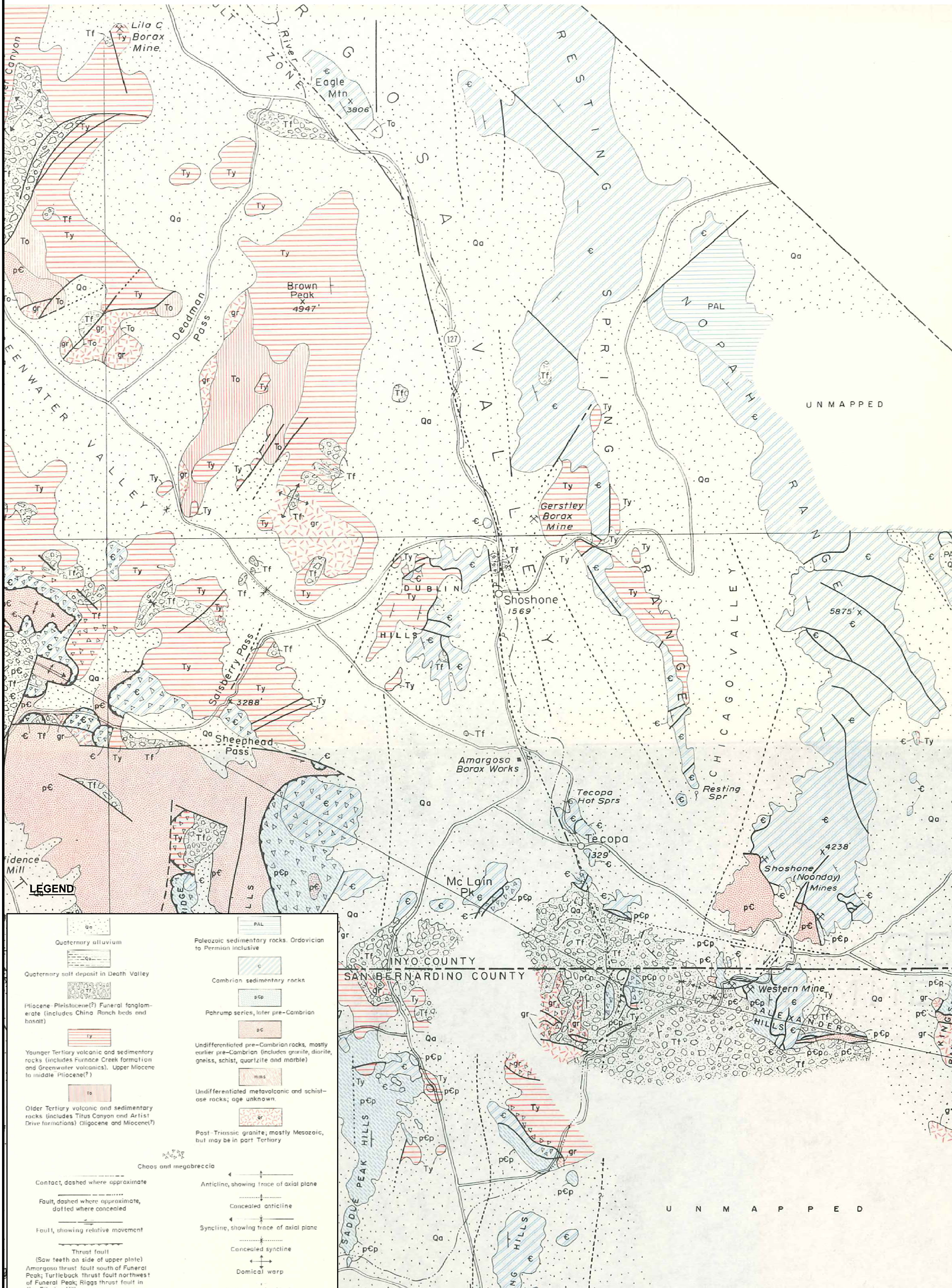
PROJECT NO.	DATE	DRAWN BY:	APP. BY:
01-AC-001	02/24/11	ZA	AZ

0 10 20
HORIZONTAL SCALE IN MILES

SGI environmental
THE SOURCE GROUP, INC.
3451-C VINCENT ROAD
PLEASANT HILL, CA 94523

N

FIGURE
3-1



SOURCE:
STATE DEPARTMENT OF CALIFORNIA, DEPARTMENT OF NATURAL RESOURCES, DIVISION OF MINES, BULLETIN 170, CHAPTER II, CONTRIBUTION 10, PLATE 7. 1954.

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AMARGOSA BASIN
CALIFORNIA-NEVADA

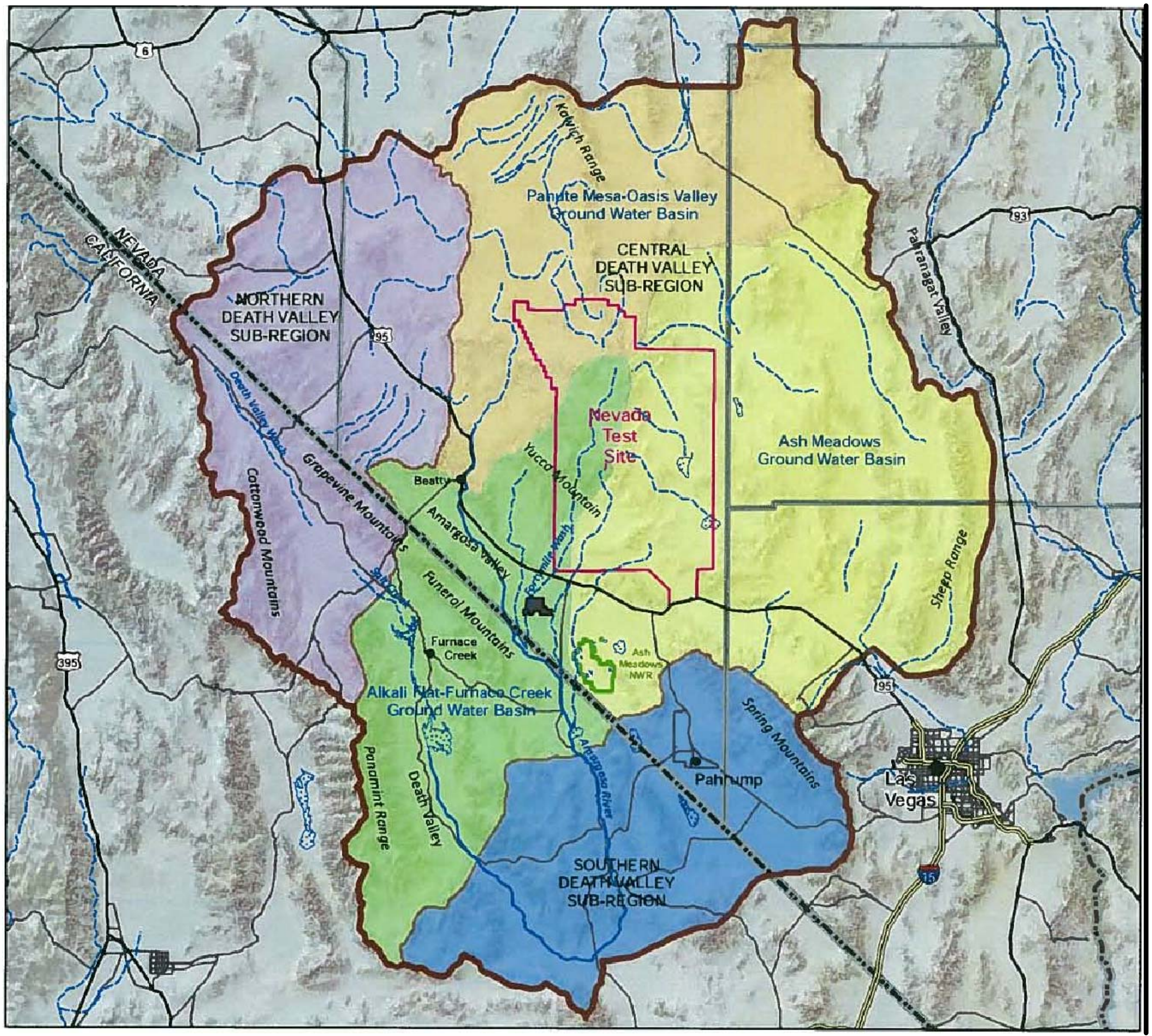
GEOLOGY OF THE SHOSHONE - TECOPA AREA

PROJECT NO.	DATE	DR.BY:	APP. BY:
01-AC-001	02/24/11	SD	XX

0 3 6
APPROXIMATE SCALE IN MILES

N

FIGURE 3-2



LEGEND

- Death Valley Regional Flow System
- Northen Death Valley Sub-region
- Southern Death Valley Sub-region

Central Sub-region Ground Water Basin

- Alkali Flat-Furnace Creek
- Ash Meadows
- Pahute Mesa-Oasis Valley

General Referance Features

- Interstate
- US Highway
- Major Road
- River
- Wash
- State Boundary
- County Boundary
- City/Town
- Playa

Source: EPG,2010

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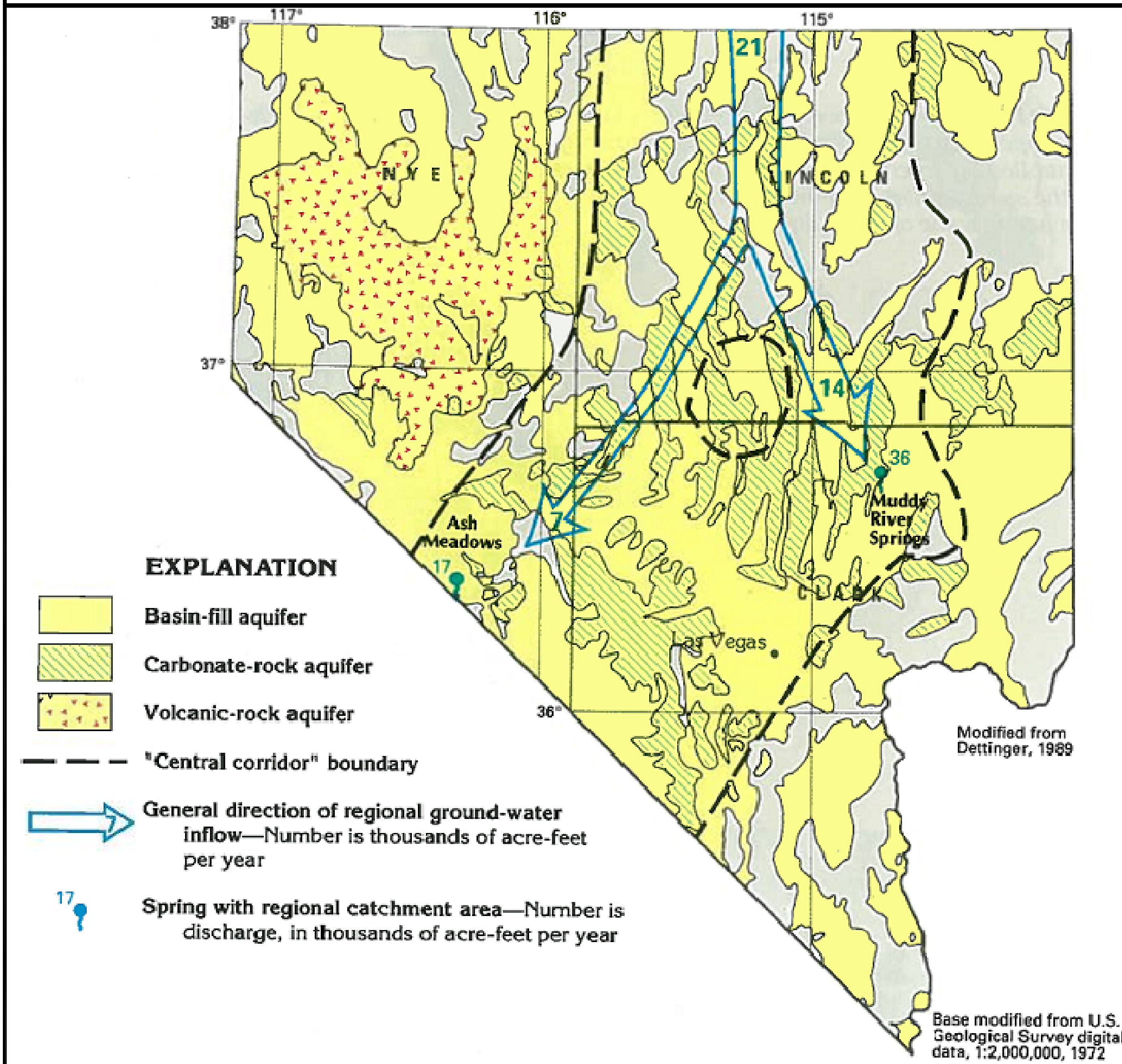
AMARGOSA BASIN
CALIFORNIA-NEVADA

EXTENT OF THE DEATH VALLEY REGIONAL FLOW SYSTEM

PROJECT NO.	DATE	DR.BY:	APP. BY:
01-AC-001	02/24/11	Z.A	AZ

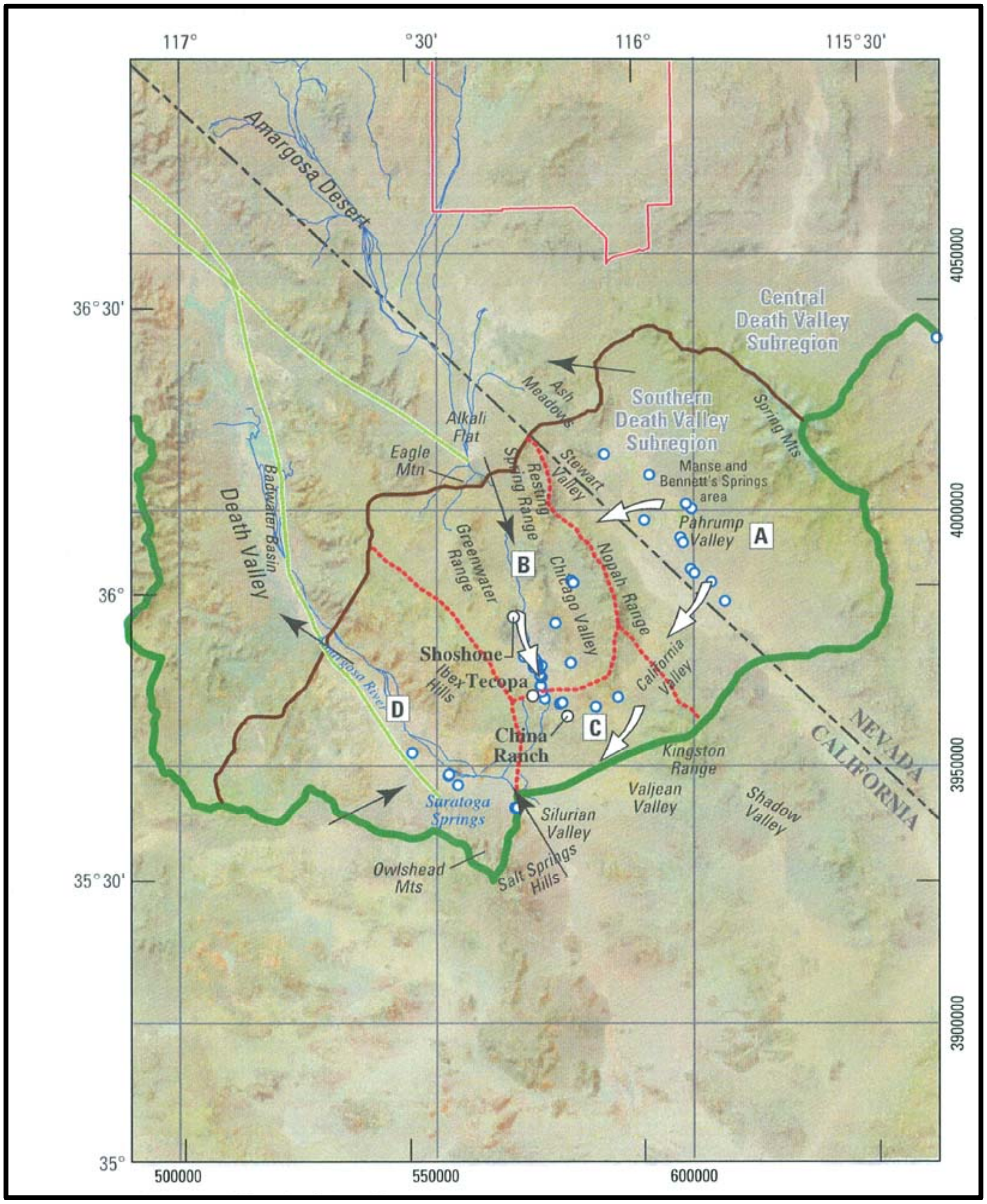
0 30 60
HORIZONTAL SCALE IN MILES

FIGURE 3-3



Source: Planert and Williams, 1995

THE SOURCE GROUP, INC. environmental 3451-C VINCENT ROAD PLEASANT HILL, CA 94523	AMARGOSA BASIN CALIFORNIA-NEVADA			PATHS FOR REGIONAL GROUNDWATER FLOW-NEVADA PORTION OF BASIN	N
	PROJECT NO. 01-AC-001	DATE 02/09/11	DR.BY: G.T. / APP. BY: A.Z.	0 25 50 HORIZONTAL SCALE IN MILES	FIGURE 3-4



Source: Faunt, D'Agnese, O'Brian, 2004

EXPLANATION

- Death Valley regional ground-water flow system model boundary
- Subregion boundary (Within model domain)
- Ground-water section boundary and name
  - A Pahrump Valley
  - B Shoshone-Tecopa
  - C California Valley
  - D Ibex Hills
- Nevada Test Site boundary
- Potential flow into or between subregions
- General direction of ground-water flow associated with ground-water section
- Death Valley fault zone
- Regional springs
- Populated place

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AMARGOSA BASIN
CALIFORNIA-NEVADA

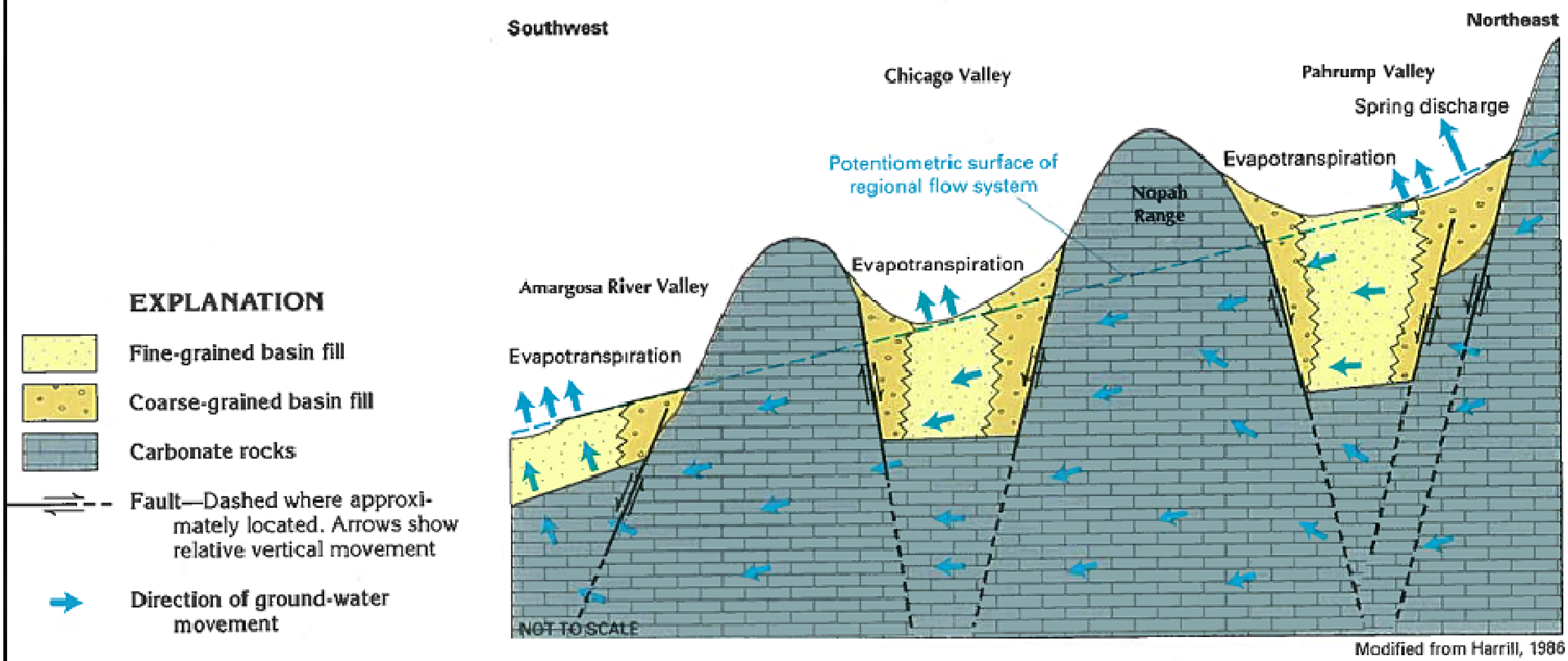
PATHS FOR REGIONAL GROUNDWATER FLOW-MIDDLE AMARGOSA RIVER AND DEATH VALLEY BASINS

PROJECT NO.	DATE	DR.BY:	APP. BY:
01-AC-001	02/24/11	ZA	AZ

0 25 50
HORIZONTAL SCALE IN MILES

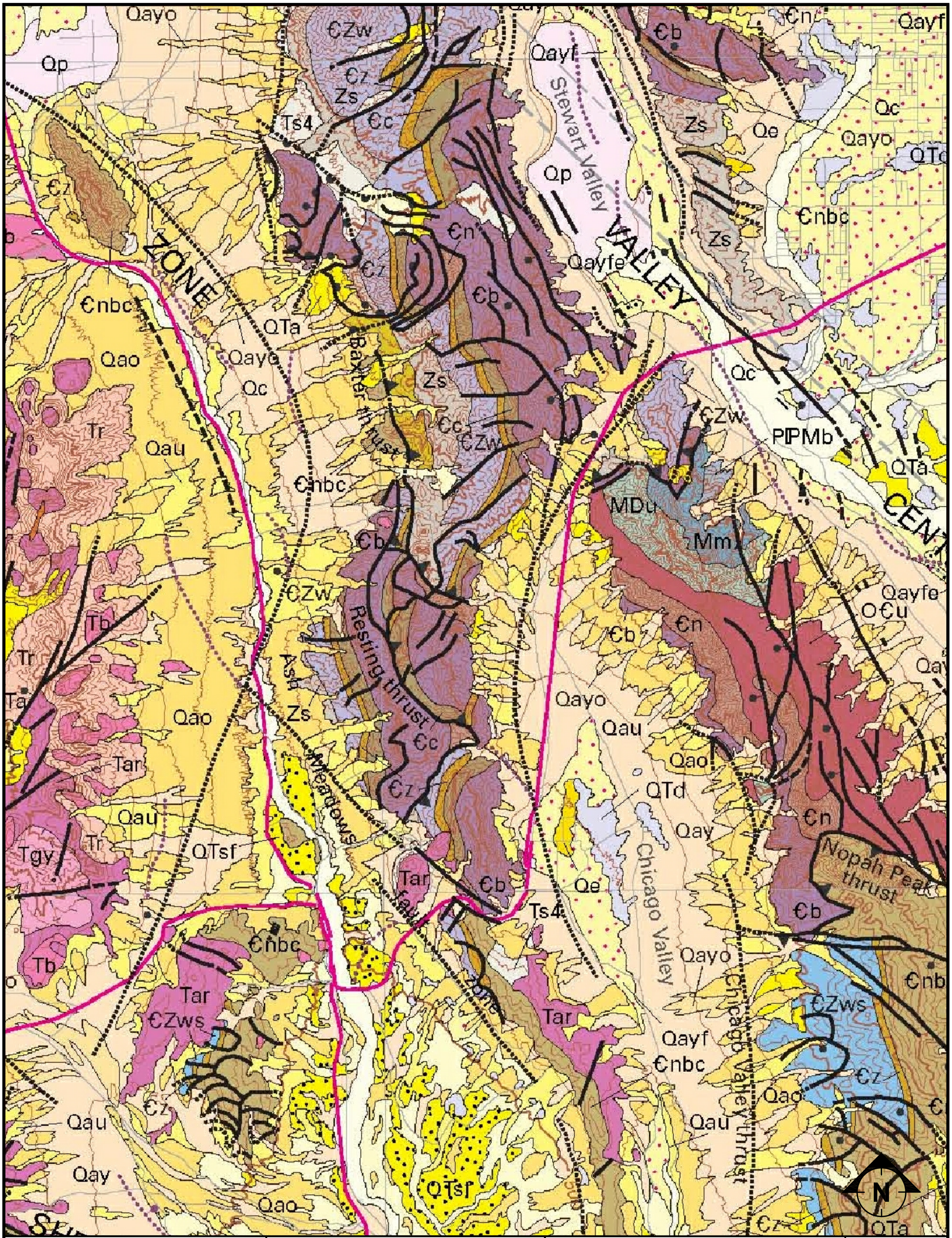
N

FIGURE 3-5

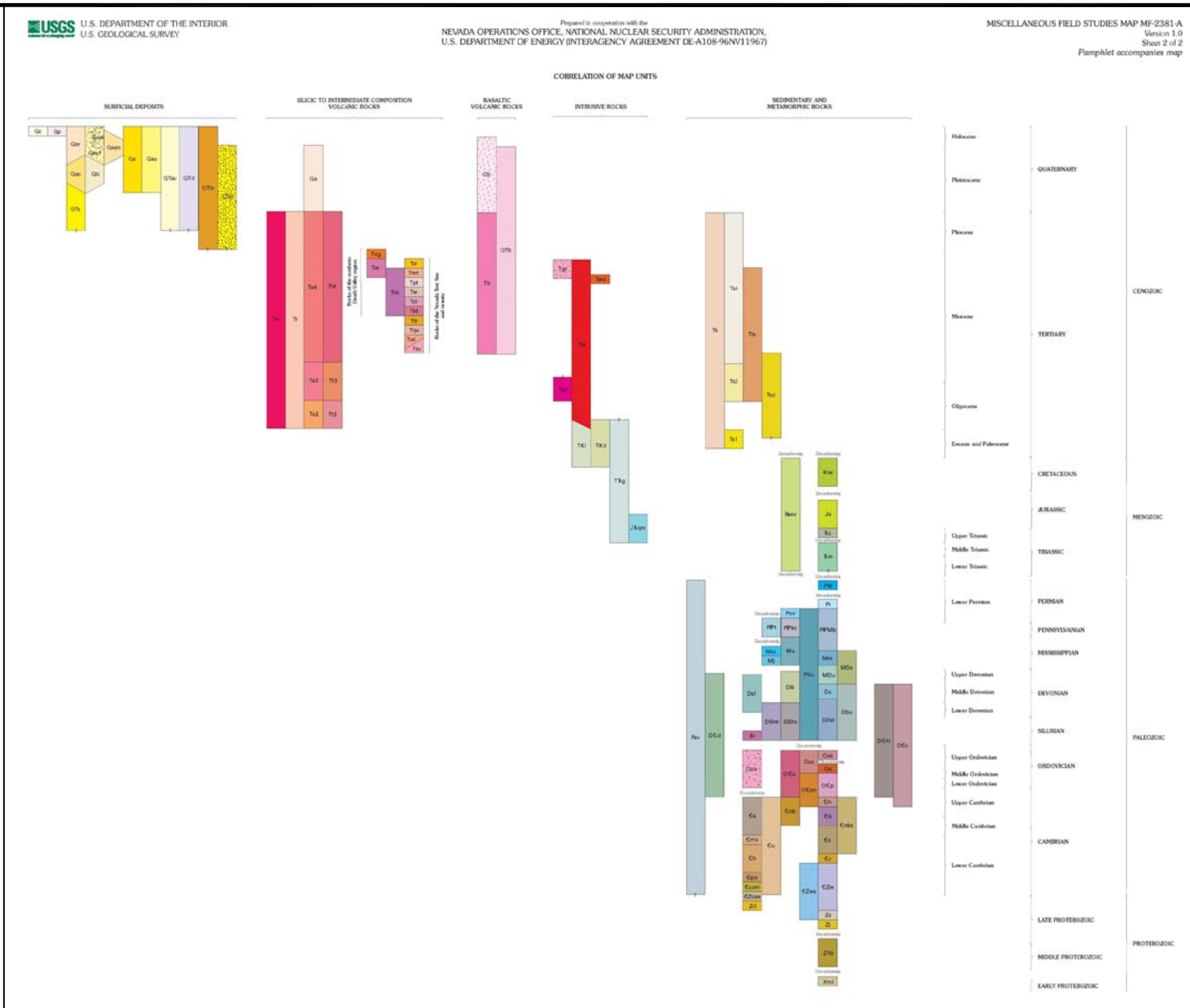


Source: Planert and Williams, 1995

THE SOURCE GROUP, INC. (SGI environmental) 3451-C VINCENT ROAD PLEASANT HILL, CA 94523	AMARGOSA BASIN CALIFORNIA-NEVADA				CONCEPTUAL CROSS-SECTION OF INTERBASINAL FLOW	
	PROJECT NO. 01-AC-001	DATE 02/09/11	DR.BY: G.T.	APP. BY: A.Z.	0 0 0 NOT TO SCALE	FIGURE 3-6



SGI environmental THE SOURCE GROUP, INC. 3478 BUSKIRK AVE, STE 100 PLEASANT HILL, CA 94523	AMARGOSA BASIN CALIFORNIA - NEVADA			GEOLOGY OF CHICAGO VALLEY AREA (WORKMAN 2002)	FIGURE 3-7
	PROJECT NO. 01-AC-001	DATE 03/11/12	DR.BY: JP / APP. BY: JP		



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3478 BUSKIRK AVE, STE 100
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AMARGOSA BASIN
CALIFORNIA - NEVADA

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GEOLOGY OF CHICAGO VALLEY AREA STRATIGRAPHY SECTION (WORKMAN 2002)

FIGURE 3-7A

LIST OF MAP UNITS

SURFICIAL DEPOSITS

- Qc — Channel alluvium (Holocene)
- Qp — Playa and (or) salt pan deposits (Holocene)
- Qay — Young alluvium (Holocene to latest Pleistocene?)
- Qayf — Young fine-grained alluvium (Holocene to latest Pleistocene?)
- Qayse — Evaporite surface crust of salts and (or) carbonate (Holocene to latest Pleistocene?)
- Qayo — Intermediate-age alluvium (middle Holocene to latest Pleistocene?)
- Qe — Eolian deposits (Holocene to middle Pleistocene)
- Qau — Undifferentiated alluvium (Holocene to Pleistocene)
- QTau — Undifferentiated older alluvium (Holocene to latest Tertiary)
- QTd — Deposits associated with modern or past ground-water discharge (Holocene to late Tertiary)
- QTls — Landslide block (Holocene to late Tertiary)
- QTst — Old alluvial, paludal, or lacustrine sediments (Pleistocene to late Tertiary)
- Qao — Old alluvium (late to middle Pleistocene)
- Qlc — Old lacustrine deposits (late to middle Pleistocene)
- QTa — Oldest alluvium (middle Pleistocene to late Tertiary)

BEDROCK UNITS

SILICIC TO INTERMEDIATE-COMPOSITION VOLCANIC ROCKS

- Qa — Young intermediate-composition lava flows, undivided (Pleistocene)
- Tv — Volcanic rocks, undivided (Pliocene to Oligocene)
- Tr — Felsic-composition lava flows, undivided (Pliocene to Oligocene)
- Ta4 — Intermediate-composition lava flows, unit 4 (Pliocene and Miocene)
- Tt4 — Ash-flow tuffs and interbedded air-fall tuffs, unit 4 (Pliocene and Miocene)

Rocks of the southern Death Valley region (Miocene)

- Tvg — Greenwater Volcanics
- Tor — Intermediate- to felsic-composition lava flows of the central Death Valley volcanic field
- Tas — Intermediate- to felsic-composition lava flows of the southern Death Valley-Kingston Range volcanic belt

Rocks of the Nevada Test Site and vicinity (Miocene)

- Tst — Stonewall Flat Tuff and tuffs of the Thirsty Canyon Group, undivided
- Tmt — Tuffs of the Timber Mountain Group
- Tpt — Tuffs of the Paintbrush Group
- Tw — Wahmonie and Salyer Formations, undivided
- Tct — Tuffs of the Crater Flat Group
- Tbt — Tuffs of the Belted Range Group
- Tlt — Lithic Ridge Tuff, rhyolite of Picture Rock, Tunnel Formation, and comendite of Quartet Dome, undivided
- Tqv — Volcanic rocks of Quartz Mountain
- Tuv — Older ash-flow tuffs and lava sequences, undivided
- Tkv — Lava flows of the Belted Range
- Ta3 — Intermediate-composition lava flows, unit 3 (Miocene and Oligocene)
- Tt3 — Ash-flow tuffs and interbedded air-fall tuffs, unit 3 (Miocene and Oligocene)
- Ta2 — Intermediate-composition lava flows, unit 2 (Oligocene)
- Tt2 — Ash-flow tuffs and interbedded air-fall tuffs, unit 2 (Oligocene)

BASALTIC VOLCANIC ROCKS

- Qb — Young basaltic lava flows (Holocene to Pleistocene)
- QTb — Basaltic lava flows, undivided (Pleistocene to Miocene)
- Tb — Old basaltic lava flows (Pliocene to Miocene)

INTRUSIVE ROCKS

- Tgy — Young granitic intrusive rocks (Miocene)
- Tai — Younger intermediate-composition intrusive rocks (Miocene to Oligocene)
- Tws — Gabbro to diorite intrusive rocks of Willow Springs (Miocene)
- Tgo — Older granitic intrusive rocks (Miocene? to Oligocene)
- TKi — Older intermediate-composition intrusive rocks (Oligocene to Cretaceous)
- TKd — Mafic intrusive rocks (Oligocene to Cretaceous)
- TŦg — Oldest granitic intrusive rocks (Tertiary? to Triassic)
- JŦqm — Avawatz Mountains quartz monzodiorite, undivided (Early Jurassic to Late Triassic)

SEDIMENTARY AND METAMORPHIC ROCKS

- Ts — Sedimentary rocks, undivided (Pliocene to Eocene)
- Ts4 — Sedimentary rocks, unit 4 (Pliocene and Miocene)
- Tls — Landslide and mega-breccia deposits (Miocene to Oligocene)
- Tso — Sedimentary rocks older than the rocks of the Nevada Test Site and vicinity (Miocene to Eocene?)
- Ts3 — Sedimentary rocks, unit 3 (Miocene and Oligocene)
- Ts1 — Sedimentary rocks, unit 1 (Eocene and Paleocene)
- Mzsv — Sedimentary and volcanic rocks, undivided (Mesozoic)
- Klw — Lavinia Wash sequence (Upper and Lower Cretaceous)
- Ja — Aztec Sandstone (Jurassic)
- Ŧc — Chinle Formation (Upper Triassic)
- Ŧm — Moenkopi Formation (Middle? and Lower Triassic)
- Pzu — Sedimentary rocks, undivided (Paleozoic)
- Pkt — Kaibab and Toroweap Formations, undivided (Lower Permian)
- Pr — Redbeds (Lower Permian)
- Pov — Owens Valley Group (Lower Permian)
- PSu — Sedimentary rocks, undivided (Permian to Silurian)
- PPMb — Bird Spring (Lower Permian and Pennsylvanian) and Indian Springs Formations (Upper Mississippian)
- PPt — Tippipah Limestone (Lower Permian and Pennsylvanian)
- PPkc — Keeler Canyon Formation (Lower Permian to Middle Pennsylvanian)
- Mu — Sedimentary rocks, undivided (Upper and Lower Mississippian)
- Msc — Scotty Wash Quartzite (Upper Mississippian) and Chainman Shale (Upper and Lower Mississippian), undivided
- Mm — Monte Cristo Group (Upper and Lower Mississippian)
- MDe — Eleana Formation (Mississippian and Upper Devonian)
- Mj — Joana Limestone (Lower Mississippian)
- MDu — Sedimentary rocks, undivided (Lower Mississippian and Upper and Middle Devonian)
- Dlb — Lost Burro Formation (Upper and Middle Devonian)
- DꞒd — Dolomite and limestone, undifferentiated (Devonian to Upper Cambrian)
- Dsf — Slope-facies carbonate rocks (Upper to Lower Devonian)
- Ds — Simonson Dolomite (Middle Devonian)
- DSu — Sedimentary rocks, undivided (Devonian and Silurian)
- DꞒm — Mountain Springs Formation (Middle Devonian, Lower Ordovician, and Upper Cambrian)
- DꞒu — Mountain Springs (Middle Devonian, Lower Ordovician, and Upper Cambrian) and Nopah Formations (Upper Cambrian), undivided
- DSsl — Sevy (Middle and Lower Devonian) and Laketown (Upper and Middle Silurian) Dolomites, undivided
- DSlm — Lone Mountain Dolomite (Lower Devonian and Silurian)
- DShv — Hidden Valley Dolomite (Lower Devonian and Silurian)
- Sr — Roberts Mountains Formation (Silurian)
- Opb — Palmetto Formation (Upper, Middle, and Lower Ordovician)
- OꞒu — Sedimentary rocks, undivided (Ordovician and Upper Cambrian)
- Oee — Ely Springs Dolomite (Upper Ordovician) and Eureka Quartzite (Upper and Middle Ordovician), undivided
- Oes — Ely Springs Dolomite (Upper Ordovician)
- Oe — Eureka Quartzite (Upper and Middle Ordovician)
- OꞒpn — Pogonip Group (Middle and Lower Ordovician and Upper Cambrian) and Nopah Formation (Upper Cambrian), undivided
- OꞒp — Pogonip Group (Middle and Lower Ordovician and Upper Cambrian)
- Ꞓe — Emigrant Formation (Upper and Middle Cambrian)
- Ꞓu — Sedimentary rocks, undivided (Upper to Lower Cambrian)
- Ꞓnb — Nopah (Upper Cambrian) and Bonanza King Formations (Upper and Middle Cambrian), undivided
- Ꞓn — Nopah Formation (Upper Cambrian)
- Ꞓnbc — Nopah (Upper Cambrian), Bonanza King (Upper and Middle Cambrian), and Carrara Formations (Middle and Lower Cambrian), undivided
- Ꞓb — Bonanza King Formation (Upper and Middle Cambrian)
- Ꞓc — Carrara Formation (Middle and Lower Cambrian)
- Ꞓms — Mule Spring Limestone (Lower Cambrian)
- Ꞓh — Harkless Formation (Lower Cambrian)
- Ꞓz — Zabriskie Quartzite (Lower Cambrian)
- ꞒZws — Wood Canyon Formation (Lower Cambrian and Late Proterozoic) and Stirling Quartzite (Late Proterozoic), undivided
- ꞒZw — Wood Canyon Formation (Lower Cambrian and Late Proterozoic)
- Ꞓpo — Poleta Formation (Lower Cambrian)

Campito Formation (Lower Cambrian and Late Proterozoic)

- Ꞓcam — Montenegro Member (Lower Cambrian)
- ꞒZcaa — Andrews Mountain Member (Lower Cambrian and Late Proterozoic)
- Zd — Deep Spring Formation (Late Proterozoic)
- Zs — Stirling Quartzite and Reed Dolomite, undivided (Late Proterozoic)
- Zj — Johnnie and Wyman Formations, undivided (Late Proterozoic)
- ZYp — Pahrump Group (Late and Middle Proterozoic)
- Xmi — Metamorphic and igneous rocks, undifferentiated (Early Proterozoic)

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AMARGOSA BASIN
CALIFORNIA - NEVADA

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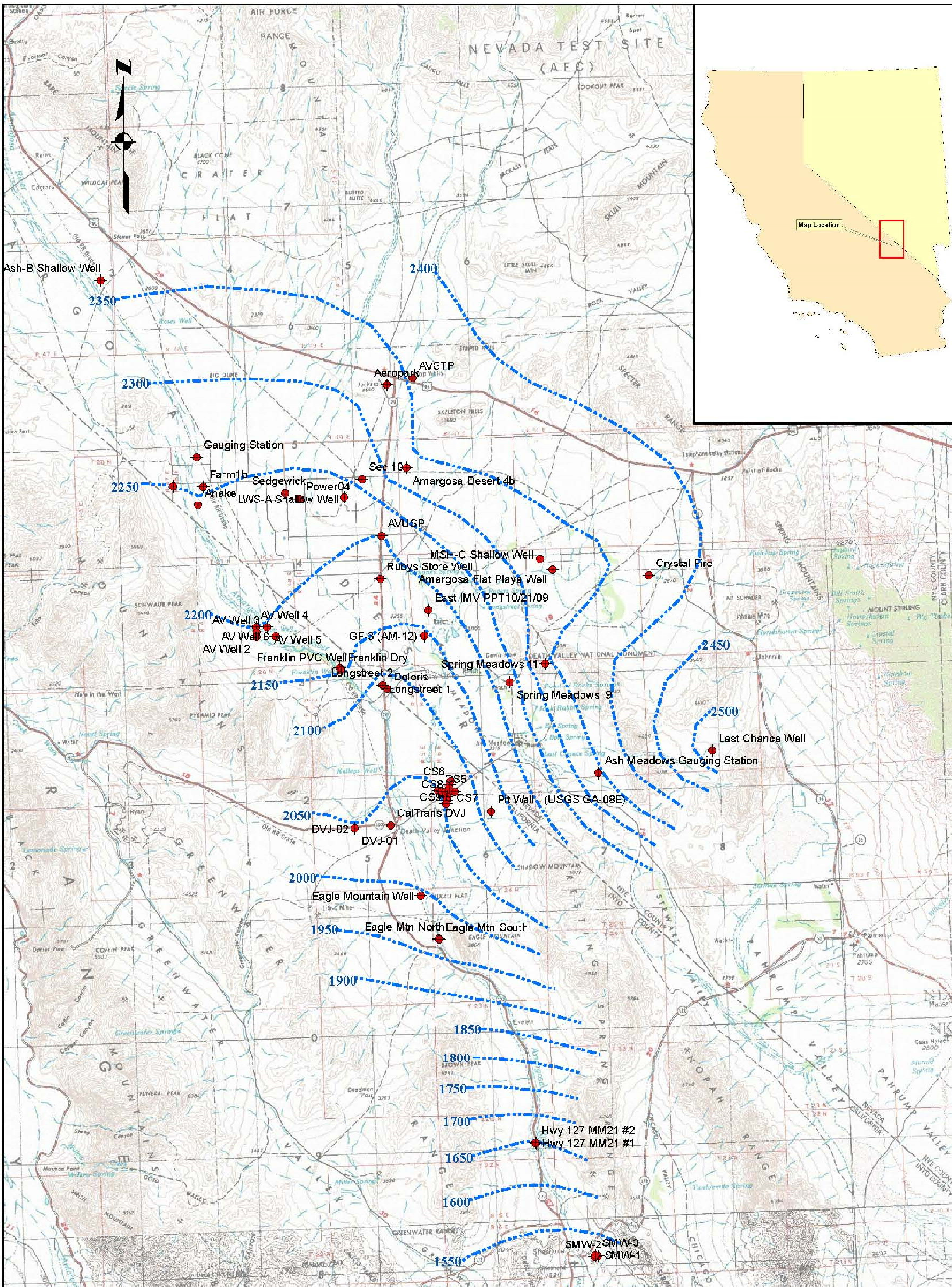
01-AC-002	03/11/12	JP	JP

GEOLOGY OF CHICAGO VALLEY AREA MAP KEY

FIGURE 3-7B



POTENTIOMETRIC SURFACE 2010 Amargosa Valley

Legend:

Monitoring Well

Approximate groundwater contour line with elevation in feet above mean sea level (interval 50 feet). Based on groundwater levels measured during the 4th Quarter of 2010.

0 4.5 9 18 Kilometers

The contour lines on this map depict the potentiometric surface of the Amargosa Valley aquifer system. Values represent the elevations recorded by Amargosa Conservancy, U.S. Geological Survey, Nye County, TEAM Engineering & Management, Inc., SGI, and BLM at various times during the end of 2010.

TEAM ENGINEERING & MANAGEMENT, INC.
Bishop and Mammoth Lakes, California

SOURCE:
TEAM ENGINEERING & MANAGEMENT, INC

SGI environmental THE SOURCE GROUP, INC.
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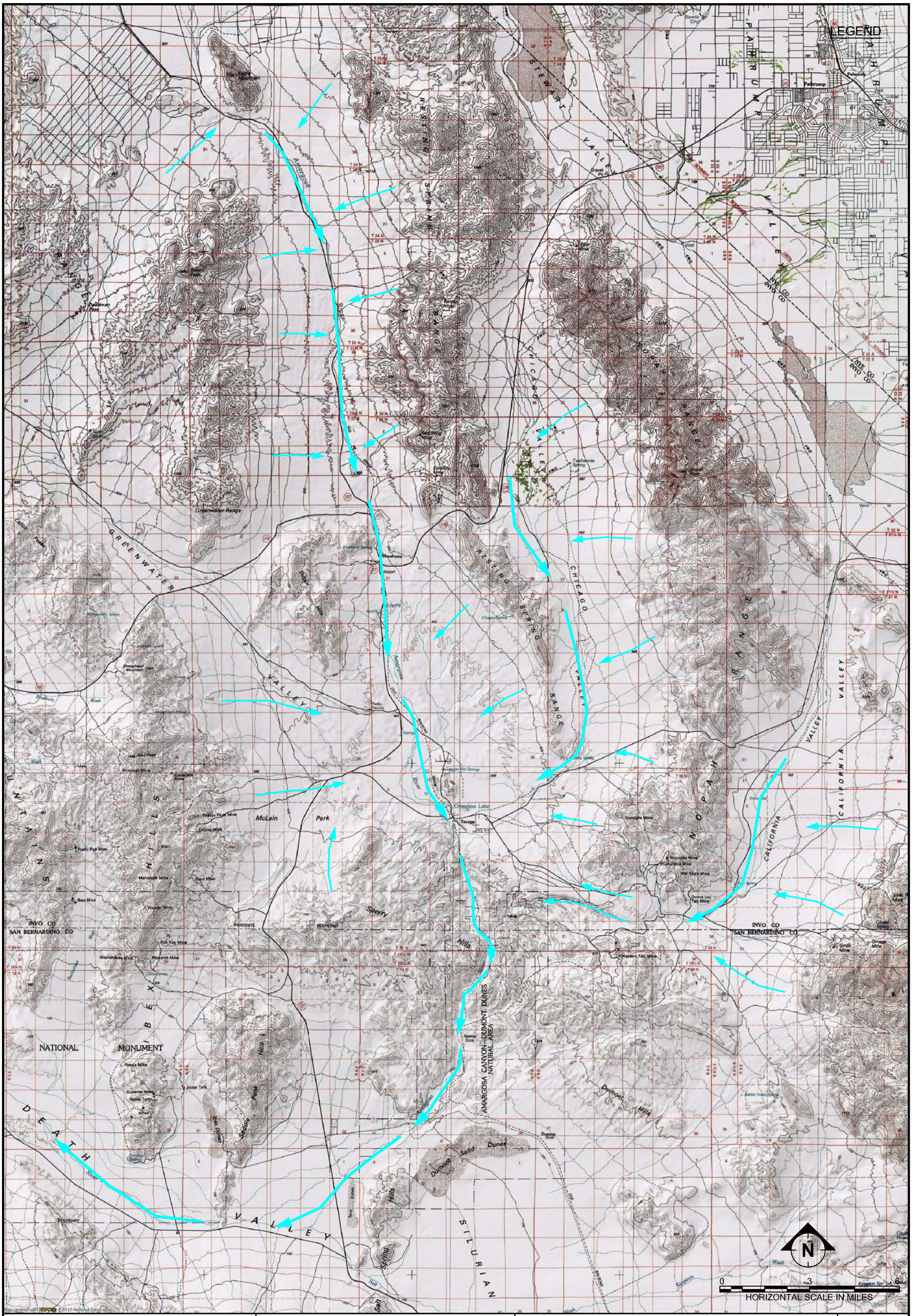
AMARGOSA BASIN
CALIFORNIA-NEVADA

PROJECT NO.	DATE	DR.BY:	APP. BY:
01-AC-001	4/25/11	NC	AZ

POTENTIOMETRIC SURFACE MAP
4TH QUARTER 2010

FIGURE
3-8



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AMARGOSA BASIN
CALIFORNIA - NEVADA

PROJECT NO.	DATE	DR.BY:	APP. BY:
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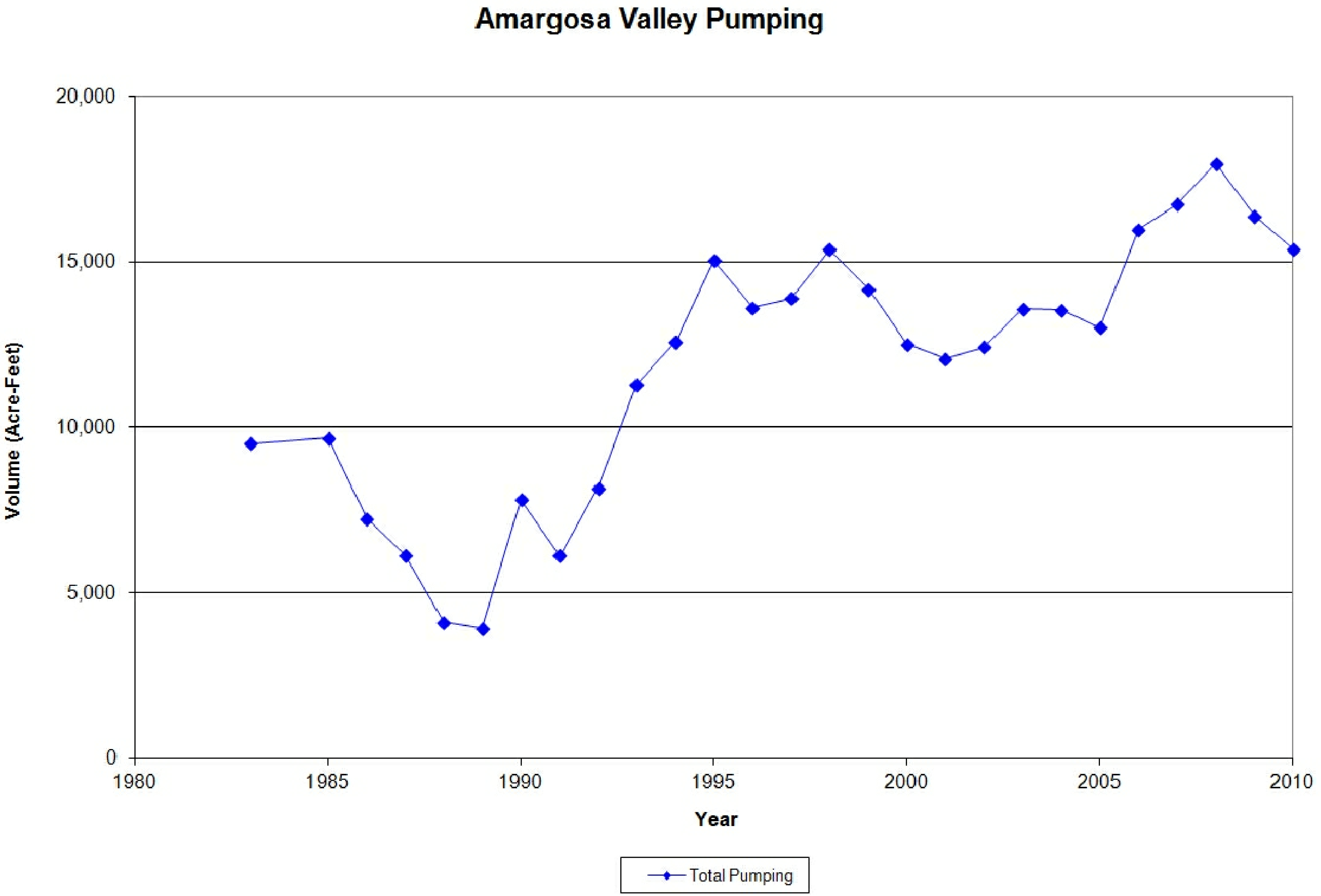
CONCEPTUAL SHALLOW ALLUVIUM FLOW PATHS WITHIN THE MIDDLE AMARGOSA RIVER BASIN

FIGURE 3-9



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AMARGOSA BASIN
CALIFORNIA - NEVADA

PROJECT NO.	DATE	DR.BY:	APP. BY:
01-AC-003	03/11/12	JP	JP

PUMPING VS TIME
AMARGOSA DESERT AREA, NEVADA

FIGURE
3-10

Nevada Division of Water Resources

Hydrographic Basin Summary By Application Status

Hydrographic Basin: 230

Hydrographic Region: 14 DEATH VALLEY BASIN

Basin Name: AMARGOSA DESERT

Yield: 24000 AFA

Reference: USGS Recon. 54

Remarks: 24,000 Combined Yield for Basins 225 thru 230

PRELIMINARY DATA SUBJECT TO REVISION

Status	Annual Duty Underground*		Annual Duty Geothermal*		Annual Duty Other Groundwater*		Annual Duty Total*	
	Acre Feet	Million Gal.	Acre Feet	Million Gal.	Acre Feet	Million Gal.	Acre Feet	Million Gal.
VST	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APP	176.70	57.58	0.00	0.00	0.00	0.00	176.70	57.58
RFA	1,681.30	547.85	0.00	0.00	0.00	0.00	1,681.30	547.85
PER	8,855.36	2,885.52	0.00	0.00	0.00	0.00	8,855.36	2,885.52
RLP	2.02	0.66	0.00	0.00	0.00	0.00	2.02	0.66
RVP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CER	16,621.48	5,416.10	0.00	0.00	0.00	0.00	16,621.48	5,416.10
DEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

STATE ENGINEER STATE OF NEVADA

NOTE: RFA Status Includes Protested Applications (RFP's)

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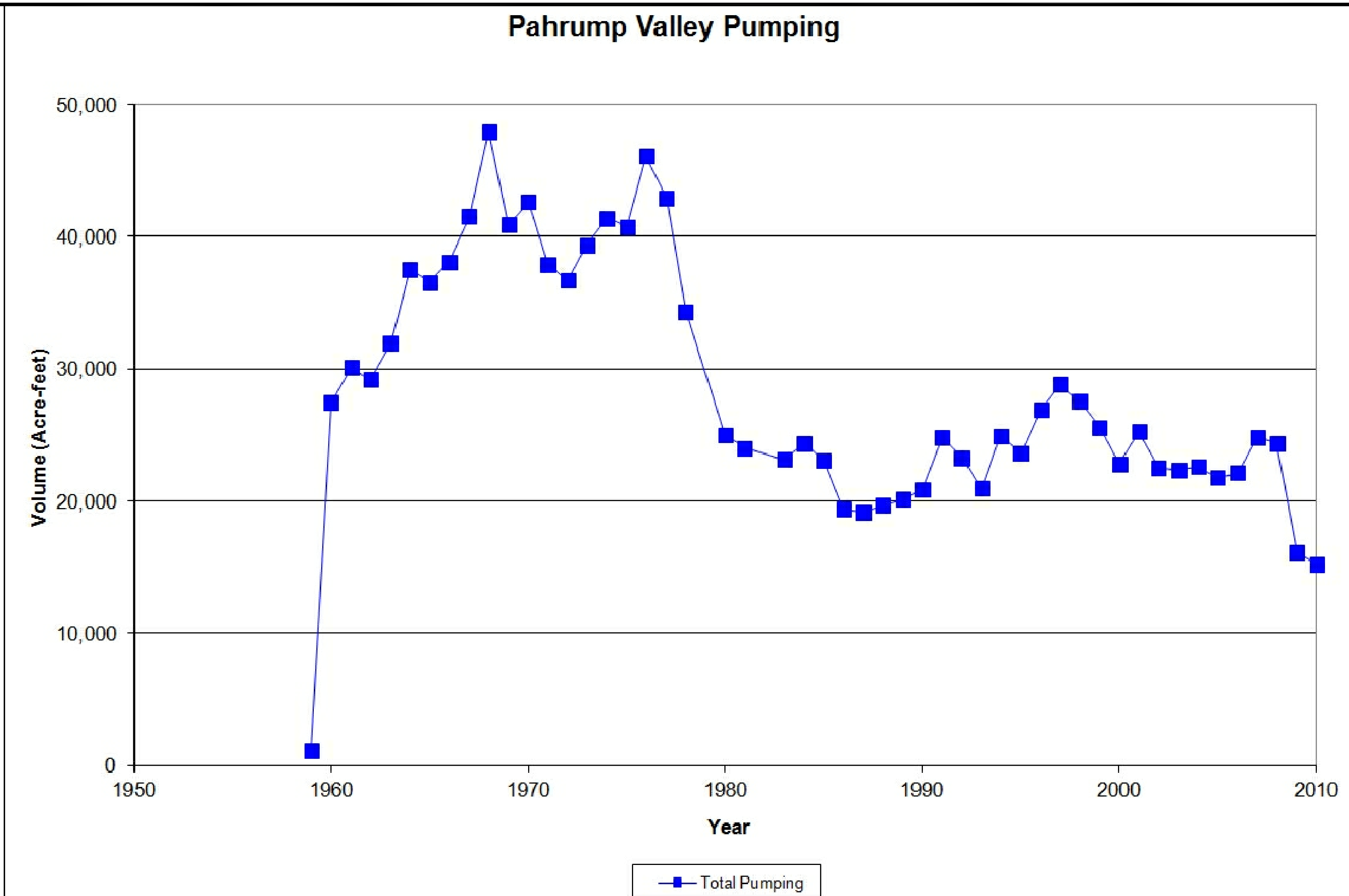
AMARGOSA BASIN
CALIFORNIA - NEVADA

PROJECT NO.	DATE	DR.BY:	APP. BY:
01-AC-003	03/11/12	JP	JP

ACTIVE DUTY
AMARGOSA DESERT, NEVADA

FIGURE 3-11



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AMARGOSA BASIN
CALIFORNIA - NEVADA

PROJECT NO.	DATE	DR.BY:	APP. BY:
01-AC-003	03/11/12	JP	JP

PUMPING VS. TIME
PAHRUMP VALLEY, NEVADA

FIGURE
3-12

TABLES

Table 2-1
Field Reconnaissance Data Summary
Amargosa Basin
California/Nevada

Name	Date of Visit	Latitude	Longitude	Elevation (ft amsl)	Flow (gpm)	Flow Measurement Method*	Temp. (deg C)	Spec. Cond. (mS/cm-deg C)	TDS (mg/L)	DO (mg/L)	pH	ORP (mV)	Notes
Springs													
Amargosa Canyon Spring 1	11/17/2010	35.83937	116.22399	1,294	38	meter	23.22	1.053	685	7.42	7.93	105.3	North end of Amargosa Canyon in burned area
Amargosa Canyon Spring 1	4/25/2011	35.83937	116.22399	1,294	--	--	22.46	1.029	669	8.62	7.94	253.5	North end of Amargosa Canyon in burned area
Amargosa Canyon Spring 1	5/11/2011	35.83937	116.22399	1,294	66.1	bucket	--	--	--	--	--	--	North end of Amargosa Canyon in burned area
Amargosa Canyon Spring 1	9/21/2011	35.83937	116.22399	1,294	40.5	bucket	25.79	1.076	700	7.74	8.12	-42.4	North end of Amargosa Canyon in burned area
Amargosa Canyon Spring 1	12/22/2011	35.83937	116.22399	1,294	78	meter	18.73	1.009	656	7.96	8.22	77.4	North end of Amargosa Canyon in burned area
Amargosa Canyon Spring 3	1/12/2011	35.82701	116.21942	1,262	30	visual	16.74	1.698	1104	9.68	8.51	186.4	Southern most Amargosa Canyon spring
Amargosa Canyon Spring 3	4/25/2011	35.82701	116.21942	1,262	25-30	visual	21.1	1.506	979	9.51	8.37	261.8	Southern most Amargosa Canyon spring
Amargosa Canyon Spring 3	9/21/2011	35.82701	116.21942	1,262	16	meter	25.79	1.597	1035	8.57	8.26	-17.8	Southern most Amargosa Canyon spring
Amargosa Canyon Spring 4	1/12/2011	35.8348	116.2226	1,382	25	visual	26.05	0.915	596	8.07	8.34	182.2	Amargosa Canyon spring eminating from east canyon wall
Amargosa Canyon Spring 4	4/25/2011	35.8348	116.2226	1,382	--	--	26.25	1.24	809	8.63	8.13	242.1	Amargosa Canyon spring eminating from east canyon wall
Amargosa Canyon Spring 4	5/11/2011	35.8348	116.2226	1,382	7.7	bucket	--	--	--	--	--	--	Amargosa Canyon spring eminating from east canyon wall
Amargosa Canyon Spring 4	9/21/2011	35.8348	116.2226	1,382	8.1	bucket	28.2	1.347	876	7.32	8.16	-18	Amargosa Canyon spring eminating from east canyon wall
Amargosa Canyon Spring 4	12/22/2011	35.8348	116.2226	1,382	9.1	bucket	26.15	1.273	828	7.34	8.33	111.3	Amargosa Canyon spring eminating from east canyon wall
Beck Spring	11/19/2010	35.78359	115.9322	4,439	5	visual	17.91	0.54	351	3.97	7.14	161.6	Located in the Kingston Range
Borax Spring	1/12/2011	35.88804	116.25789	1,342	6.8	bucket	30.53	3.019	1963	0.61	9.91	-296.7	
Borax Spring	5/5/2011	35.88804	116.25789	1,342	6.9	bucket	--	--	--	--	--	--	
Borax Spring	9/21/2011	35.88804	116.25789	1,342	5.9	bucket	30.51	2.981	1938	1.71	10.14	-404.7	
Bore Hole Spring	11/11/2010	35.88608	116.23416	1,356	20	visual	47.77	4.156	2704	2.28	8.62	141.4	Likely part of Tecopa Hot Spring system
Bore Hole Spring	5/2/2011	35.88608	116.23416	1,356	20	visual	43.98	4.176	2711	1.95	8.71	109.5	Likely part of Tecopa Hot Spring system
Bore Hole Spring	9/21/2011	35.88608	116.23416	1,356	26.2	meter	47.48	4.202	2731	1.31	8.68	-74.6	Likely part of Tecopa Hot Spring system
Chappo Spring	11/12/2010	35.94723	116.18992	1,989	~1	visual	24.52	0.782	508	0.92	7.48	48.9	
Chappo Spring	5/1/2011	35.94723	116.18992	1,989	~1	visual	23.23	0.755	491	3.81	7.81	82.6	
Crystal Spring	11/19/2010	35.79503	115.96176	3,808	5	visual	21.09	0.632	411	4.23	7.45	165.6	Located in the Kingston Range
Crystal Spring	4/26/2011	35.79503	115.96176	3,808	13.5	bucket	21.18	0.61	397	5.73	7.52	257.5	Located in the Kingston Range
Crystal Spring	9/22/2011	35.79503	115.96176	3,808	9.5	bucket	21.38	0.637	414	5.12	7.29	-0.4	Located in the Kingston Range
Crystal Spring	12/22/2011	35.79503	115.96176	3,808	8.3	bucket	21.3	0.607	395	4.26	7.45	153.1	Located in the Kingston Range
Five Springs	1/18/2011	36.46457	116.3193	2,349	30	bucket	34.44	0.523	336	3.96	7.77	107.1	Located in Ash Meadows
Five Springs	5/1/2011	36.46457	116.3193	2,349	28.6	bucket	34.24	0.693	454	4.44	7.6	179.3	Located in Ash Meadows
Horse Thief Spring	11/19/2010	35.77294	115.88824	4,637	5	visual	16.04	0.444	288	2.86	6.94	158.1	Located in the Kingston Range
Horse Thief Spring	4/26/2011	35.77294	115.88824	4,637	10.1	bucket	15.31	0.436	284	6.91	7.37	269	Located in the Kingston Range
Horse Thief Spring	9/22/2011	35.77294	115.88824	4,637	7.9	bucket	17.61	0.473	308	2.26	7.04	22.8	Located in the Kingston Range
Horse Thief Spring	12/22/2011	35.77294	115.88824	4,637	8	bucket	17.26	0.441	287	3.53	6.96	124.6	Located in the Kingston Range
Ibex Spring	11/4/2010	35.77211	116.4111	1,133	no flow	visual	18.78	2.486	1617	0.98	8.76	30.5	
Ibex Spring	4/24/2011	35.77211	116.4111	1,133	no flow	visual	16.35	2.234	1452	2.99	7.98	114.4	
Owl Hole Spring	11/16/2010	35.63931	116.64766	1,911	no flow	visual	17.01	4.098	2664	0.29	6.86	-73	
Resting Spring	1/23/2011	35.87728	116.15757	1,767	150	bucket	26.84	0.923	600	5.62	8.36	157.8	
Salsberry Spring	1/10/2011	35.93162	116.4182	3,410	5	visual	2.35	0.595	386	13.01	8.24	181.8	Spring water mixed with runoff from melting snow and ice
Salt Spring	11/5/2010	35.62622	116.28041	550	~1	visual	20.48	6.514	4235	0.74	7.94	-176.9	
Salt Spring	5/10/2011	35.62622	116.28041	550	~1	visual	19.46	8.944	5814	5.79	7.7	196.2	
Saratoga Spring	11/4/2010	35.6809	116.42254	207	unknown	visual	28.8	4.73	3075	2.49	7.71	259.1	
Sheep Creek Spring	11/5/2010	35.58863	116.36047	1,719	5	visual	23.1	0.614	400	8.57	9.02	62.5	

Table 2-1
Field Reconnaissance Data Summary
Amargosa Basin
California/Nevada

Name	Date of Visit	Latitude	Longitude	Elevation (ft amsl)	Flow (gpm)	Flow Measurement Method*	Temp. (deg C)	Spec. Cond. (mS/cm-deg C)	TDS (mg/L)	DO (mg/L)	pH	ORP (mV)	Notes
Sheep Creek Spring	4/24/2011	35.58863	116.36047	1,719	5	visual	21.4	1.216	789	7.67	7.78	188.2	
Sheephead Spring	1/17/2011	35.89979	116.40629	3,253	2	visual	11.58	0.818	531	8.59	8.22	169.8	
Shoshone Spring	1/23/2011	35.98056	116.27384	1,611	250+	meter	33.54	1.624	1056	3.75	7.79	162.7	This is from the Shoshone Spring source
Shoshone Spring	4/27/2011	35.98056	116.27384	1,611	250+	meter	--	--	--	--	--	--	This is from the Shoshone Spring source
Smith Spring	11/19/2010	35.78814	115.99752	3,066	~1	visual	21.41	0.451	293	5.36	7.81	86.9	Data from piping below spring source
Smith Spring	4/26/2011	35.78814	115.99752	3,066	2-3	visual	--	--	--	--	--	--	Data from piping below spring source
Tecopa Hot Spring	11/11/2010	35.8789	116.23812	1,332	6**	bucket	40.76	4.306	2799	0.84	8.61	120.7	Sample from Amargosa Conservancy Trailer spring outlet
Tecopa Hot Spring	9/21/2011	35.8789	116.23812	1,332	5.1**	bucket	38.85	6.4	4100	2.74	9.18	-71.1	Sample from Amargosa Conservancy Trailer spring outlet
Thom Spring	11/11/2010	35.85661	116.22677	1,408	5	visual	24.81	1.571	1021	2.77	7.63	148.3	Data from flowing water within the vegetation
Twelvemile Spring	11/14/2010	36.02172	116.15531	2,240	no flow	visual	19.23	0.8	520	1.38	7.66	-141	Data from shallow puddle
Wild Bath Spring	11/11/2010	35.87277	116.21932	1,424	1.7	bucket	29.88	1.642	1067	4.69	7.9	165.5	Tub located off Furnace Creek Road behind Tecopa Hot Springs
Wild Bath Spring	9/21/2011	35.87277	116.21932	1,424	1.9	bucket	37.99	1.664	1083	5.59	7.83	-2.2	Tub located off Furnace Creek Road behind Tecopa Hot Springs
China Ranch Cyn Spring 1	1/13/2011	35.80335	116.14099	1,770	10	visual	13.94	1.215	789	9.34	8.5	44.5	a.k.a. Willow Canyon 1 spring
China Ranch Cyn Spring 2	1/13/2011	35.80445	116.14235	1,767	20+	visual	21.28	0.931	606	6.22	8.17	46.6	a.k.a. Willow Canyon 3 spring
Willow Spring 1	11/3/2010	35.80556	116.18284	1,420	28	bucket	23.73	1.502	958	5.72	8.26	3.4	Junction of spring water capture piping (above pond)
Willow Spring 1	4/26/2011	35.80556	116.18284	1,420	--	--	21.92	1.141	737	6.21	7.29	93.1	Junction of spring water capture piping (above pond)
Willow Spring 1	9/23/2011	35.80556	116.18284	1,420	20	bucket	--	--	--	--	--	--	Combined pond outflow and spring box
Willow Spring 2	1/18/2011	35.80098	116.19449	1,235	120-130	meter	17.98	1.91	1241	8.34	8.18	-31.1	Measurement taken at culvert
Willow Spring 2	9/23/2011	35.80098	116.19449	1,235	52.9	meter	24.16	1.028	668	8.08	8.14	-29.2	Measurement taken at culvert
Amargosa River													
Amargosa River/USGS 1	11/3/2010	35.84954	116.23081	1,325	40	USGS	12.95	0.142	121	8.12	9.2	45.3	At the Tecopa USGS flow station
Amargosa River/USGS 1	4/29/2011	35.84954	116.23081	1,325	94	USGS	--	--	--	--	--	--	At the Tecopa USGS flow station
Amargosa River/USGS 1	9/22/2011	35.84954	116.23081	1,325	--	USGS	--	--	--	--	--	--	At the Tecopa USGS flow station
Amargosa River/USGS 1	12/22/2011	35.84954	116.23081	1,325	583	USGS	--	--	--	--	--	--	At the Tecopa USGS flow station
Amargosa River/USGS 2	4/28/2011	35.79042	116.20777	1,094	558	meter	18.13	3.876	2520	12.65	8.52	152	At China Ranch USGS flow station
Amargosa River/USGS 2	5/10/2011	35.79042	116.20777	1,094	656	meter	15.9	3.481	2263	11.45	8.46	189.6	At China Ranch USGS flow station
Amargosa River/USGS 2	9/20/2011	35.79042	116.20777	1,094	--	USGS	23.05	3.658	2378	10.22	8.53	-33.4	At China Ranch USGS flow station
Amargosa River/USGS 2	12/22/2011	35.79042	116.20777	1,094	943	USGS	--	--	--	--	--	--	At China Ranch USGS flow station
Willow Creek	4/29/2011	35.78757	116.20039	1,107	42.9	bucket	20,75	1.474	954	9.4	8.42	190.6	Above confluence with Amargosa River
Willow Creek	12/22/2011	35.78757	116.20039	1,107	dry	bucket	--	--	--	--	--	--	Above confluence with Amargosa River
Amargosa River Confluence	4/29/2011	35.785	116.2023	1,053	662	meter	20.23	3.88	2523	9.25	8.64	205	Confluence with Willow Creek
Amargosa River Confluence	9/22/2011	35.785	116.2023	1,053	332	meter	19.24	4.226	2748	9.5	8.48	-7.2	Confluence with Willow Creek
Amargosa River Confluence	12/22/2011	35.785	116.2023	1,053	463	meter	3.77	5.657	3677	11.7	8.38	63.6	Confluence with Willow Creek
Amargosa River 3	11/16/2010	35.74637	116.22219	846	477	meter	19.08	4.015	2610	10.89	8.79	172.1	At Sperry Wash
Amargosa River 3	4/29/2011	35.74637	116.22219	846	462	meter	19.67	4.225	2745	10.08	8.6	202.3	At Sperry Wash
Amargosa River 3	5/5/2011	35.74637	116.22219	846	271	meter	19.4	4.198	2728	10.81	8.64	190.4	At Sperry Wash
Amargosa River 3	9/20/2011	35.74637	116.22219	846	158	meter	26.58	4.429	2879	10.18	8.91	-11.8	At Sperry Wash
Amargosa River 3	9/23/2011	35.74637	116.22219	846	119	meter	17	4.321	2809	11.03	8.6	-10.5	At Sperry Wash
Amargosa River 3	12/21/2011	35.74637	116.22219	846	389	meter	9.33	5.179	3366	11.3	8.6	130.7	At Sperry Wash
Amargosa River 4	4/29/2011	35.69609	116.25082	649	70	meter	15.67	4.472	2904	11.88	8.93	206.3	At crossing of Dumont Dunes Road
Amargosa River 4	5/5/2011	35.69609	116.25082	649	dry	meter	--	--	--	--	--	--	At crossing of Dumont Dunes Road
Amargosa River 4	9/23/2011	35.69609	116.25082	649	dry	meter	--	--	--	--	--	--	At crossing of Dumont Dunes Road

Table 2-1
Field Reconnaissance Data Summary
Amargosa Basin
California/Nevada

Name	Date of Visit	Latitude	Longitude	Elevation (ft amsl)	Flow (gpm)	Flow Measurement Method*	Temp. (deg C)	Spec. Cond. (mS/cm-deg C)	TDS (mg/L)	DO (mg/L)	pH	ORP (mV)	Notes
Amargosa River 4	12/21/2011	35.69609	116.25082	649	136	meter	3.79	4.727	3073	12.35	8.6	214.1	At crossing of Dumont Dunes Road
Amargosa River 2	11/16/2010	35.66418	116.29722	443	256	meter	21.4	4.295	2793	8.64	8.89	126.7	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	4/29/2011	35.66418	116.29722	443	dry	meter	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	5/5/2011	35.66418	116.29722	443	dry	meter	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	9/23/2011	35.66418	116.29722	443	dry	meter	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	12/21/2011	35.66418	116.29722	443	dry	meter	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Wells					**Depth to Water (ft from top of casing)**								
Cynthia's Well	1/16/2011	35.8461	116.20478	1,447	38.87	dtw meter	20.61	0.898	584	7.1	8.5	110.4	Located in Tecopa Heights
Cynthia's Well	5/12/2011	35.8461	116.20478	1,447	40.51	dtw meter	--	--	--	--	--	--	Located in Tecopa Heights
Cynthia's Well	9/23/2011	35.8461	116.20478	1,447	42.75	dtw meter	--	--	--	--	--	--	Located in Tecopa Heights
Eagle Mountain Well	11/4/2010	36.24987	116.3953	2,007	14.82	dtw meter	22.76	3.35	2177	4.25	8.85	54.4	Located west of Eagle Mountain
Eagle Mountain Well	5/1/2011	36.24987	116.3953	2,007	14.78	dtw meter	--	--	--	--	--	--	Located west of Eagle Mountain
Eagle Mountain Well	9/21/2011	36.24987	116.3953	2,007	14.77	dtw meter	--	--	--	--	--	--	Located west of Eagle Mountain
Junior's Well	1/16/2011	35.8512	116.24252	1,346	NA	NA	24.29	2.04	1326	6.63	8.33	69	Located west of Amargosa River (opposite of Tecopa)
Tecopa School Well	11/11/2010	35.84854	116.21743	1,372	NA	NA	20.06	1.372	892	4.59	7.6	161.2	Sample from spigot adjacent to well head
Tule Spring Well	11/13/2010	35.81178	116.04909	1,989	10.4	dtw meter	18.85	0.855	556	0.23	7.42	-54.8	Data from well. Strong odor of decay

Notes:
ft amsl = feet above mean sea level
gpm = gallons per minute
Temp. = temperature
deg C = degrees Celcius
mS/cm-deg C = milliSiemans per centimeter degrees Celcius
Spec. Cond. = specific conductivity
TDS = total dissolved solids
mg/L = milligrams per liter
DO = dissolved oxygen
ORP = oxidation-reduction potential
mV = millivolts

*Flow Measurement Method = spring and river flow were measured either directly with a solid state meter (meter), indirectly using time to fill a 5-gallon bucket (bucket), or using visual estimation techniques (visual).

Table 3-1
Mean Annual Flow
Amargosa River
California/Nevada

Year	**Discharge** (cfs)				
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**
1962	ND	1.04	ND	ND	ND
1963	ND	2.54	ND	ND	ND
1964	ND	0.786	ND	ND	0.011
1965	ND	1.03	ND	ND	0.019
1966	ND	7.67	ND	ND	0.000
1967	ND	0.736	ND	ND	0.776
1968	ND	1.68	ND	ND	0.249
1969	ND	9.19	ND	ND	ND
1970	ND	1.36	ND	ND	ND
1971	ND	0.648	ND	ND	ND
1972	ND	0.626	ND	ND	ND
1973	ND	ND	ND	ND	ND
1974	ND	0.596	ND	ND	ND
1975	ND	0.722	ND	ND	ND
1976	ND	9.93	ND	ND	ND
1977	ND	8.80	ND	ND	ND
1978	ND	8.59	ND	ND	ND
1979	ND	0.567	ND	ND	ND
1980	ND	4.86	ND	ND	ND
1981	ND	1.06	ND	ND	ND
1982	ND	0.948	ND	ND	ND
1983	ND	14.9	ND	ND	ND
1984	ND	ND	ND	ND	ND
1985	ND	ND	ND	ND	ND
1986	ND	ND	ND	ND	ND
1987	ND	ND	ND	ND	ND
1988	ND	ND	ND	ND	ND
1989	ND	ND	ND	ND	ND
1990	ND	ND	ND	ND	ND
1991	ND	ND	ND	ND	ND
1992	ND	3.38	ND	0.046	ND
1993	ND	11.70	ND	0.095	ND
1994	ND	0.222	0.014	0.000	ND
1995	ND	6.36	0.220	1.72	ND
1996	ND	ND	ND	ND	ND
1997	ND	ND	ND	ND	ND
1998	ND	ND	ND	ND	ND
1999	ND	ND	ND	ND	ND
2000	1.82	0.726	ND	ND	ND
2001	1.14	0.864	ND	ND	ND
2002	ND	0.724	ND	ND	ND
2003	ND	5.23	ND	ND	ND
2004	ND	1.26	ND	ND	ND
2005	ND	11.1	ND	ND	ND

Table 3-1
Mean Annual Flow
Amargosa River
California/Nevada

Year	Discharge (cfs)				
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**
2006	ND	0.629	ND	ND	ND
2007	ND	4.89	ND	ND	ND
2008	ND	0.512	ND	ND	ND
2009	ND	0.531	ND	ND	ND
2010	ND	1.52	ND	ND	ND
2011	ND	ND	ND	ND	ND

Notes:

Station 1 = USGS 10251375 Amargosa River at Dumont Dunes near Death Valley, San Bernardino County, California (Latitude 35º41'45", Longitude 116º15'02" NAD27).

Station 2 = USGS 10251300 Amargosa River at Tecopa, Inyo County, California (Latitude 35º50'45", Longitude 116º13'45" NAD27).

Station 3 = USGS 10251259 Amargosa River at Hwy 127 near Nevada State Line, Inyo County, California (Latitude 36º23'12", Longitude 116º25'22" NAD27).

Station 4 = USGS 10251218 Amargosa River at Hwy 95 below Beatty, Nevada, Nye County, Nevada (Latitude 36º52'52", Longitude 116º45'04" NAD27).

Station 5 = USGS 10251220 Amargosa River near Beatty, Nevada, Nye County, Nevada (Latitude 36º52'01.76", Longitude 116º45'37.53" NAD83).

ND = No Data

Complete Annual Data Sets Only.

Table 3-2
Fourth Quarter 2010 Groundwater Level Data
Amargosa Basin
Nevada

Common Site ID	Latitude	Longitude	X Coord (meters)	Y Coord (meters)	LS Altitude (ft asl)	Date	GWE
CS1	36.32884225	-116.3752152	556076	4020604	2047	10/22/2010	2043.82
CS2	36.32865345	-116.3718742	556376	4020585	2054	10/22/2010	2050.2
CS3	36.32847357	-116.3685332	556676	4020567	2064	10/22/2010	2062.39
CS4	36.32831163	-116.365192	556976	4020551	2080	10/22/2010	2077.81
CS5	36.32799337	-116.3596127	557477	4020519	2073	10/22/2010	2070.32
CS6	36.33619912	-116.3633341	557137	4021427	2064	10/22/2010	2061.77
CS7	36.33353493	-116.3641468	557066	4021131	2080	10/22/2010	2078.26
CS8	36.33090679	-116.3649593	556995	4020839	2080	10/22/2010	2077.95
CS9	36.32439924	-116.3669395	556822	4020116	2060	10/22/2010	2057.98
CS10	36.32178911	-116.3677516	556751	4019826	2053	10/22/2010	2051.11
CS11	36.31940381	-116.3684615	556689	4019561	2054	10/22/2010	2051.97
DVJ-01	36.3031334	-116.4550483	548926.77	4017708.991	2161.6	12/15/2010	2050.46
DVJ-02	36.30310288	-116.4550122	548930.031	4017705.624	2161.76	12/15/2010	2051.8
USGS NA-9 Shallow Well	36.42523214	-116.4633796	548103.553	4031248.349	2190.9	10/14/2010	2158.45
Ash-B Shallow Well	36.72554155	-116.6757605	528952.959	4064475.496	2677	10/26/2010	2362.38
LWS-A Shallow Well	36.55467566	-116.453104	548943.177	4045612.071	2396	10/27/2010	2238.63
Amargosa Desert 4b	36.5750583	-116.3937556	554240.226	4047904.889	2478	11/9/2010	2347.46
GF-3 (AM-12)	36.4469111	-116.3826583	555324.235	4033696.349	2196.97	10/14/2010	2144.98
MSH-C Shallow Well	36.50217478	-116.2708739	565295.774	4039896.466	2330	10/27/2010	2332.68
Amargosa Flat Playa Well	36.49328887	-116.2592067	566348.21	4038918.756	2322	10/27/2010	2316.51
Spring Meadows 9	36.40945608	-116.3040123	562402.311	4029589.641	2248	10/27/2010	2227.72
Spring Meadows 11	36.4223729	-116.269928	565447.521	4031045.015	2442	10/27/2010	2348.57
Eagle Mountain Well	36.24987	-116.3953	554328.035	4011832.793	2005	11/4/2010	1993.69
AV Well 5	36.45803	-116.53047	542071.705	4034855.061	2241	11/9/2010	2194.5
AV Well 4	36.45803	-116.54063	541161.323	4034850.676	2247	11/9/2010	2205.5
AV Well 3	36.45427	-116.54063	541163.31	4034433.601	2244	11/9/2010	2205.71
AV Well 2	36.4508	-116.54063	541165.144	4034048.694	2244	11/9/2010	2189.5
AV Well 6	36.45085	-116.52274	542768.289	4034062.026	2234	11/9/2010	2189
Tecopa MW-1	35.85098	-116.180732	573975.41	3967733.12		11/11/2009	1473.02
Tecopa MW-2	35.852313	-116.182703	573799.15	3967875.43		11/11/2009	1460.87
Tecopa MW-3	35.851114	-116.184192	573666.78	3967744.43		11/11/2009	1457.12
Shoshone MW-1	35.971118	-116.242438	568302.17	3981010.91		11/10/2010	1523.04
Shoshone MW-2	35.970685	-116.245729	568008.86	3980956.3		11/10/2010	1520.8
Shoshone MW-3	35.971835	-116.244704	568097.83	3981086.48		11/10/2010	1522.58
Aeropark	36.64005822	-116.409741	552845.735	4054909.717	2639.18	10/26/2010	2311.3
AVUSP	36.52600608	-116.4204334	551966.153	4042252.651	2343.79	10/21/2010	2197.65
Doloris	36.40966079	-116.4205307	552034.918	4029347.194	2168.68	10/21/2010	2081.93

Table 3-2
Fourth Quarter 2010 Groundwater Level Data
Amargosa Basin
Nevada

Common Site ID	**Latitude**	**Longitude**	**X Coord** (meters)	**Y Coord** (meters)	**LS Altitude** (ft asl)	**Date**	GWE
Longstreet 1	36.41225108	-116.4246876	551660.502	4029632.287	2157.1	10/21/2010	2085.67
Farm1b	36.56821385	-116.5870253	537031.676	4046857.709	2372.09	10/21/2010	2251.52
Gauging Station	36.59042918	-116.5918644	536588.235	4049320.075	2396.11	10/21/2010	2256.36
Anake	36.5540071	-116.5924042	536557.046	4045279.802	2351.97	10/21/2010	2249.01
Sedgewick	36.56075912	-116.5099748	543930.313	4046063.076	2376.27	10/21/2010	2237.75
Power04	36.55623586	-116.4962526	545160.896	4045567.669	2373.63	10/21/2010	2229.09
Longstreet 2	36.41284059	-116.4246258	551665.655	4029697.709	2157.62	10/21/2010	2085.04
Sec 10	36.56922654	-116.4364584	550503.444	4047038.334	2440.85	10/21/2010	2256.04
Crystal Fire	36.48784915	-116.1698532	574436.029	4038184.346	2386.92	10/21/2010	2355.72
Hwy 127 MM21 #1	36.06039752	-116.2973999	563355.156	3990680.131	1736.53	10/21/2010	1648.68
Hwy 127 MM21 #2	36.06055078	-116.2977546	563323.081	3990696.899	1736.89	10/21/2010	1647.99
Last Chance Well	36.35319111	-116.1168744	579318.057	4023289.609	3085.41	10/21/2010	2528.36
CalTrans DVJ	36.30611627	-116.422105	551962.316	4017861.047	2052.36	10/21/2010	2042.51
Eagle Mtn North	36.21851085	-116.3809177	555722.055	4008166.708	1997.39	10/21/2010	1977.53
Eagle Mtn South	36.21820112	-116.3806712	555744.432	4008132.495	1996.95	10/21/2010	1977.55
Ash Meadows Gauging Station	36.33963863	-116.2249965	569628.774	4021703.076	2430.99	10/21/2010	2347.92
AVSTP	36.64482629	-116.3850987	555045.217	4055452.449	2674.4	10/21/2010	2370.84
Pit Wall (USGS GA-08E)	36.3133229	-116.3273389	560464.762	4018715.357	2226.34	10/21/2010	2119.9
HWWT Gravel Pit	36.56906052	-116.6149673	534531.074	4046941.286	2367.5	10/21/2010	2250.44
Rubys Store Well	36.49306697	-116.4228261	551773.832	4038597.634	2276.23	10/21/2010	2188.95
East IMV PPT10/21/09	36.46823278	-116.3791559	555702.803	4035867.239	2184.55	10/21/2010	2170.56

Table 3-3
Summary of Pumping
Amargosa Desert
Nevada

Year	**Pumping** (AFY)					
	Irrigation	**Mining**	**Commercial**	**Quasi Municipal & Domestic**	**Other**	**Total Pumping**
1983	9,105	125	20	250	NA	**9,500**
1985	8,472	950	20	230	NA	**9,672**
1986	6,553	550	10	125	NA	**7,238**
1987	5,700	302	10	125	NA	**6,137**
1988	2,978	996	10	125	NA	**4,109**
1989	1,566	2,220	10	125	NA	**3,921**
1990	4,953	2,720	10	125	NA	**7,807**
1991	4,942	1,070	10	100	NA	**6,122**
1992	5,761	2,293	10	100	NA	**8,164**
1993	8,709	2,481	10	100	NA	**11,300**
1994	9,977	2,508	10	100	NA	**12,595**
1995	12,354	2,571	10	100	NA	**15,035**
1996	11,043	2,285	205	50	30	**13,613**
1997	10,454	2,506	576	366	0	**13,902**
1998	12,040	2,417	537	382	0	**15,376**
1999	10,835	2,389	593	364	0	**14,181**
2000	9,711	1,366	1,057	378	10	**12,522**
2001	9,407	1,187	1,067	396	10	**12,067**
2002	9,576	1,302	1,128	415	0	**12,421**
2003	10,471	1,356	1,324	437	0	**13,588**
2004	10,603	1,169	1,319	453	0	**13,544**
2005	10,764	438	1,332	466	4	**13,004**
2006	13,124	527	1,844	491	2	**15,988**
2007	14,059	377	1,793	505	2	**16,736**
2008	12,356	1,108	3,984	517	2	**17,967**
2009	11,477	510	3,905	487	1	**16,380**
2010	9,898	313	4,683	498	1	**15,393**

APPENDIX A

CATALOG OF SPRINGS – MIDDLE AMARGOSA RIVER BASIN

APPENDIX B

CALIFORNIA WATER RIGHTS SUMMARY

"A MULTIPLE ISOTOPIC INVESTIGATION OF THE AMARGOSA RIVER: INYO-SAN BERNARDINO COUNTIES, CA AND NYE COUNTY, NV"

APPENDIX C	**NEVADA WATER RIGHTS SUMMARY**
APPENDIX D	**GROUNDWATER LEVEL DATA AND REPORTS**
APPENDIX E	**GROUNDWATER QUALITY DATA AND REPORTS**
APPENDIX F	**KEY REPORTS**

(PROVIDED ON ENCLOSED CD)