PARTNER
Engineering and Science, Inc.

2020 AMARGOSA STATE OF THE BASIN REPORT

Amargosa River Basin
Inyo and San Bernardino Counties, California

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Prepared For:
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TABLE OF CONTENTS

1.0 INTRODUCTION.. 1

1.1 Current Scope of Work..2

1.1.2 Discharge, Groundwater Level and Seepage Run Monitoring 3

1.1.3**.** Water Chemistry Data Collection..3

1.1.4. Data Assessment and Reporting..3

1.2 Location and Physiographic Setting 4

1.3 Climate..5

1.4 Land Use 5

1.4.1 Water Rights 6

1.4.1.1 Devil's Hole..6

1.5 Groundwater Management..7

1.6 Sources of Information..8

2.0 CURRENT FIELD AND LABORATORY METHODS.. 9

2.1 Spring Discharge, Groundwater Level and River Surface Flow Monitoring..9

2.2 Spring Discharge Monitoring 10

2.3 Groundwater Level Monitoring..11

2.4 Amargosa River Flow Monitoring 12

2.5 Water Quality..13

2.6 Previous Isotope Investigations..14

2.7 Field Methods..16

2.8 Results - Geochemistry..17

3.0 AMARGOSA WILD AND SCENIC RIVER – CONCEPTUAL MODEL 20

3.1 Regional Setting and Geologic Conditions 20

3.2.1 Hydrogeologic Units..20

3.2.2 Valley fill..21

3.2.3 Volcanic Rocks..21

3.2.4 Bedrock Units 22

3.3 Geologic Structure 22

3.4 Surface Water..24

3.5 Groundwater System..26

3.5.1 Aquifer Characteristics..27

3.5.2 Regional Groundwater Inflow and Outflow..28

3.5.2.1 Springs 30

3.5.2.1.3 Dodge City Spring 33

3.5.2.1.5 Thom Spring..34

3.5.2.1.6 Vole Spring ... 34
3.5.2.1.7 Homestead Spring ... 35
3.5.2.1.8 Stormy Spring ... 35
3.5.2.1.9 West-side Spring ... 35
3.5.2.1.10 Christian Spring ... 35
3.5.2.1.11 Amargosa Canyon Springs ... 36
3.5.2.1.12 Willow Creek ... 36
3.6 Groundwater Discussion – Water Levels, Changes in Storage, Water Level Changes – Decreases in Spring Flow at Chappo/12 Mile/Resting Spring ... 38
3.6.1 Groundwater Trends in Monitoring Wells ... 40
3.7 Future Water Use – (within California and Nevada) ... 42
4 RECOMMENDATIONS ... 44
4.1 Water Management and SGMA ... 45
4.1.1 Monitoring – Practical Alternatives for Monitoring River System in Changing Channel ... 46
4.1.2 Consideration by Land Managers of AWSR In Future Development Scenarios ... 47
4.1.3 Tamarisk ... 47
4.2 Science ... 48
4.2.1 Monitoring / River Monitoring Alternative ... 51
4.2.2 Modeling / River Management Tool ... 52
4.2.3 Mitigation Tied to Monitoring ... 52
5.0 SIGNATURES OF PARTICIPATING PROFESSIONALS ... 53
6.0 REFERENCES ... 54

ATTACHMENTS

Tables: 1. Hydrologic Data Summary
2. Amargosa River Flow Summary

Figures: 1. Location Map
2. AWSR Location
3. Monitoring Well Locations
4. Regional Geologic Map
5. AWSR Area Geology
6. Regional Flow Paths
7. Geologic Map

8. Geologic Map – Legend
9. Geologic Map – Legend
10. USGS Flow Paths
11. Groundwater Surface
12. Amargosa Valley Pumping
13. Pahrump Valley Pumping
14. Amargosa River Canyon
15. Borax Spring
16. Borehole Spring
17. Dodge City Spring
18. Thom Spring
19. Vole Spring
20. Homestead Spring
21. Stormy Spring
22. Westside Spring
23. Christian Spring
24. Amargosa Canyon Spring #4
25. Willow Creek #1
26. Willow Creek #2

LIST OF APPENDIXES

A. Well Logs and Permits
B. Laboratory Analytical Reports
C. References
D. Isotope Report
E. Amargosa River Cross-Sections
F. Spring Summaries
G. AWSR Spring and Monitoring Well Hydrographs

1.0 INTRODUCTION

This 2019 State of the Basin Report (SOBR) was prepared by Partner Engineering and Science, Inc. (Partner) on behalf of the Amargosa Conservancy (AC) as part of a much larger effort that is being conducted between AC, The Nature Conservancy (TNC), U.S. Bureau of Land Management (BLM), the U.S. Geological Survey (USGS) and Nye and Inyo Counties. This report focuses on conditions in the Middle Amargosa Basin (California Department of Water Resources groundwater basin #6-20).

This report and field activities and analysis inclusive of monitoring since Fall 2016 and new monitoring well construction and monitoring, has been conducted under a grant from the California Department of Water Resources (DWR) under the Integrated Regional Water Management Planning effort under Proposition 84. The goals of the overall project are to improve the understanding of the water that sustains the Amargosa River and desert ecosystems that flourish along the river, and its adjoining springs, and to provide 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 our understanding of the groundwater flow paths to the Amargosa River and surrounding springs, and to continue to develop baseline spring, river flow and groundwater-level monitoring, and to 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 Amargosa River. It is essential that hydrogeologic characterization of the California portion of the basin take place 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 development occur, or if occurring, accelerate.

With the exception of domestic wells in the Tecopa Heights area, the Shoshone-Tecopa area derives its domestic and municipal water supplies from springs. Shoshone Spring is the source of water for the village of Shoshone. Tecopa Hot Springs provides a recreational opportunity that is the economic hub of Tecopa. China Ranch date farm obtains its irrigation water from spring-fed Willow Creek.

Many of the springs that feed the Amargosa River are relatively small springs that individually are not significant components to the overall area water budget. Additionally, other small springs and watering holes are present away from the Amargosa River. Nonetheless, these springs, regardless of size and/or location, are important ecological resources. This SOBR provides up to date hydrologic information and a current real-time snapshot of water resource conditions in the Middle Amargosa Basin area. As mentioned above, springs and watering holes such as those identified in this SOBR are frequently overlooked in hydrologic investigations since their discharges are frequently inconsequential to the overall water budget of the area being studied. This is unfortunate as these sensitive receptors are critically important resources for vegetation, and wildlife (both resident and migratory). It is essential that baseline hydrologic characterization of the region take place for future land and water resource management to have a firm basis.

Prior to the initial reconnaissance work conducted by Source Group, Inc. (SGI) during 2010-2011 (SGI, 2011), regional hydrogeologic investigations in the Middle Amargosa Basin had been virtually non-existent. The objectives of the current project described in this report were to:

- Conduct new 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 Spring;
- Continue to develop an understanding of Amargosa River conditions in the Middle Amargosa Basin;
- Describe the results of groundwater-level monitoring and evaluate future monitoring locations; and,
- Continue to enhance the conceptual model of the Middle Amargosa Basin.

1.1 Current Scope of Work

The current scope of work included the following tasks:

- Comprehensive monitoring of springs, groundwater levels and river flow;

- Installation of five monitoring wells and outfitting those wells with groundwater-level monitoring devices; and,
- Data analysis and preparation of this SOBR.

1.1.2 Discharge, Groundwater Level and Seepage Run Monitoring

Flow discharge and groundwater elevation measurements have been collected on a periodic basis from a select group of springs and wells within the Middle Amargosa Basin area since November 2010 as part of studies conducted by AC and TNC. During this timeframe, the USGS has periodically conducted seepage run studies on the Amargosa River from between Shoshone and Tecopa, California to the bottom of the Amargosa River Canyon. The results of USGS seepage studies have been summarized (Belcher, 2019). Basic water quality data (e.g. temperature, pH, conductivity) were also collected at all discharge, elevation and seepage run monitoring points.

1.1.3. Water Chemistry Data Collection

Water samples from the five new monitoring wells and from one historic artesian well were collected and analyzed for a specific suite of constituents. These water samples were analyzed for stable isotopes, tritium and radiocarbon. The water samples from the five new monitoring wells were also analyzed for general chemistry and trace metals. Isotope analyses were conducted by Isotech Laboratories of Champaign, Illinois. General chemistry and trace metals analyses were conducted by Alpha Analytical Laboratories, Inc., a California-certified laboratory. M.L. Davisson & Associates was retained to provide high-level expert analysis and interpretation.

1.1.4. Data Assessment and Reporting

This task included the time required to analyze the data obtained from the wells, along with the newly collected monitoring data and other sources to be compiled in this updated SOBR. This included updating and expanding the existing “catalog of springs” provided in Appendix F.

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). 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 northeast 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 approximately 900 square miles.

The Middle Amargosa Valley Groundwater Basin (Groundwater Basin #6-20 as designated by DWR) 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 ft msl near Salt Creek in the southern portion of the basin to about 2,300 ft msl at the California-Nevada state line near Death Valley Junction. The basin is bounded by consolidated rocks of the Resting Spring 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 up to 7,335 ft msl at Kingston Peak in the Kingston Range (to the southeast) and up to 6,275 ft msl at Pyramid Peak, the high point of the Funeral Range to the northwest. The Middle Amargosa Valley Groundwater Basin covers approximately 609 square miles. Although considered a separate groundwater basin, California Valley Groundwater Basin

(Groundwater Basin #6-079), and the Lower and Upper Kingston Wash Groundwater Basins adjoin (Groundwater Basins #6-021 and #6-022, respectively) the Middle Amargosa Valley Groundwater Basin on the east.

The Death Valley Groundwater Basin (Groundwater Basin #6-18 as designated by DWR) 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 Basin range from -282 ft msl at Badwater, to 11,049 ft msl at Telescope Peak, the high point 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 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 (°F) while winter temperatures can fall below freezing. The average annual precipitation at Shoshone, California (at an elevation of 1,546 ft msl) is 4.79 inches based on a record from 1972 to 2011 (Calclim, 2019). The average maximum high temperature is 83.2 °F and average minimum is 58.8 °F. Mean monthly high temperatures range from 58.8 °F in December to 108.7 °F in July. Mean monthly low temperatures in Shoshone range from 38.0 °F in December to 78.3 °F in July. Temperatures decrease, and precipitation increases in the surrounding mountains with increasing elevation.

1.4 Land Use

The principal land uses (not including open space and wild lands) in the project area are agricultural, recreational, wildlife, livestock, and domestic/municipal uses. With increasing regional development (including solar development and indications of future cannabis growing), use is expected to increase in the future. Agricultural and domestic water is generally supplied with groundwater from springs or private wells. Water for the town of Shoshone, California is supplied by Shoshone Spring. The town of Beatty, Nevada to the north derives its water from groundwater wells, however some residents rely solely on spring water. Sewage is generally treated by individual septic systems with the exceptions of the communities of Beatty, Nevada, and Shoshone and Tecopa (both in California) where sewage systems are present serving some areas. Agricultural land use is crops such as alfalfa (Nevada) and to a much lesser extent dates (California). Recreational uses include bathing at Tecopa Hot Springs.

1.4.1 Water Rights

Water right summaries for California and Nevada are provided in Appendices B and C, respectively. Additional discussion regarding permitted rights, water usage, and estimated recharge for the Amargosa Basin are provided in Section 3.0 In California, there has been no change in the status of water rights in the Middle Amargosa Basin since 2011.
Changes in Nevada water rights for the Amargosa Desert (Nevada groundwater basin #230) during the past five years (since 2014) were a net decrease of approximately 571 acre-feet per year (afy) in annual duty (underground). Nevada water rights (underground) for Pahrump Valley (Nevada hydrographic unit #162) are approximately 58,972 afy.

1.4.1.1 Devil's Hole

In 2008, the Nevada State Engineer issued Order 1197 concerning applications to appropriate additional groundwater from the Devil's Hole area. This order stated that:

"…with the following exceptions, any applications to appropriate additional underground water and any application to change the point of diversion of an existing ground-water right to a point of diversion closer to Devil's Hole, described as being with a 25-mile radius from Devil's Hole within the Amargosa Desert Hydrographic Basin, will be denied:

- *Any application within the described area that seeks to change an existing point of diversion closer to Devil's Hole but remains within its existing place of use and is no more than ½ mile from its original point of diversion;*
- *Those applications filed which seek to appropriate 2.0 acre-feet per year or less, may be considered and shall be processed according to Nevada Revised Statutes (NRS) 533 and 534;*
- *For projects that require change of multiple existing rights the State Engineer may compare the net impact to Devil's Hole of the proposed changes to the impacts to Devil's Hole of the base rights. If the net impact of the proposed changes is the same or less than its base right impacts, as determined by the State Engineer, such change applications may be*

considered and shall be processed subject to NRS 533 and 534. In no such case shall new points of diversion be allowed within ten (10) miles of Devil's Hole;

- *Those applications for environmental permits filed pursuant to NRS 533.437 and 533.4377, inclusive; and,*
- *Those applications filed pursuant to NRS 533.571."*

For point of reference, NRS 533 and 534 are the chapters of the Nevada water law that pertain to adjudication of vested water rights / appropriation of public water and underground water and wells, respectively. Environmental permits referenced in NRS 533.437 and 533.4377 are temporary permits for wells used for avoidance of groundwater contamination (e.g. remediation wells).

1.5 Groundwater Management

Groundwater quality issues in the California portion of the basin are regulated by the California State Water Resources Control Board – Lahontan Region (CRWQCB-Lahontan). 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 Waste Management 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 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 Resource Plan (Buqo, 2004) provides guidance for ensuring adequate supplies of water remain available for 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 (e.g. Saratoga Spring) throughout the park. Likewise, the BLM oversees water-related issues on BLM-managed 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 Partner and used in this report were from the archives and reports by the USGS, NDWR, CRWQCB-Lahontan Region, 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 Partner and others.

2.0 CURRENT FIELD AND LABORATORY METHODS

The field activities performed during this project were designed following the previous 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 more detailed hydrogeologic investigations. Additionally, methodologies for describing spring conditions developed for other areas (Sada & Pohlmann, 2002, and Sky Island Alliance, 2012) formed the basis of field descriptions of springs. The field work for this more detailed hydrogeologic investigation was conducted during May 2014 and included the collection of water chemistry samples at four springs and one well, flow volumes, water levels, and ongoing field 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 and sustainable groundwater monitoring effort that will be protective of the environmental and cultural resources of the basin. The locations of key points monitored or reconnoitered during along the AWSR for this work are shown on Figure 2.

2.1 Spring Discharge, Groundwater Level and River Surface Flow Monitoring

During the past ten years, spring flow discharge and groundwater elevation data have been gathered from springs and wells in the Middle Amargosa River Basin. Additionally, until 2017, seepage run monitoring (i.e. the measurement of flow at several distinct locations) was conducted by AZI 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 as measured during previous monitoring events. Seepage runs were subsequently discontinued as due to changes in channel geometry resulting from seasonal flooding, flow measurement locations, and character of flow (e.g. defined single channel vs. braided channel) was resulting in temporally non-comparable flow data. Field water quality measurements have continued to be measured at the Amargosa River below the confluence with Willow Creek, and at the Dumont Road crossing (and periodically at the Highway 127 crossing). 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 ongoing 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.

2.2 Spring Discharge Monitoring

For the current monitoring event, springs not previously visited since the initial baseline work in 2011 were revisited to evaluate changes over the past three years. Previously, springs designated for ongoing quantifiable discharge measurement included Amargosa Canyon Spring 1, Amargosa Canyon Spring 4, Borax Spring, Borehole Spring, Crystal Spring, Horse Thief Spring, Tecopa Hot Spring (as measured near the Nature Conservancy trailer), Twelvemile Spring, and Willow Spring. Data from other springs were collected as practical, including Resting Spring, Shoshone Spring, Thom Spring and Five Springs. These springs were chosen for long-term monitoring as they were the springs from which reliable water samples could be obtained as opposed to the remaining springs where conditions were such that sampling was not practicable at the time of the initial work (SGI, 2011). Since that time, additional springs have been monitored on a regular basis including Dodge City Spring and Tule Spring. Kingston Spring, several other spring vents in the Shoshone Spring complex, Chappo Spring and Vole Spring have been monitored periodically.

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. At other locations, such as at 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 Borehole Spring. Due to changes in Borehole Spring flow measurements (by USGS) and the use of bucket/stopwatch method at Amargosa Canyon Spring #1, the flow meter method is no longer used on springs in this area. All of the spring flow measurements recorded starting with the initial spring survey (including visual estimations of flow) are summarized on Table 1. Spring flow measurements are also found in the spring summaries (Appendix F).

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 of the flow from a spring would be fully captured and channeled into a pipe or flume, allowing for much greater accuracy in measurement of flow. This is the case for Borax Spring and Tecopa Hot Spring at the Nature 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.

2.3 Groundwater Level Monitoring

The wells designated for ongoing groundwater elevation measurement include those wells previously installed as part of the Amargosa Hydrologic Survey (wells ARHS-01 through ARHS-04); and the newly-installed groundwater monitoring wells (ARHS-05 through ARHS-10, absent ARHS-07 which was not installed. BLM NEPA documents, well logs and permits for the new monitoring wells conducted under the current scope are provided in Appendix A. Additionally, the Eagle

Mountain Well near the California/Nevada state line and Cynthia's Well in Tecopa have periodically been measured. None of these wells have a surveyed mark for ground level, thus surface elevation has been estimated using USGS topographic 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 1. The nine ARHS wells have been outfitted with In-Situ transducer / data-logger set-ups and collect groundwater level measurements at one-hour intervals (ARHS-01 through ARHS-04) and 12-hour intervals (ARHS-05, ARHS-06, ARHS-08, ARHS-09, and ARHS-10). The results of the groundwater level monitoring are discussed later in this report. ARHS-07 was not constructed due to flooded conditions at the time of drilling and the potential for damage to saltgrass meadow that the drilling equipment would cause.

2.4 Amargosa River Flow Monitoring

River flow was formerly 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 was the USGS gauging station located in the town of Tecopa, California (station no. 10251300) and the second is located near China Ranch, just above the 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.

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 Amargosa 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.

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. This was also the case during the May 2014 monitoring event. 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 monitoring event 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.

These data, along with consistent later observations by long-time residents, provides strong indications that flow in the Amargosa River is generally 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 evapotranspiration 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.

2.5 Water Quality

As a continuing step to determine relationships between waters found in the Middle Amargosa River Basin, water samples were collected during the current work (under the DWR grant) from a select group of spring and wells, including the following:

- Radiocarbon at wells ARHS-05, ARHS-06, ARHS-08, ARHS-09, ARHS-10 and at Crystal Spring, Amargosa Canyon Spring #3, Twelvemile Spring, Scofield Spring, and at Thom Spring (spring samples under separate funder); and,

- Stable Isotopes at Wells ARHS-01, ARHS-03, ARHS-05, ARHS-06, ARHS-08, ARHS-09, ARHS-10 and at all springs where surface water is present and previously not sampled for stable isotopes.

The locations of the monitoring wells are presented on Figure 3.

2.6 Previous Isotope Investigations

A number of previous reports have been published on groundwater geochemistry and isotope abundances in southern Nevada and southeastern California. Notable reports relevant to the Amargosa River area include those of Winograd and Thordarson (1975), Thomas et al. (1996), Davisson et al. (1999), and Larsen et al. (2001). Additional studies that include directly related data can be found in Thomas et al. (2003a) and Hurst (2012).

Winograd and Thordarson (1975) developed one of the early frameworks for groundwater flow in southern Nevada related to the Nevada Test Site, and that included extensive discussion of the Ash Meadows springs discharge area. Based on earlier work, they also summarized types of groundwater hydrochemistry that showed calcium magnesium bicarbonate groundwater associated with both the carbonate rock of the Spring Mts. and adjacent Pahrump Valley. In contrast, sodium potassium bicarbonate groundwater drains the largely volcanic rock areas south of the Nevada Test Site (e.g., Oasis Valley and Jackass Flats). Ash Meadows spring discharge consequently has calcium magnesium sodium bicarbonate water that Winograd and Thordarson inferred as a mixture of recharge of the two latter water types.

Thomas et al. (1996) also compiled and summarized groundwater chemistry types as well as isotope abundances in areas that included groundwater throughout southern Nevada and southeastern California with a focus on the regional carbonate aquifers. They concluded from isotope results that the calcium magnesium sodium bicarbonate water discharging from Ash Meadows springs comprised 60 percent Spring Mountains recharge and 40 percent from Pahranagat Valley to the east. They also argue from radiocarbon data that groundwater velocities ranged approximately from 10 to 144 feet per year.

Davisson et al. (1999) showed that radiocarbon was not a reliable method for age dating groundwater in the regional carbonate aquifer due to continual isotope exchange reactions combined with mixing of local recharge sources during long-range transport. They further showed that stable isotopes of oxygen-18 and deuterium measured in southern Nevada groundwater had been previously evaporated during its original recharge as melted snow in central Nevada (Rose et al., 1999). By applying a methodology that removed the effects of evaporation on oxygen-18 and deuterium they showed a systematic decrease in their abundances with increasing latitude and local elevation throughout southern Nevada, a result inconsistent with previous studies purporting Pleistocene age groundwater recharge during the last glacial period (Claassen et al., 1986).

Larsen et al. (2001) studied the water quality and stable isotope abundances of groundwater in the Tecopa and Death Valley regions of the Amargosa River and related them to groundwater of southern Nevada to delineate potential recharge sources. They recognized three water types comprising a Spring Mountains recharge source, a deep regional groundwater derived from fracture flow of southern Nevada, and groundwater derived from basin-filled groundwater of the Amargosa Desert.

Additional studies providing a greater variety of isotope measurement types have been reported by Thomas et al. (2003a) and Hurst (2012). Thomas et al. (2003a) focused specifically on Oasis Valley and its hydraulic connection to Pahute Mesa, showing that Oasis Valley groundwater is replenished by groundwater flow through Pahute Mesa that was ultimately derived further north. The Oasis Valley groundwater ultimately replenishes the Amargosa Desert basin fill aquifers. Hurst (2012) specifically focused on tritium, oxygen-18, deuterium, strontium isotopes, and uranium isotopes in regions along the Amargosa River. He showed that spring samples are largely tritium absent, the oxygen-18 and deuterium show only limited evaporation, and that strontium and uranium isotopes show mixing along the entire length of the Amargosa River.

Lastly, one study reported by Thomas et al. (2003b) measured dissolved noble gases in the regional carbonate aquifer of southern Nevada. They showed that noble gas abundances that are typically incorporated in recharging groundwater and reflect the local recharge temperature were systematically being lost during long-range transport from Pahranagat Valley in east-central Nevada towards Ash Meadows at its terminal discharge point. They concluded this loss of dissolved gas was due to fault barriers and cavities in the regional carbonate aquifer that forces groundwater to migrate upward and encounter gas loss in air pockets. This subsequently masked the calculated recharge temperatures derived from the noble gases.

Zdon, Davisson and Love (2015) considered the entire stable isotope data record from springs and wells in the Amargosa Basin (within Nevada and California) along with geologic conceptualization to update and test the existing conceptual model of the Amargosa Basin.

2.7 Field Methods

During the current analysis, field work was conducted in accordance with the methods previously used in spring survey work on behalf of BLM (Andy Zdon & Associates, 2014). Water samples were collected directly from the source vents of the springs visited and of the newly-installed monitoring wells. Where spring vents were submerged, samples were collected by either submerging a closed sample bottle to the immediate spring vent or removing the bottle lid at the vent to allow for direct inflow discharging water; or, by use of a sampling device allowing collection of water samples at depth. At monitoring wells, water samples were collected after well development was conducted.

Water samples were collected and analyzed for stable isotopes and radiocarbon (conducted by Isotech Analytical Laboratories, Inc., in Champaign, Illinois). Laboratory analytical reports are provided in Appendix B. Samples for radiocarbon analysis were collected in 1-quart HDPE sample bottles (no preservative was used). Samples were maintained on ice and shipped to the laboratory in proper holding times (with the exception for nitrate). Samples for oxygen ($\delta^{18}O$), and deuterium (δD) were collected in 1-liter HDPE sample bottles provided by the laboratory. The $^{18}O/^{16}O$ and D/H ratios were measured as a gas using standardized mass spectrometry methods.

The $\delta^{18}O$ and δD results are reported as a normalization to Standard Mean Ocean Water (SMOW), which is an internationally recognized standard in stable isotope analysis. The normalization converted to standard δ ("del") notation following the convention:

$$\delta = \left(\frac{R}{R_{std}} - 1\right)1000$$

Where R is the isotope ratio of the sample and R_{std} is the ratio of the standard.
During site visits, field water quality parameters of temperature, pH, electrical conductivity and dissolved oxygen were measured at the sources of the springs. Field instruments were checked for calibration on a daily basis, if not at higher frequencies.

As with the samples collected for stable isotope analysis, the water samples were analyzed for radiocarbon and tritium (tritium) by Isotech. The samples were collected in

1-liter high density polyethylene (HDPE) sample bottles provided by the laboratory. Samples were shipped in a chilled cooler to Isotech where the radiocarbon analyses involved acidification of water to convert dissolved inorganic carbon (DIC) to carbon dioxide (CO2) which was then extracted, purified, and submitted for final analysis by mass spectrometry.

The $\delta^{13}C$ results are reported as a normalization to the Vienna Pee Dee Belemnite (VPDB), an internationally recognized standard in $\delta^{13}C$ analysis. The ^{14}C content of DIC is reported as a percentage of modern carbon. ^{14}C decays at a steady rate with a half-life of 5,730 years. Therefore, waters with 50% modern carbon would have an apparent age of 5,730 years, waters with 25% modern carbon would have an apparent age of 11,460 years and so on.

2.8 Results - Geochemistry

Stable isotope and other geochemical data indicate that Middle Amargosa River area groundwater appears to be a mixture of Ash Meadows, Spring Mountains and Kingston Range sources (Zdon, Davisson and Love, 2015). This paper is included within Appendix C (references) and in Appendix D. The pathways for that groundwater to reach the area probably consist of one or a combination of:

- Water that moves through carbonate rocks from the Spring Mountains to the Ash Meadows and then southward toward the Shoshone-Tecopa area;
- Water that moves through carbonate rocks beneath the northern portion of the Nopah Range into Chicago Valley, then toward the Amargosa River; and,
- Water that moves from Pahrump Valley through the low, faulted divide into California Valley then towards the River.

Most of the spring/groundwater samples have characteristics indicative of having been influenced by Spring Mountain recharge by some route. Most of the mixing is probably occurring via fractured rock at depth, and less so in the alluvium. Water quality in the springs in the Shoshone-Tecopa area likely evolves from a mixture of regional carbonate and Tertiary volcanic rock influences but acquires increased chloride and sulfate possibly from the Tecopa lake bed deposits. Additionally, regional subsurface heat flow increases groundwater temperature and contributes to increased dissolved silica, decreased bicarbonate, and possibly increased pH, with the latter resulting in the high arsenic concentrations. The source of the arsenic could be from multiple sources, but as pH increases the solubility increases to significantly high levels as presented in Appendix D.

Noble gas concentrations of the water in the Shoshone-Tecopa area (Andy Zdon & Associates, 2014) are strongly similar to those measured in the regional carbonate – Ash Meadows (of southern Nevada) groundwater noted by Thomas, et.al. (2003b). Their conclusions were that dissolved gas loss occurred during subsurface transport across faulted boundaries and compromised recharge temperature/elevation calculations. The noble gas recharge temperatures/elevation calculations for Amargosa River Valley groundwater mostly support the conclusions of Thomas, et.al. (2003b).

The ^{3}He/^{4}He ratios (Andy Zdon & Associates, 2014) for the four measured springs (Thom, Wild Bath, Tecopa and Borehole) were unusually low, indicating old groundwater ages. The values were 5 to 10 times lower than measured groundwater under the Nevada Test Site. These low ratios could be due to high influx of ^{4}He from the Earth's crust caused by deep faults. Otherwise, if the low ratio is due to steady-state accumulation from local deposits, then groundwater ages greater than 100,000 years would be required. Additionally, the helium ratios did not suggest the presence of a shallow magmatic heat source for the Tecopa Hot Springs area and indicate that the heat source is via deep circulation, probably along the faults that run through the area. The elevated temperature of the Tecopa Hot Spring water is not unusual since similar temperatures are seen at depth under the Nevada Test Site. However, at Tecopa, the warm water is driven to the surface probably by some structural control (Andy Zdon & Associates, 2014).

The radiocarbon results from groundwater samples collected from the monitoring wells indicated the following apparent groundwater ages (corrected for C13):

- ARHS-05 (Dumont Road below Amargosa Canyon) – 2,291 years;
- ARHS-06 (Davis Well – California Valley) – 16,867 years;
- ARHS-08 (Evelyn Well north of Shoshone) – 6,366 years;
- ARHS-09 (southern Stewart Valley) – 8,287 years;

- ARHS-10 (Tule Well – California Valley) – 20,379 years; and,
- Grimshaw Well (artesian well near Borehole Spring/Tecopa) – 33,212 years

The ages indicate that:

- ARHS-05 is a mixture of modern water (tritium was detected in the water sample) and older spring-fed river waters;
- ARHS-06 and ARHS-10 in California Valley are sourced in Pahrump Valley and assuming for the purposes of this report that these waters are recharged at the top of the Manse alluvial fan approximately 28 miles distant from these wells, groundwater takes approximately 16,900 years and 20,400 years to reach MW-6 and MW-10, respectively. As MW-10 is approximately three miles downgradient from MW-6, this indicates that groundwater moves at a rate of 4.5 feet per year from MW-6 toward MW-10. This low rate is consistent with the presence of fine-grained lakebed deposits as observed in the well logs for these wells. Additionally, this is indicative of groundwater moving at an average rate of approximately 9 feet per year from the Manse alluvial fan to MW-6.
- ARHS-08 is likely a mixture of water that rises from a fault that trends northward up the valley north of Shoshone, southward moving alluvial groundwater parallel to the Amargosa River and from limited recharge that may occur on Brown Peak in the Greenwater Range to the west (the apparent age being a weighted-average of the apparent ages of the different sources);
- ARHS-09 is water that is sourced in the Spring Mountains/Pahrump Valley moving northwest toward Ash Meadows.

3.0 AMARGOSA WILD AND SCENIC RIVER – CONCEPTUAL MODEL

3.1 Regional Setting and Geologic Conditions

The Amargosa River Basin is located in Inyo and San Bernardino Counties, California, and Nye County, Nevada. The Amargosa Wild and Scenic River (AWSR) is entirely within the California portion of the basin in what is called the "Middle Amargosa River Basin" by the California Department of Water Resources. The principal communities in the area are Shoshone and Tecopa. The Middle Amargosa River Basin extends from the California-Nevada state line on the north, roughly to the boundary of Death Valley National Park on the south. The AWSR is fed by groundwater sourced in both California and Nevada. Because of this, a more regional description of the hydrogeology AWSR is provided.

The AWSR is within the Basin and Range geomorphic province, an area characterized by basins of internal drainage with considerable topographic relief. The topography alternates between narrow faulted mountain chains and flat arid valleys or basins. The ranges generally trend north-northwest parallel to the regional geologic structures. The geology of the Amargosa Basin is very diverse containing 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 4. AWSR area geology is presented on Figure 5.

The valley areas are covered by coalescing alluvial fans forming broad slopes between the surrounding mountains and the valley floors. 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, with the river eventually reaching the flat playa in Death Valley.

3.2.1 Hydrogeologic Units

In the Amargosa River Basin, the principal water-bearing hydrogeologic units consist of unconsolidated valley fill materials, volcanic rocks (primarily in Nevada), and the carbonate rock (limestone) aquifer. The following provides a summary of these three hydrogeologic units. Other less permeable bedrock units are also present.

3.2.2 Valley fill

Tertiary and Quaternary-aged valley fill deposits are present throughout the basin as alluvial (shed from the surrounding mountains), fluvial (river) and lacustrine (lakebed) deposits. Coarse-grained deposits (primarily sand and gravel) within the valley fill are responsible for transmitting the greatest quantities of groundwater and are most relied upon for groundwater production in the region. The valley fill is generally unconsolidated, moderately to well-sorted sand, gravel, silt and clay, and wells completed in the valley 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 valley 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.

3.2.3 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 area of the AWSR, the volcanic rocks are generally of lesser importance to the overall groundwater system as opposed to the northern portion of the basin in Nevada.

3.2.4 Bedrock Units

Bedrock units underlying the alluvial valleys and generally comprising mountain ranges such as the Nopah and Resting Spring Ranges, the Amargosa Range, and portions of the Sperry Hills through which the AWSR flows. These bedrock units consist of Precambrian to Mesozoic-aged metamorphic and sedimentary rocks, including Paleozoic-age carbonate rocks (the "carbonate rock aquifer"); quartzite, and shale which have been folded and faulted (Figure 4. 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., 2017).

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.

3.3 Geologic Structure

The rocks in the Amargosa River Basin and along the AWSR 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 System 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 valley 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 5). Just north of the AWSR, Shoshone Spring 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, Kellogg, 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 valley 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.

A notable exception is north of the Nopah Thrust in the northern portion of the Nopah Range. North of this fault, the carbonate-rock sequence is down-dropped relative to the carbonate rocks south of the thrust fault resulting in a potential pathway for an undetermined amount of water to seep from Pahrump Valley into Chicago Valley. Of note is the presence of Twelvemile Spring situated approximately west of this thrust fault, and an absence of springs along the west base of the Nopah Range further south.

3.4 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 the perennial wild and scenic portions of the river in California, and perennial segments of the river 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. As described earlier, except during runoff events from rainstorms, the perennial flow in the Wild and Scenic section of the river is completely supplied by groundwater.

On a regional basis, 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 where water is forced to the surface, 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. The wild and scenic-designated reach of the river begins just south of Shoshone.

Between Shoshone and Tecopa, California, the river generally alternates between perennially-flowing segments and an ephemeral stream channel (seasonal or flood flow only). The perennial segments are generally in areas where low permeability units within the Tecopa lakebeds forces water to the surface providing limited perennial surface flow. South of Tecopa, the river enters the Amargosa Canyon, and is augmented by spring flow along its course. South of the Amargosa Canyon, the river flows by Dumont Dunes, and then heads west rounding the Amargosa Range on the south, and then northward flowing into Death Valley.

A series of conceptual cross-sections following the course of the Amargosa River from near the California-Nevada state line to Sperry below the Amargosa River Canyon in California are provided in Appendix E. As can be seen, areas with continual flow are typically where rock units create constrictions to flow, and that flow is driven to the surface. Beyond the constrictions, the flows typically percolate into the subsurface some distance downgradient. In the general area of the AWSR, this prominently occurs at Shoshone Spring area, and at the Amargosa River Canyon south of Tecopa. As can also be seen in the cross-sections, the groundwater surface tends to flatten up-gradient of these constrictions, then steepens once past them, as would be anticipated.

This condition also emphasizes the sensitivity of the relatively constant, or perennial reaches of the AWSR to changes in groundwater level. It appears that a considerable portion of the underflow moving through the Middle Amargosa system can be accounted for by the flow observed at the surface, for example in the Amargosa River canyon, plus spring discharge and any pumping. This does not result in a substantial amount of underflow, and further highlights the sensitive nature of the river system.

The USGS monitors the flow of the Amargosa River (USGS, 2013) 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 42 full years of data between 1962 and 2017 (some years missing) is 3.43 cubic feet per second (cfs), though is skewed high as a result of flood flows. 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.

Additional non-governmental sponsored flow measurements conducted at three locations along the AWSR have been conducted and are also provided on Table 3. Field water quality parameters that have been measured indicate 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. This monitoring has provided strong indications that the extent of flow in the Amargosa River is significantly 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 evapotranspiration 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.

Other surface water bodies in the AWSR area consist of 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 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.

3.5 Groundwater System

The regional groundwater flow system is considerably more extensive than the Middle Amargosa River Basin watershed (Figure 6). This is due to 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).

Within the Middle Amargosa River Basin, it had formerly been assumed that groundwater moves directly through the carbonate aquifer southwest from the Spring Mountains and beneath Pahrump Valley toward the Tecopa – Shoshone – Chicago Valley – California Valley areas (Faunt, D'Agnese and O'Brien, 2004). However, based on more recent aqueous geochemistry investigations such as Andy Zdon & Associates (2014) and Zdon, Davisson and Love (2015), and more recent detailed mapping by the USGS (Workman, et.al., 2002), it appears that the mechanism by which groundwater moves from the Spring Mountains/Pahrump Valley area toward the Shoshone-Tecopa area may be more complicated.

Figures 7 through 9 present a portion of the 2002 geologic map indicating that Precambrian to Cambrian bedrock units underlying the carbonate rocks 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 quartzite, shale, siltstone and dolomite of lesser permeability than would be expected of the Paleozoic-age carbonate rocks. Alternative groundwater flow paths toward the AWSR likely include one or more of the following:

- Spring Mountain recharge moving toward Ash Meadows through carbonate rocks and valley fill, then southward toward the Shoshone-Tecopa area;

- Via carbonate rocks at the north end of the Nopah Range into Chicago Valley then toward the Amargosa Valley; and ,
- From Pahrump Valley via the shallow divide into California Valley then toward the Amargosa River.

These deeper flowpaths are most likely influential on the spring flows and discharge to the alluvium. The deeper flowpath beneath the northern Nopah Range was previously discussed (JWI, 2013a) as a potential source for Twelvemile Spring. These flowpaths are consistent with that previously proposed by others (Figure 10). As described earlier, beyond the Middle Amargosa River Basin, groundwater moves west toward the Death Valley Basin, then north augmented by underflow from the Owlshead Mountains area, to the Death Valley Playa.

The regional groundwater flow system covers an area of nearly 40,000 square miles. A groundwater surface map in the basin fill is presented in Figure 11. The following sections describe the occurrence and movement of groundwater, the aquifer characteristics of the valley fill and carbonate rock aquifers, and groundwater basin inflow and outflow components.

3.5.1 Aquifer Characteristics

Groundwater within the basin is held within the sand, gravel, silt and clay that make up the valley fill aquifer. Within the Amargosa Desert, hydraulic conductivity (the ability for a geologic material to transmit water) in the valley 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). PARTNER is unaware of any aquifer testing that has occurred within the valley 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).

3.5.2 Regional Groundwater Inflow and Outflow

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.

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. It is unlikely that water use in the Shoshone-Tecopa area has changed significantly since the last State of the Basin Report (SGI, 2014). Furthermore, any additional water usage resulting from the proposed new potable water supply for Tecopa will be insignificant to the overall water budget of the area.

Desert Research Institute (2016) developed a groundwater flow model for the Pahrump Valley area which puts this discussion of inflow and outflow in better context. Although the details of the modeling effort are not provided here, given that the model provides a groundwater budget for the system, and the simulated underflow from Pahrump Valley is likely a reasonable estimate assuming the modeled recharge and evapotranspiration numbers are also reasonable averages. The model estimates approximately 7,550 acre-feet per year of underflow from Pahrump Valley under pre-pumping, steady-state conditions. This is an important number when looking at sources of springs in the California portion of the basin.

The USGS (Laszniak, et.al.) have estimated the following evapotranspiration losses:

- Chicago Valley: 430 acre-feet per year;
- Tecopa – California Valley: 6,400 acre-feet per year
- Shoshone area: 2,100 acre-feet per year
- Stewart Valley: 1,000 acre-feet per year (part of the outflow in the model is toward Stewart Valley).

Additionally, USGS has estimated that approximately 800 acre-feet per year of underflow from below the Amargosa Canyon into southern Death Valley (Belcher, et.al.,2020); and there is an estimated 100 acre-feet per year of pumping/use in the basin (Belcher, et.al., 2020). This ends up totaling 10,830 acre-feet per year of groundwater discharge from the California portion of the basin in the Shoshone-Tecopa area. Johnson Wright (2013) estimated, based on Maxey-Eakin approach, approximately 728 acre-feet per year of recharge into the basin from the Kingston Range. Recharge from the Nopah Range and others is minimal. Subtracting out the Kingston Range recharge this leaves approximately 10,102 acre-feet per year of discharge.

Going back to the DRI model, as can be seen, the estimated outflow from Pahrump Valley is insufficient to account for the amount of discharge estimated in the Shoshone Tecopa area (the difference is approximately 2,550 acre-feet per year. This likely represents a good estimate of what could be expected to enter the basin from the north (Amargosa Desert/Ash Meadows area). Therefore, in the Shoshone-Tecopa area, approximately 75% of groundwater could be sourced from the Spring Mountains/Pahrump Valley with 25% coming from the north. This is consistent with past work in the area (Zdon, Davisson and Love, 2014).

Outside of the "Middle Amargosa River Basin" but within the regional flow system, pumpage is primarily within the Amargosa Desert area to the north and Pahrump Valley, both in Nevada. This water is largely used for irrigation. Table 3 summarizes groundwater pumping from the Amargosa Desert since 1983 (NDWR, 2017). This represents the most up to date pumping data available from the Nevada Division of Water Resources at the time of this report. Total pumping over time is also represented on Figure 12. Average annual pumping in the Amargosa Desert area since 1983 and through 2015 has been 12,350 AFY. In the most recent year reported (2015), pumping was 16,192 AFY. As can be seen, over the 31 years of pumping records, the Amargosa Desert has seen a steady increase in pumping. For comparison purposes the annual duty for the Amargosa Desert is 26,109 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).

In Pahrump Valley, pumping records available since 1959 (NDWR, 2017) indicate that beginning with in 1959, groundwater pumping in the Pahrump Valley rapidly increased to a maximum pumpage of 47,950 AFY in 1968 (Figure 13). 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 2011, total groundwater pumping in the Pahrump Valley was 13,352 AFY, the lowest pumpage since the initial record in 1959. The 2011 pumping rate (which also represented a 2739 AFY reduction in pumping since 2009) was likely attributable to economic conditions and represented a temporary decrease from the 20,000 to 25,000 AFY of pumping that has been characteristic of the Pahrump Valley since 1980. In 2016 (the most recent record), total pumping in Pahrump Valley was 16,085 AFY, a 20% increase in pumping over that time period (2011 to 2016).

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 reported. However, Thompson (1929) referred to a site called Yeoman Spring that had at the time an estimated flow of 90 gpm. Although there is no spring currently called Yeoman Spring, this appears to be the same spring now referred to as Chappo Spring. The only surface expression of flow at Chappo Spring is a "puddle" surrounded by trees (including non-native palms) and shrubs. Additionally, early reports indicated that Resting Springs had flows of substantially more than 200 gpm (up to 250 gpm). Both of these springs flow at rates lower than those reported in the first half of the 1900's. While this may be the result of spring modification and additional vegetation uptake, it is possible then, that spring flow in the Middle Amargosa Basin may have been affected by past pumping in the Nevada portion of the basin.

Recently, localized stabilization and recovery has been reported in selected areas of Pahrump Valley indicative of a basin beginning to come closer to balance with recently reduced pumping rates, although in some areas, groundwater levels continue to decline (e.g. California Valley) despite the absence of the groundwater pumping in that immediate valley.

3.5.2.1 Springs

Spring flow and evapotranspiration have been combined as a basin outflow component in this basin as in this area as they are unavoidably linked. Spring flow data including summaries of conditions, field data, water rights information, photographs and video documentation and other available pertinent information are provided in Appendix E. Hydrographs of flow and field parameters for springs adjacent to the AWSR are provided in Appendix F. Spring discharge and field parameter data are presented on Table 1 for all springs. 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 within 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, 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), and those with shallow and potentially more local circulation paths (such as at Willow Creek). With respect to specific spring flow (not including evapotranspiration or Amargosa River flow), PARTNER's total field estimated spring surface flow (not evapotranspiration) has typically been approximately 1.8 cfs during the spring reconnaissance activities (approximately 1,300 AFY). Springs such as Crystal and Horse Thief are sourced within the Kingston Range and are from recharge of precipitation that has fallen solely from on that range. Schofield Spring appears to the be a mixture of northwest seepage from California Valley toward the southern end of Chicago Valley along with occasional bank storage/recharge from precipitation in the group of hills immediately south of the spring.

The following springs fall within the boundaries of the AWSR and described in more detail.

3.5.2.1.1 Borax Spring

This is an artesian spring/well located at the site of a former borax processing facility (Figure 15). Ruins of the former 19th-century era facility can be seen on both sides of Highway 127. The source of the surface flow is a PVC pipe set in concrete with an approximately 1-inch diameter, cracked discharge pipe attached to the side. The spring is in a flat area, with low hills comprised of Tecopa lakebed deposits to the west. The discharging water forms a 1.0-acre riparian area consisting of a series of pools ringed by low grasses (salt grass). The pooled area is approximately 150 feet long in the north-south direction and 60 feet at its widest point. The flow parallels the adjacent road and eventually disappears into the alluvium approximately 700-feet south of the source.

Periodic monitoring conducted at Borax Spring since 2010 has ranged from 3.6 gpm (on April 10, 2017) to 9.4 gpm on December 8, 2015. Overall, flow appears steady long-term, with flow increasing during the winter months and decreasing during periods of higher evapotranspiration indicating that flow is affected by near-surface processes. Field water quality parameters including temperature, pH and electrical conductivity have remained relatively constant throughout the monitoring record.

3.5.2.1.2 Borehole Spring

This man-made spring was initially an exploratory drill hole that started in 1967 advanced by Stauffer Chemical for mineral exploration. Water was encountered under pressure at a depth of approximately 360 feet. Attempts were made to plug the boring but discharge under artesian conditions around each successive well seal had the effect of creating a large void at depth. Attempts to seal the hole were abandoned and Borehole (or Bore Hole) Spring came into being (Figure 16). The void was eventually backfilled with 10,000 cubic yards of fill/gravel, though the flow was never completely contained. There is no obvious source of the water and no trace of the original well. The spring now is a series of connected pools (and several non-connected pools).

The water emanating at the spring is hot, with the hottest pool being farthest from the road. In this pool, small streams of bubbles can be seen emanating from an area on the bottom, which is the likely point at which the spring is being fed. The water in the connected pools is hot, has a greenish tint, is relatively deep (3+feet in areas) and contains fish. The water in the disconnected pools is much cooler, reddish in color, very shallow and contains no fish. The water flows toward the road through a large expanse of three-square bulrush, reeds and grass (covering approximately 2.5 acres).

At the road, a culvert directs the water under the road and into Grimshaw Lake. Flow is monitored by the USGS and can be altered, so to an extent, some flow changes may be human-induced by activities at the culvert (typically to maintain water conditions in the bulrush for Amargosa Vole habitat). Flow has varied considerably since 2011 with measured flows ranging from 20 gpm to 148 gpm. There does appear to be a long-term decrease in temperature at the spring. Other field water quality parameters (pH and electrical conductivity) appear to be stable.

3.5.2.1.3 Dodge City Spring

Dodge City Spring issues from a small, reed-choked pond immediately adjacent to Furnace Creek Road (just east of Tecopa Road) and follows a small channel approximately 50 feet to a marshy area that extends westward across Tecopa Road (Figure 17). The full extent of the riparian area of the spring is approximately 2.5 acres. Despite the proximity of the road, the site is generally undisturbed except where a culvert at the Tecopa Road allows drainage underneath. At the source, all vegetation is emergent, and along the channel, all vegetation is as bank-cover. Vegetation includes phragmites, three-square bulrush, salt grass and yerba mansa.

Flow in Dodge City Spring has generally decreased (along with electrical conductivity) since monitoring began in 2014. Flow may be affected by annual rainfall conditions and continued discharge from the borehole at Bore Hole Spring.

3.5.2.1.4 Tecopa Hot Springs

This spring system encompasses the town of Tecopa Hot Springs. Historically, the spring was contained in two pools that produced approximately 225 gpm (Waring, 1915). The water temperature was noted to be about 107ºF at that time. Now there are multiple outlets to the spring as people have directed the water to both public and private baths via the installation of wells. Runoff from the spring flows downhill into Tecopa Wetlands, located to the north and east of Tecopa Hot Springs. The temperature of the water at the county facilities currently is approximately 104°F.

Mendenhall (1909) wrote: “There are two hot springs on the eastern edge of Resting Springs Dry Lake, about three miles southeast of Zabriskie. These springs yield about 200 gallons per minute of water which contains, according to qualitative determinations, sulphates of soda and magnesia, some borax, and some niter. In the fall of 1908, there was an old tent at the springs, which are occasionally used for bathing purposes. The temperature of the water is about 107 degrees.”

Data was formerly collected on property owned by The Nature Conservancy. This spring outlet is simply a pipe in the hillside below and is derived from a well. Monitoring is now conducted primarily at the county park. The monitoring record at the county park is not of enough duration to describe trends at this time.

3.5.2.1.5 Thom Spring

Flowing water emanates from a hillside beneath a large Athol tree on the south flank of the bedrock hills south of Tecopa Hot Springs (Figure 18). The actual point of discharge is obscured by the dense vegetation in the area. In general, the foliage around the spring is very dense and precludes an in-depth investigation of water flow. The vegetation at the spring and downstream covers approximately 1.1 acres and includes stressed and dead screwbean mesquite, three-square bulrush, phragmites, baccharis (sp.), bunchgrass, and cattails and tamarisk. There was considerable purple thistle present on May 31, 2016.

Downstream of the source, a group of cattails are growing out of a small pool of water. Water from this small pool runs overland for several hundred feet. The flow supports a population of small fish. Between April 2012 and January 2013, a small portion of vegetation was cleared out and several small hoses were pushed into the hillside. Spring water now emanates from the hoses. Under the Athol tree is a small pipe that was part of an old well that still has water in it.

The flow at Thom Spring was noted to have decreased when the borehole at Borehole Spring was developed in the 1960’s. Since monitoring began in 2010, flow appears to have decreased from 2-5 gpm to typically less than 1 gpm or standing water only. Field water quality parameters appear relatively stable. This is a cool/warm spring with temperatures ranging from approximately 64°F to 85° (temperature variations do not appear to be seasonal).

3.5.2.1.6 Vole Spring

Vole Spring’s riparian area covers approximately 3.7 acres, and consists of a dense thicket of mesquite, three-square bulrush, baccharis (sp.), and tamarisk (Figure 19). The actual spring vent is unclear and inaccessible due to the thick brush. The mesquite is bimodal – screwbean mesquite is generally dead, while honey mesquite is healthy. There appears to have been a decrease in spring flow since 2015 with one peak period which may have been influenced by human-caused additional diversion to measuring point. Fish have been observed in the water here, and field water quality parameters have been stable. There has been some diversion of flow in the past (there are ditches and old piping present).

3.5.2.1.7 Homestead Spring

This is a spring located east of Thom Spring and north of Stormy Spring (Figure 20). It is a bulrush and cattail-choked spring (surface water is present) in a bedrock narrows where groundwater flowing from the east is forced to the surface. It is a cool spring without discernible flow (standing water only).

3.5.2.1.8 Stormy Spring

Stormy Spring is in a dense thicket phragmites thicket against the low hills to the east of Vole Spring (Figure 21). The springs consist of seeps along the base of the hillside…there are probably multiple spring vents obscured by dense vegetation. Approximately 5.5 acres of phragmites, yerba mansa, saltbush (sp.) and saltgrass are present, as are tamarisk and cattails. The spring is in an undisturbed state.

3.5.2.1.9 West-side Spring

This spring rises immediately west of the river south of Tecopa Hot Springs and north of the old Tecopa. Flow reaches Amargosa River via channel flowing at about 10 gpm. Site is undisturbed, with mesquite, rushes, willows, and cattails, present (Figure 22).

3.5.2.1.10 Christian Spring

Christian Spring (formerly called Amargosa Canyon Spring #1) flows out of earthen bank above the Amargosa River south of the town of Tecopa (Figure 23). The spring was uncovered in the fall of 2010 following a fire that burned much of the vegetation in the northern part of the Amargosa Canyon. As the vegetation grows back, access to the spring is becoming more difficult. Vegetation at Christian Spring consists primarily of phragmites, coyote willow, baccharis (sp.), arrowweed, grapevine and Gooding’s willow. The spring appears to result from an accumulation of springs, seeps and pond outflow from the Zellhoeffer property to the north. Spring flow appears to vary considerably over time (ranging from approximately 38 gpm to 85 gpm) and may be influenced by conditions in the pond on the Zellhoeffer property. Field water quality parameters have remained stable over the time period.

3.5.2.1.11 Amargosa Canyon Springs

These are a series of springs/seeps along the eastern canyon wall below old Tecopa and above the confluence of the Amargosa River and Willow Creek (Figure 24). It is likely that many of the springs were exposed during the construction of the railroad bed, which was carved out of the eastern wall of the Canyon. A photograph is available showing a Tonopah & Tidewater Railroad car (#4) stopped to take on water at "Red Cut" where a pipe was bored into the hillside tapping into the water from one of the springs (Serpico, 2013).

These rheocrene springs are present along the floor and wall of the eastern side of Amargosa Canyon along a 1.3-mile stretch of the Amargosa River. Flow at these springs range from less than 5-gpm to greater than 30-gpm. Total flow from all the springs in Amargosa Canyon remains unknown. Along the canyon wall carved out by the railroad, spring water seems to be emanating from the contact between an alluvial conglomerate which is situated above a mudstone formation. It is likely that the water is flowing in the permeable alluvium overlying the much less permeable mudstone below.

Amargosa Canyon #4 spring is a series of gushets (concentrated flow from a cliff face) springs located on the eastern bank of the Amargosa River, along the west-facing wall of the Amargosa Canyon. Water from this spring pours out of the canyon wall at the interface between a quartzite unit and the alluvium above. There is significant vegetation in the form of grasses that grow on the canyon wall. Vegetation present include mesquite, Gooding's and Coyote willow, three-square bulrush, baccharis (sp.), saltgrass, and sawgrass. The combined spring discharge enters a railroad cut at the base of the canyon wall. A manmade ditch from the railroad cut directs the flow to the Amargosa River.

3.5.2.1.12 Willow Creek

Willow Spring at China Ranch has long been noted as a source of excellent quality water in the area. Mendenhall (1909) stated: "China Ranch...also known as Morrison Ranch and Willow Creek Ranch, is on the main road from Daggett to Resting Springs." Mendenhall continues, "The springs that furnish this water rise in Tertiary rocks, which outcrop around the ranch to a height of 500 to 600 feet. Good hay can be obtained here, the first to be had after leaving Daggett, 110 miles south. Willow Creek furnishes sufficient water to irrigate about 100 acres of land. This ranch is one of the real oases of the desert, and travelers appreciate the cool water, the supply of alfalfa, and the shade of fig trees.... J.C. Fremont passed this spot on April 29, 1844, on his way from Tomaso Springs to Resting Springs. He says of it "The raving (Amargosa Canyon) opened into a valley (Willow Creek), where there were springs of excellent quality"."

Waring (1915) reported that China Ranch Springs were flowing at a rate of 50 gallons per minute (water temperature 60ºF) and being used for irrigation. Waring states, "The China Ranch is situated in the canyon of Willow Creek, half a mile or so above its junction with Amargosa River and 5 miles north of Sperry station on the Tonopah & Tidewater Railroad. Willow Creek is supplied by springs of considerable flow and of good quality, which issue from sandstones and clays of Tertiary age that form the canyon walls. The water is used to irrigate several acres of alfalfa and garden vegetables, and the ranch forms one of the few oases in the desert eastern part of the State. It is a stopping place and supply point on one of the main desert routes between the mining camps of eastern California and western Nevada. The springs were visited by Frémont in 1844, when returning eastward from his exploring expedition."

The riparian area of Willow Creek (spring) covers approximately 65 acres from the uppermost point of flow at China Ranch (generally designated as Willow #2 to a point approximately 1,500 feet below the lowest date grove). From there a ribbon of riparian vegetation extends all the way to the Amargosa River.

Spring flow is initially intercepted in a shallow French-drain system installed across the Canyon by China Ranch for irrigation purposes. The captured water is directed through piping into a series of spring boxes and then into a holding tank. From the holding tank, the water is gravity fed into an irrigation system. The flow captured by this system is approximately 28-gpm. When the system is not in use, the water overflows a spring box and continues downstream as overland flow. The spring itself comes to the surface at a point downstream of the french drain capture system. All overland flow through China Ranch itself flows through a culvert near the entrance to the facility. The flow recorded at the culvert location was approximately 120 to 130-gpm (which at the time included the overflowing irrigation system water). This water continues down China Ranch Wash toward the Amargosa River.

Flow measurement (Figures 25 and 26) on Willow Creek by the U.S. Geological Survey is conducted at Willow #2. While problematic in relation to actual flow measurements (for example on September 25, 2013 an instream metered flow measured 37 gallons per minute while the gage was measuring 4.5 gallons per meter with the former flow more likely based on visual observation), the meter does provide a record of changes over time that are not captured by periodic field measurements.

At Willow Creek #1, vegetation included mesquite (honey and screwbean), willows (Goodings and coyote), phragmites, three-square bulrush, grasses, saltbush (sp.) and tamarisk. In December 2015, the vegetation was quite overgrown as compared to past visits. At Willow Creek #2, vegetation present include mesquite (screwbean and honey), willows (Gooding's and coyote), three-square bulrush, saltgrass, cottonwood and other riparian shrubs. At Willow Creek #1 there were Desert Bighorn Sheep tracks. There is much sign of coyote and bobcat, and these are frequently seen at these locations.

Spring flow and field water quality parameters at Willow Creek have remained stable since monitoring began in 2010.

1.5.5 Groundwater Quality

Groundwater quality in the Amargosa River Basin is highly variable. In recharge areas, the concentrations of dissolved solids in groundwater is 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 Amargosa Desert 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.

3.6 Groundwater Discussion – Water Levels, Changes in Storage, Water Level Changes – Decreases in Spring Flow at Chappo/12 Mile/Resting Spring

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 expected 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, there will always be groundwater drawdown (and the removal of water from storage) in the vicinity of pumping wells, a necessity to induce the flow of groundwater to said wells. 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 valley fill aquifer has been postulated as early as the 1960’s (Walker & Eakin, 1963). Elevated pumping in the valley 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. Currently, there are no groundwater flow models with sufficient detail to develop this level of understanding in the AWSR area. 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 and springs in the Shoshone – Tecopa area, the groundwater system appears to be going through a period of very slow hydrologic decline. Decreases in spring flow at Chappo Spring have been noted previously (Andy Zdon & Associates, 2014). That decrease in spring flow is likely due to the long-term groundwater level declines that were noted in Pahrump Valley. Springs in the Tecopa area have also decreased in flow since the 1960’s, at least partially the result of the bore hole at Bore Hole Spring and likely due to the number of wells used to tap the hot springs in Tecopa Hot Springs by private residents. In both cases, given the expanse of the groundwater system and the distant nature of the groundwater extraction that could most affect the groundwater system that feeds the AWSR, changes to groundwater flow in springs and groundwater levels in wells will occur very slowly. These are changes that may only be noticeable on a generational basis. It follows that recovery of groundwater levels or springs in flows may occur on an even slower basis. Therefore, identifying change, and potential impacts, to the groundwater system early is essential for managing the AWSR.

3.6.1 Groundwater Trends in Monitoring Wells

As part of this, and previous, investigations, nine monitoring wells have been installed in the Shoshone-Tecopa region and outfitted with groundwater-level recording devices. A summary of groundwater level trends in each of these wells follows and hydrographs for each of the wells are presented in Appendix F. The monitoring wells are discussed generally northwest to southeast:

- ARHS-08: This is the northwestern-most monitoring well at the former railroad-siding site of Evelyn, along the current Highway 127 north of Shoshone and south of Eagle Mountain. This monitoring well was installed during Spring 2018 and approximately 1.5 years of data have been recorded for this well. Groundwater levels appear stable at this monitoring well.
- ARHS-01: The first well installed, also being one of the most informative in developing the conceptual model of the Shoshone-Tecopa area. This monitoring well was installed during 2012 and approximately 6.5 years of data have been recorded for this well (the transducer was pulled during Spring 2019 for repair and has been replaced as of September 2019. Groundwater levels are generally stable as measured with the transducer although hand-measured groundwater levels suggest that current groundwater levels are approximately 1.2 feet lower than when the well was first installed. This variation may be the result of the transducer cable stretching over time. With the installation of the replacement transducer (ordered from manufacturer but not yet installed) this should become clarified.
- ARHS-09: This is the northeastern-most monitoring well in southern Stewart Valley (within California). The monitoring well was installed during Spring 2018 and approximately 1.5 years of data have been recorded for this well. There appears to be a general decline in groundwater levels at this monitoring well (see hydrograph in Appendix F).
- ARHS-03: This monitoring well at Twelvemile Spring in Chicago Valley was installed in 2013 and approximately 6 years of data have been collected at this location and are approximately 1.8 feet lower in elevation than measured when the well was first installed reflecting regional decline as no significant pumping wells in Chicago Valley.
- ARHS-06: This monitoring well at the old Davis Well site in California Valley was installed in Spring 2018 and approximately 1.5 years of data have been collected although the casing collapsed sometime after the spring 2019 monitoring event (possibly as a result of Ridgecrest earthquake on July 4, 2019). As nearby Tule Spring has been declining, one foot of continued drawdown could result in the absence of surface water at downgradient Tule Spring unless the spring source is manually-deepened.

- ARHS-10: This monitoring well at the former Davis Well site was installed during spring 2018 and approximately 1.5 years of data have been collected. A groundwater level declining trend was present until July 4, 2019 (prior to July 4 Ridgecrest earthquake). After the earthquake groundwater levels have been noted to be rising. This may be the result of cracking of a clay layer allowing a hydraulic connection between a deeper water-bearing zone under pressure. Once this new groundwater condition has stabilized, at least another year of data will be needed prior to beginning to see a post-earthquake trend on this well.
- ARHS-04: This monitoring well is at the head of China Ranch Canyon and at the former site of "Married-Man's Camp." This monitoring well was installed in 2013. Shallow groundwater levels in this monitoring well have remained relatively stable.
- ARHS-02: This monitoring well is along Willow Creek at the upper end of the China Ranch date farm property and was installed during 2012. Groundwater levels in this monitoring well are affected by water usage at the date farm but appear relatively stable from a long-term perspective.

3.7 Future Water Use – (within California and Nevada)

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 of water. However, there is significant potential for pumping to increase considerably should water rights holders fully exercise their water rights. This is also true in the Pahrump Valley. Given the over-allocated nature of the Amargosa Desert and expected increased pumping in Pahrump Valley, significant impacts to the groundwater resource could result. 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 construction, mirror washing, and other uses are likely. Additionally, potential development of the proposed Yucca Mountain Nuclear Waste Repository could result in an increase in groundwater usage and degradation of groundwater quality.

The competing demands for renewable energy and other uses, and protection of the Amargosa River point to the need for increased knowledge and continued baseline hydrologic data collection in the Middle Amargosa River Basin. Recommendations for future investigations are provided in the following sections of this report.

4 RECOMMENDATIONS

Given the regional nature of the groundwater source that feeds the Amargosa Basin and AWSR, it is clear that an effective monitoring program for the basin and AWSR will include sites well away from the AWSR. This future monitoring should be conducted under a management plan which could be for the basin or could be inclusive in a future AWSR management plan. In any event, although a future mandated AWSR management plan would be for a specific water course, the unique hydrology and the expansive area that contributes to the river through complex groundwater flowpaths would make a purely river-centric monitoring program of limited value. Based on the results of current and past work, decreases in groundwater level and associated underflow in the northern Amargosa basin (Amargosa Desert) and Pahrump Valley (both in Nevada) will likely affect springs in the Middle Amargosa Basin and the AWSR fed by those springs. Based on the historic record, this change would likely occur slowly making management difficult.

The Middle Amargosa Basin is undergoing slow but continual groundwater decline, primarily from water-gathering from within the basin, but outside of California. Under the Sustainable Groundwater Management Act (SGMA), the basin is ranked as having "very low priority." Consideration and action should be given to up-grading the ranking for this basin.

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, until recently the California portion of the basin has seen little in the way of regional hydrogeologic investigations. Therefore, it is essential that a monitoring program be incorporated into management of the AWSR that identifies changes in the groundwater system, prior to the Amargosa River being impacted.

In the Amargosa Desert groundwater is already over-allocated (as it is in Pahrump Valley as well). Although pumping does not currently take place at the full amount entitled to by water rights holders, considerable impacts to the groundwater reservoir and associated springs could occur (and may already be occurring) should those holders eventually fully exercise their water rights. Groundwater usage within the Amargosa Desert has steadily increased over the past 25 years, and the addition of a new industry to the area (solar) will likely provide additional pressure on the groundwater resource. Also, as groundwater usage increases in the Amargosa Desert, 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 and associated springs.

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. Whether that plan, or a future general basin plan is developed, it is essential that hydrogeologic characterization of the California portion of the basin continue to take place in order for a 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. Based on the results of the current and past hydrologic work along the Amargosa River, the following sections highlight technical needs that should be incorporated into a management plan for the Amargosa Basin.

4.1 Water Management and SGMA

Given the limited groundwater pumping in the Shoshone-Tecopa area, the AWSR system and springs in the area are ultimately going to persist or continue to decline based on groundwater management decisions in Nevada. It follows that the ecological and economic benefits to the AWSR system in California will persist or decline based on groundwater management decisions in Nevada. Interstate groundwater management efforts and cooperation will be essential to protect the ecology Amargosa River system in California and the economy of eastern Inyo County. As described above, the Middle Amargosa Basin has a “very low” ranking under SGMA. This despite:

- the population present (albeit low) largely being from within a disadvantaged community (as outlined in the application for this Proposition 84 grant that funded the work herein);

- a local economy based and supported on spring-flow;
- the groundwater system being in a downward trend due to groundwater development outside of California but within the watershed;
- the presence of a federally-designated Wild and Scenic River inclusive of the habitat for the most critically endangered mammal in North America, the Amargosa Vole; and,
- being the home, either seasonally or perennially, to numerous other listed species.

Efforts should be undertaken to change the ranking of this basin to a higher ranking that would provide funding to assist in the development of future groundwater management planning and activities in coordination with the States of California and Nevada, and federal agencies such as the U.S. Bureau of Land Management. Best Management Practices (BMPs) for future groundwater development projects in the Amargosa River region should be established that are focused on protection of the Wild and Scenic Amargosa River and associated springs. This would also have the effect of protecting existing water users in the basin and the local economy. The existing monitoring and that proposed is a starting point. With additional monitoring wells as listed in Section 4.2 and additional investigations being conducted, the monitoring program will likely need to adapt to meet our growing knowledge of how the Amargosa River system works. Future groundwater management of the basin will need to be dynamic, able to guide management with our ever-growing knowledge of how the basin and AWSR work and sustain their fragile economy and ecology.

4.1.1 Monitoring – Practical Alternatives for Monitoring River System in Changing Channel

One of the complexities of monitoring surface water flow in the Amargosa Basin is the dynamic river channel that changes in character annually due to flood scouring, deposition of bedload from floods, and changing vegetation conditions. The current river gaging location used by the USGS above the confluence with Willow Creek, was not part of the river channel 20 years ago. Nimbler river monitoring will be needed to account for surface flows but also to adjust with changing conditions. Given the groundwater-driven river system, depending on sedimentation in the Amargosa Canyon from one year to the next, the same amount of water flow through the canyon (surface water plus groundwater underflow) may produce less surface expression of river flow one year, and more the next. Linking river monitoring with both surface flow gaging with groundwater monitoring using shallow piezometers (that may occasionally need to be replaced due to flood events) will provide the best means for long-term river monitoring.

4.1.2 Consideration by Land Managers of AWSR In Future Development Scenarios

The noted slow decline can be seen in reduced spring flow up-gradient of the river such as at Chappo, Twelvemile, and Resting Springs (Andy Zdon & Associates, 2014) and the declining groundwater levels observed in Chicago Valley and Stewart Valley as part of this investigation. The U.S. Geological Survey (Thompson, 1929) originally measured flow at Chappo Spring as being 112 gallons per minute while current estimated flow is approximately 5 gallons per minute. At Twelvemile Spring, indications of greater spring flow in the past is noted by the flow channels that are now dry, with the existing spring flow level substantially below those channels. Long-time residents also recall Twelvemile Spring being a more substantial spring than currently exists.

As was described in the previous sections, there is the potential for substantially increased groundwater usage in the Pahrump and Amargosa Desert groundwater basins in Nevada. These basins are currently over-allocated. Future groundwater development proposals (for projects throughout the groundwater flow system extending into Nevada) and recently proposed in Pahrump Valley, and associated environmental analyses should address how proposed activities will affect (long-term) the AWSR. This will include numerical groundwater flow modeling as described in other management documents such as the Desert Renewable Energy Conservation Plan.

4.1.3 Tamarisk

River gaging and monitoring, including monitoring the downstream extent of surface flow, has shown that the Amargosa River has peak flow and extent during periods of low evapotranspiration (winter) and lowest extent and flow during late spring and summer during periods of maximum evapotranspiration. Given the extent of tamarisk growth in the canyon, particularly below the confluence with Willow Creek, removal of tamarisk could have a marked effect on enhancing river flow. Such activity would need to be conducted with careful planning as abrupt removal of tamarisk could remove valuable cover for birds such as Least Bell's Vireo that nest in willows where there is sufficient cover surrounding the willows. It is our understanding that vireo nesting is substantially less in willows without the surrounding cover.

Additionally, field mapping of vegetation, and water/soil conditions should be conducted in areas currently covered by tamarisk thickets to evaluate vegetation types that both provide maximum ecological/wildlife benefit.

4.2 Science

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 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), subsurface underflow beyond Salt Creek and analyzing associated groundwater level trends. The recommendations for additional investigations are based on our experience in the Amargosa Basin and elsewhere.

Based in the results of past and 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 fall into three categories including; 1) monitoring well installation to improve our understanding of the system and provide protective monitoring points; 2) additional investigation for sourcing of springs and the river; and 3) additional investigations to better understand the overall system.

- Additional Piezometer/Monitoring Well Installation – Shallow and deep 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. PARTNER anticipates the wells would consist of both shallow (assumed depth of 25 feet below ground surface (ft bgs) and deep wells extending possibly in excess of 1,000 ft bgs. We anticipate wells in the following general locations:
    - Two shallow wells along the Amargosa River between Shoshone and Tecopa;
    - One shallow monitoring well along the Amargosa River near Tecopa and the USGS Amargosa River gaging station there;

Deep monitoring wells in the carbonate rock aquifer would be particularly helpful in evaluating flow paths and refining the conceptual model. However, they would also be costly. At this time, as it is anticipated that most future groundwater production will occur in the valley fill aquifer, a focus on monitoring wells in the valley fill is recommended here, although there has been recent consideration in Nevada of introducing deep production wells to tap the underlying carbonate aquifer (e.g. in Pahrump Valley). Should sufficient funding become available for the installation of deep monitoring wells that could penetrate the carbonate rock aquifer in a meaningful way, locations that should be considered would be at Twelvemile Spring; ARHS-01 north of Shoshone, and in the Death Valley Junction/Eagle Mountain area.

- 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, anions, cations, 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.

- Low-levels Metals Analysis – Although metals analysis has been conducted at springs in the Middle Amargosa Basin, many of the metals are not detectable at standard laboratory detection limits. Metals suites can be quite informative to understanding the relationship between waters, so this would entail specialized analysis to obtain metals concentration information at substantially lower detection limits than typically conducted.

- Additional radiocarbon Dating and Chlorofluorocarbons (CFCs) Analysis – Carbon-13 and Carbon-14 analysis along with CFCs to age date waters, particularly in light of the results of the current analysis. Measuring radiocarbon abundance of spring water in the Amargosa River Valley with the lowest helium ratios would indicate either high flux along faults or whether waters are very old.

- Analysis of Salts in Discharge Areas – To identify elements in discharge areas that may be introduced into spring waters at specific discharge points and their solubilities that may alter the chemical makeup of waters. This would provide comparative data to spring water containing high concentrations of total dissolved solids to determine if this is a viable mechanism to explain spring water compositions.

- Geophysical Investigations – Geophysical surveys in the vicinity of Tecopa to evaluate faulting in the vicinity of the thermal springs. Additional surveys north of ARHS-01 to evaluate the geologic connectivity between the northern portion of the basin and the area south of Eagle Mountain. This would also help inform our understanding of monitoring results in that area.

- 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 recharge sources and the effects of precipitation events on groundwater-level fluctuations, four precipitation stations should be installed at the following locations:
    - South flank of Eagle Mountain;
    - Twelvemile Spring;
    - Saratoga Spring; and
    - Horsethief Spring (in the Kingston Range).

Precipitation samples could be collected from these stations (particularly the Kingston Range station) to evaluate recharge sources. These precipitation stations would also provide key data for any future investigations on effects of climate change on the Amargosa River and its feeder springs. These locations (along with the existing station in Tecopa) provide good areal coverage 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 the hydrologic monitoring. 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.

4.2.1 Monitoring / River Monitoring Alternative

Monitoring forms the basis for any water management activities in that it is impossible to manage any resource without a basis for what that resource comprises. The recommendations provided below contain provisions for both automated monitoring techniques and regular field monitoring. In desert areas where river channel or spring conditions can radically change as the result of one summer thunderstorm, having regular field observations taking place is key to not only monitor the resource, but to assure that automated data collection devices are working correctly (and to perform maintenance) and that physical conditions on the ground have not changed to the extent that automated data collection is compromised (e.g. river changing course and stream gage station no longer accurately measuring flow).

As described earlier, flow along the Amargosa River will be highly sensitive to changes in groundwater level. Generally, water rises to the surface of the river channel where constrictions are encountered forcing water to the surface. Groundwater monitoring will therefore be an essential component to river management. Additionally, infestation of non-native vegetation such as tamarisk will also have a negative effect on river flow and spring flow where it is present at spring discharge points. Visual monitoring of vegetation, particularly for the presence of tamarisk or other water-using, non-native vegetation will be a key component of river management.

Partner makes the following monitoring recommendations:

- Spring Discharge, Water Level, and Precipitation Monitoring - Flow discharge and groundwater elevation measurements should continue and be collected on a regular basis from the existing suite of springs and wells being monitored in addition to new wells.

- Groundwater Level Measurements should continue to be collected with pressure transducer/data logger installations at all existing (currently in place) and future monitoring wells.

- Visual Monitoring – Photographic and video (where applicable) documentation should be collected from specific locations to identify noticeable changes in the spring and river environments. This will assist in identification of tamarisk or other non-native vegetation encroachment that could affect river and spring flows. Additionally, periodic crosschecking with aerial imagery should be conducted to identify changes to areas not specific to monitoring sites.

- Groundwater Usage – Monitoring existing and proposed groundwater usage throughout the basin both in Nevada and California will be a key monitoring component protective of the Amargosa Basin.

4.2.2 Modeling / River Management Tool

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, non-profit and for-profit private sector constituents and stakeholders. This will enable all future projects to be evaluated using the same tool which is useable in a timely, cost effective manner.

4.2.3 Mitigation Tied to Monitoring

As a general matter, a proposed monitoring program should be attached to some well-reasoned triggers to provide a means to anticipate future action if a problem develops. Therefore, to develop a useful monitoring program. One of the first steps to accomplish this will be the development of a modeling/river management tool. Work on such a tool should begin as soon as possible. That tool then should be used as a basis to identify quantification and potential rates of change for reduction in river flow (surface and groundwater) and to develop mitigation for future projects that is effective and provides sufficient early warning to allow for management changes protective of the AWSR and the wider Amargosa Basin in the Shoshone-Tecopa area.

5 SIGNATURES OF PARTICIPATING PROFESSIONALS

Thank you for the opportunity to be of service. If you have questions regarding this report, please contact the undersigned at (310) 615-4500.

Sincerely,

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TABLES

Table 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)	Elec. Conductivity (uS)	TDS (mg/L)	DO (mg/L)	pH	ORP (mV)	Notes
Springs													
Christian Spg (AM CYN1)	11/17/2010	35.83937	116.22399	1,294	38	meter	23.22	1053	685	7.42	7.93	105.3	North end of Amargosa Canyon in burned area
Christian Spg (AM CYN1)	4/25/2011	35.83937	116.22399	1,294	--	--	22.46	1029	669	8.62	7.94	253.5	North end of Amargosa Canyon in burned area
Christian Spg (AM CYN1)	5/11/2011	35.83937	116.22399	1,294	66.1	bucket	--	--	--	--	--	--	North end of Amargosa Canyon in burned area
Christian Spg (AM CYN1)	9/21/2011	35.83937	116.22399	1,294	40.5	bucket	25.79	1076	700	7.74	8.12	-42.4	North end of Amargosa Canyon in burned area
Christian Spg (AM CYN1)	12/22/2011	35.83937	116.22399	1,294	78	meter	18.73	1009	656	7.96	8.22	77.4	North end of Amargosa Canyon in burned area
Christian Spg (AM CYN1)	1/12/2012	35.83937	116.22399	1,294	67.7	bucket	23.27	573	363	--	--	--	North end of Amargosa Canyon in burned area
Christian Spg (AM CYN1)	5/1/2012	35.83937	116.22399	1,294	80.2	bucket	21	1274	828	--	--	--	North end of Amargosa Canyon in burned area
Christian Spg (AM CYN1)	1/26/2013	35.83937	116.22399	1,294	83.4	bucket	22.44	1020	663	8.4	7.67	--	North end of Amargosa Canyon in burned area
Christian Spg (AM CYN1)	4/19/2013	35.83937	116.22399	1,294	83.4	bucket	22.44	1020	663	8.4	7.67	-106.5	North end of Amargosa Canyon in burned area
Christian Spg (AM CYN1)	9/25/2013	35.83937	116.22399	1,294	61	bucket	23.74	886	576	5.09	7.85	-180.4	North end of Amargosa Canyon in burned area
Christian Spg (AM CYN1)	5/6/2014	35.83937	116.22399	1,294	72.4	bucket	22.2	1278	--	7.15	8.17	68.2	
Christian Spg (AM CYN1)	12/6/2014	35.83937	116.22399	1,294	60	bucket	22.5	1054	527	8.05	nm	--	North end of Amargosa Canyon in burned area
Christian Spg (AM CYN1)	12/8/2015	35.83943	116.22397	1,298	70	visual	20.0	1001	500	5.53	8.02	--	Spring appears to result from accumulation of springs, seeps and pond outflow from zellhoeffer property.
Christian Spg (AM CYN1)	6/4/2016	35.83943	116.22397	1,298	~40	visual	22.6	1012	506	nm	7.95	--	
Christian Spg (AM CYN1)	9/14/2016	35.83937	116.22399	1,294	48	bucket	23.5	925	462	nm	8.04	--	
Christian Spg (AM CYN1)	4/9/2017	35.83943	116.22397	1,298	~40	visual	21.0	1046	523	nm	8.06	--	
Christian Spg (AM CYN1)	1/17/2018	35.83943	116.22397	1,298	80	visual	20.2	927	464	4.08	8.26		
Christian Spg (AM CYN1)	4/27/2018	35.83943	116.22397	1,298	40	visual	23.5	900	449	6.98	8.31		
Christian Spg (AM CYN1)	4/23/2019	35.83943	116.22397	1,298	88.4	bucket	23.5	900	450	0.09	7.96		
Amargosa Canyon Spring 2	1/12/2011	35.83843	116.22237		N/A	--	15.33	1271	826	8.69	8.16	--	
Amargosa Canyon Spring 3	1/12/2011	35.82701	116.21942	1,262	30	visual	16.74	1698	1,104	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	1506	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	1597	1,035	8.57	8.26	-17.8	Southern most Amargosa Canyon spring
Amargosa Canyon Spring 3	5/6/2014	35.82701	116.21942	1,262	9	bucket	20.9	1741	1,229	8.9	8.55	58.5	Southern most Amargosa Canyon spring
Amargosa Canyon Spring 3	10/23/2018	35.82701	116.21942	1,262	10	visual	23.7	1616	808	9.24	8.55	116.2226	
Amargosa Canyon Spring 4	1/12/2011	35.8348	116.2226	1,382	25	visual	26.05	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	1240.000	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	7.7	bucket	28.2	1347	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	8.1	bucket	26.15	1273	828	7.34	8.33	111.3	Amargosa Canyon spring eminating from east canyon wall
Amargosa Canyon Spring 4	5/1/2012	35.8348	116.2226	1,382	9.1	bucket	26.11	1220.000	795	9.93	8.6	28.4	Amargosa Canyon spring eminating from east canyon wall
Amargosa Canyon Spring 4	1/26/2013	35.8348	116.2226	1,382	7	bucket	26.39	1537	999	9.42	8.31	55.2	Amargosa Canyon spring eminating from east canyon wall
Amargosa Canyon Spring 4	4/19/2013	35.8348	116.2226	1,382	7.9	bucket	26.64	1333	867	8.4	7.86	-106.1	Amargosa Canyon spring eminating from east canyon wall
Amargosa Canyon Spring 4	9/25/2013	35.8348	116.2226	1,382	7	bucket	27.73	1100	714	5.44	8.16	-168.5	Amargosa Canyon spring eminating from east canyon wall
Amargosa Canyon Spring 4	5/6/2014	35.8348	116.2226	1,382	7	visual	26.4	1640	1,066	7.04	8.52	38.1	Amargosa Canyon spring eminating from east canyon wall
Amargosa Canyon Spring 4	12/6/2014	35.8348	116.2226	1,382	20	bucket	27.2	1326	663	nm	8.21	--	Amargosa Canyon spring eminating from east canyon wall
Amargosa Canyon Spring 4	12/8/2015	35.8348	116.2226	1,382	3.6	visual	26.5	1268	634	2.30	8.18	--	
Amargosa Canyon Spring 4	6/4/2016	35.8348	116.2226	1,382	12	visual	26.9	1320	662	nm	8.10	--	
Amargosa Canyon Spring 4	9/14/2016	35.83473	116.22274	1,372	nm	visual	28.9	1175	588	nm	8.19	--	Springflow has changed direction
Amargosa Canyon Spring 4	4/9/2017	35.83473	116.22274	1,372	9	visual	24.7	1331	670	nm	8.53	--	
Amargosa Canyon Spring 4	1/17/2018	35.83473	116.22274	1,372	>20	visual	25.4	1133	568	2.59	8.57		
Amargosa Canyon Spring 4	10/23/2018	35.83473	116.22274	1,372	12.5	visual	26.9	1333	666	7.94	8.4		
Amargosa Canyon Spring 5	1/12/2011	35.83602	116.22243	1,372	N/A	--	18.88	1.445	939	4.4	7.81	--	
Amargosa Canyon Spring 5	5/6/2014	35.83602	116.22243	1,372	8-10	visual	20.4	1.647	--	8.32	8.49	--	
Beck Spring	11/19/2010	35.78359	115.93220	4,439	2-3	visual	17.91	0.467	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	1,963	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	1,938	1.71	10.14	-404.7	
Borax Spring	4/30/2012	35.88804	116.25789	1,342	5.7	bucket	30.52	2.740	1,781	3.2	10.31	-217.1	pipe cracked on casing
Borax Spring	1/28/2013	35.88804	116.25789	1,342	5.8	bucket	30.02	3.451	2,242	0.99	10.08	-107.5	pipe cracked on casing
Borax Spring	4/18/2013	35.88804	116.25789	1,342	6.1	bucket	30.44	2.985	1,940	0.49	9.45	-307.2	pipe cracked on casing
Borax Spring	9/23/2013	35.88804	116.25789	1,342	6.1	bucket	30.14	2.498	1,624	0.07	9.74	-324.8	pipe cracked on casing
Borax Spring	5/12/2014	35.88804	116.25789	1,342	8.1	bucket	29.88	3.525	--	0.27	10.02	-260.2	pipe cracked on casing

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Amargosa Basin
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Name	Date of Visit	Latitude	Longitude	Elevation (ft amsl)	Flow (gpm)	Flow Measurement Method*	Temp. (deg C)	Elec. Conductivity (uS)	TDS (mg/L)	DO (mg/L)	pH	ORP (mV)	Notes
Borax Spring	12/5/2014	35.88804	116.25789	1,342	7	bucket	24.7	2.969	1,476	nm	9.74	--	pipe cracked on casing
Borax Spring	12/8/2015	35.88804	116.25789	1,342	9.4	bucket	26.5	2.756	1,372	0.74	9.71	--	Flowing well west of Highway 127
Borax Spring	9/15/2016	35.88804	116.25789	1,342	8.6	bucket	32.5	2.590	1,296	nm	9.66	--	
Borax Spring	1/10/2017	35.88804	116.25789	1,342	7.7	bucket	29.8	3.001	1,496	0.18	9.68	--	
Borax Spring	4/10/2017	35.88804	116.25789	1,342	7.5	bucket	30.3	2.949	1,470	0.11	9.81	--	
Borax Spring	1/17/2018	35.88804	116.25789	1,342	10.5	bucket	29.8	2568	1282	0.05	9.88		
Borax Spring	4/27/2018	35.88804	116.25789	1,342	9	bucket	30	2560	1279	0.12	9.95		
Borax Spring	4/23/2019	35.88804	116.25789	1,342	11.2	bucket	30.8	2713	1355	0.08	9.68		
Borax Spring	10/1/2019	35.88804	116.25789	1,342	16.5	bucket	30.8	2745	1368	0.18	9.82		
Bore Hole Spring	11/11/2010	35.88608	116.23416	1,356	20	visual	47.77	4.156	2,704	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	2,711	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	2,731	1.31	8.68	-74.6	Likely part of Tecopa Hot Spring system
Bore Hole Spring	4/30/2012	35.88608	116.23416	1,356	90	bucket	47.68	3.890	2,529	0.16	8.93	-13.3	Likely part of Tecopa Hot Spring system
Bore Hole Spring	1/25/2013	35.88608	116.23416	1,356	105	meter/visual	46.83	4.852	3,157	1.62	8.85	29.6	Likely part of Tecopa Hot Spring system
Bore Hole Spring	4/18/2013	35.88608	116.23416	1,356	81	meter/visual	47.75	4.202	2,731	0.35	8.47	-143.3	Likely part of Tecopa Hot Spring system
Bore Hole Spring	9/24/2013	35.88608	116.23416	1,356	105.2	meter	46.59	3.571	2,323	0.46	8.48	-240	Likely part of Tecopa Hot Spring system
Bore Hole Spring	5/10/2014	35.88608	116.23416	1,356	148	USGS$^+$	46.3	6.215	2,899	1.10	8.71	44.5	Likely part of Tecopa Hot Spring system
Bore Hole Spring	12/3/2014	35.88608	116.23416	1,356	140	USGS$^+$	41.1	>4.000	>2,000	nm	8.49	--	Likely part of Tecopa Hot Spring system
Bore Hole Spring	12/6/2015	35.88608	116.23416	1,356	nm	visual	36.9	3.893	1,988	2.18	8.57	--	Water is more turbid than past visits, cannot see bottom of uppermost pool. Gage measurement: 12.42
Bore Hole Spring	5/31/2016	35.88608	116.23416	1,356	nm	USGS$^+$	40.9	>4.000	>2,000	1.66	8.52	--	Water disturbed/stirred up by bathers; more algae growth than previous
Bore Hole Spring	9/15/2016	35.88620	116.23439	1,340	80	visual	41.3	3.582	1,794	nm	8.60	--	Water level at source appears low
Bore Hole Spring	1/8/2017	35.88620	116.23439	1,340	>50-60	USGS$^+$	43.2	>4.000	>2,000	0.30	8.61	--	Gage at 12.52; 50-60 GPM + at Tecopa Road
Bore Hole Spring	4/10/2017	35.88620	116.23439	1,340	nm	USGS$^+$	42.4	>4.000	>2,000	1.28	8.74	--	Lots of bathers so substantial cloudiness to water.
Bore Hole Spring	1/16/2018	35.88620	116.23439	1,340	nm	USGS$^+$	40.7	3337	1686	1.55	8.59		
Bore Hole Spring	10/22/2018	35.88620	116.23439	1,340	nm	USGS$^+$	43.9	>4000	>2000	1.76	8.65		
Bore Hole Spring	1/18/2019	35.88620	116.23439	1,340	nm	USGS$^+$	37.6	3815	1904	--	8.76		
Bore Hole Spring	4/23/2019	35.88620	116.23439	1,340	nm	USGS$^+$	46.1	3903	1975	0.07	8.41		
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	
Chappo Spring	5/9/2014	35.94723	116.18992	1,989	~5	visual	26.6	1.025	650	0.83	7.47	82.7	
Chappo Spring	12/5/2014	35.94723	116.18992	1,989	5	visual	21.3	0.786	392	nm	7.65	--	
Chappo Spring	2/19/2016	35.94775	116.18944	2,016	~1	visual	24.4	0.696	348	0.55	7.45	--	
Chappo Spring	10/2/2019	35.94775	116.18944	2,016	1	visual	28.5	715	357	1.57	7.61		
China Ranch Cyn Spring 1	1/13/2011	35.80335	116.14099	1,770	20	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
Cottonrod Seep	2/21/2016	35.97975	116.27260	1,598	2	visual	16.2	1.940	971	nm	8.19	--	
Cottonwood Spring	2/17/2016	35.59139	116.38649	1,647	0.1	visual	13.8	2.857	1,428	4.81	8.05	--	No cottonwood present
Cowboy Seep #1	10/23/2018	35.82038	-116.20439	1,474	0	visual	--	--	--	--	--	--	
Cowboy Seep #2	10/23/2018	35.82097	-116.20862	1,444	<1	visual	--	--	--	--	--	--	
Cowboy Seep #3	10/23/2018	35.82131	-116.20960	1,399	1.5	visual	22.1	1893	946	7.65	7.78	--	
Cowboy Seep #4	10/23/2018	35.82299	-116.21081	1,396	1.5	visual	23.4	1521	760	9.11	8.19	--	
Crystal Spring	11/19/2010	35.79503	115.96176	3,877	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	3,877	13.5	bucket	21.18	0.610	397	5.73	7.52	257.5	Located in the Kingston Range
Crystal Spring	9/22/2011	35.79503	115.96176	3,877	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	3,877	8.3	bucket	21.3	0.607	395	4.26	7.45	153.1	Located in the Kingston Range
Crystal Spring	4/30/2012	35.79503	115.96176	3,877	5.9	bucket	21.19	0.586	381	6.06	7.61	34.2	Located in the Kingston Range
Crystal Spring	1/25/2013	35.79503	115.96176	3,877	6.8	bucket	20.86	0.732	476	5.68	7.43	50.1	Located in the Kingston Range
Crystal Spring	4/21/2013	35.79503	115.96176	3,877	5.4	bucket	21.19	0.638	415	5.26	6.93	-100.5	Located in the Kingston Range
Crystal Spring	9/24/2013	35.79503	115.96176	3,877	7.1	bucket	21.52	0.538	349	3.51	7.3	-192.7	Located in the Kingston Range
Crystal Spring	5/4/2014	35.79503	115.96176	3,877	4.3	bucket	21.2	0.880	--	3.54	7.43	--	Located in the Kingston Range
Crystal Spring	12/7/2014	35.79503	115.96176	3,877	>5	bucket	20.8	0.644	322	--	7.48	--	Located in the Kingston Range
Crystal Spring	12/8/2015	35.79503	115.96176	3,877	~2	bucket	20.7	0.629	315	3.65	7.50	--	Spring issues from adit below mining operations, was previously piped to trough/pool that is no longer used.
Crystal Spring	5/31/2016	35.79503	115.96176	3,877	~5	visual	22.8	0.635	318	4.80	7.46	--	

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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)	Elec. Conductivity (uS)	TDS (mg/L)	DO (mg/L)	pH	ORP (mV)	Notes
Crystal Spring	9/15/2016	35.79503	115.96176	3,877	1,5	visual	21.7	0.620	3.09	nm	7.63	--	Lowest Zdon has ever observed; Heavy cattle impact - heavily used by livestock since June 2016; Substantial livestock; Scat in Spring outflow; Stream within fenced enclose, multiple breaches in fence; Scat also present at source; Worse disturbance from livestock to date; Lots of bee activity
Crystal Spring	1/8/2017	35.79503	115.96176	3,877	2+	visual	20.5	0.703	352	0.36	7.37	--	Much fresh livestock scat within exclosure.
Crystal Spring	4/11/2017	35.79503	115.96176	3,877	~5	visual	21.2	0.656	329	1.14	7.60	--	
Crystal Spring	1/15/2018	35.79503	115.96176	3,877	8	visual	21.2	612	306	3.75	7.61		
Crystal Spring	4/26/2018	35.79503	115.96176	3,877	8	visual	23.9	588	298	4.85	7.62		
Crystal Spring	10/22/2018	35.79503	115.96176	3,877	10	visual	21.6	663	332	3.06	7.41		
Crystal Spring	1/9/2019	35.79503	115.96176	3,877	5	visual	20.5	599	295	--	7.88		
Crystal Spring	4/22/2019	35.79503	115.96176	3,877	10	visual	21.3	598	299	3.63	7.56		
Crystal Spring	10/1/2019	35.79503	115.96176	3,877	8	visual	21.2	594	297	2.85	6.81		
Denning Spring	3/17/2016	35.58727	116.46915	1,921	0.1	visual	nm	nm	nm	nm	nm	--	Spring featrue on terrace above surrounding larger washes. Current discharge is evapotranspiration though!
Dodge City Spring	5/4/2014	35.88018	116.22955	1,387	~20+	visual	23.0	4.141	nm	8.20	8.79	80.4	Located near Tecopa Hot Springs
Dodge City Spring	12/3/2014	35.88018	116.22955	1,387	20	visual	23.7	3.832	1,914	nm	8.63	--	Located near Tecopa Hot Springs
Dodge City Spring	12/6/2015	35.88018	116.22955	1,387	8	visual	23.0	3.564	1,780	6.60	8.60	--	
Dodge City Spring	5/31/2016	35.88018	116.22955	1,387	8	visual	24.0	3.955	1,983	4.36	8.65	--	Spring source area choked with 3 square bulrush growth; Yerba manza present and vibrant; All vegetation vibrant
Dodge City Spring	9/15/2016	35.88018	116.22955	1,399	1.5	visual	27.6	3.324	1,662	nm	8.52	--	
Dodge City Spring	1/8/2017	35.88018	116.22955	1,399	~5	visual	22.4	3.725	1,862	2.55	8.60	--	
Dodge City Spring	4/10/2017	35.88018	116.22955	1,399	~8	visual	23.2	>4.000	>2,000	10.80	8.67	--	
Dodge City Spring	1/6/2018	35.88018	116.22955	1,399	6	visual	21	3499	1749	3.49	8.83		
Dodge City Spring	4/27/2018	35.88018	116.22955	1,399	10	visual	23.5	3234	1617	10.28	8.79		
Dodge City Spring	10/22/2018	35.88018	116.22955	1,399	5	visual	26	3793	1897	2.03	8.6		
Dodge City Spring	1/8/2019	35.88018	116.22955	1,399	10	visual	23.2	3333	1667	--	8.78		
Dodge City Spring	4/23/2019	35.88018	116.22955	1,399	5	visual	23.2	3418	1709	0.38	8.67		
Dodge City Spring	10/1/2019	35.88018	116.22955	1,399	7.6	bucket	26.3	3459	1730	2.09	8.75		
East Tecopa Seep	12/6/2015	35.8669	116.2226	1,423	<1	visual	12.9	1.888	937	nm	7.84	--	
East Tecopa Seep	6/4/2016	35.8669	116.2226	1,423	<1	visual	29.6	1.744	871	2.21	7.92	--	Discharge zone along fault - bare soil also saturated despite high evaportranspiration conditions. Ambient air temperature approximately 105^{o}F
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
Five Springs	5/4/2012	36.46457	116.3193	2,349	22.1	bucket	34.52	0.664	432	5.26	7.68	30.1	Located in Ash Meadows
Five Springs	1/24/2013	36.46457	116.3193	2,349	23.8	bucket	34.18	0.826	536	4.68	7.69	38.6	Located in Ash Meadows
Five Springs	4/24/2013	36.46457	116.3193	2,349	23.8	bucket	34.41	0.718	467	4.18	7.25	-105.3	Located in Ash Meadows
Five Springs	9/23/2013	36.46457	116.3193	2,349	21	bucket	34.55	0.607	395	2.83	7.31	-195.6	Located in Ash Meadows
Five Springs	5/5/2014	36.46457	116.3193	2,349	23.5	bucket	34.3	0.873	566	3.83	7.59	97.3	Located in Ash Meadows
Five Springs	12/7/2014	36.46457	116.3193	2,349	23	bucket	33.6	0.729	364	--	7.44	--	Located in Ash Meadows
Five Springs	6/1/2016	36.46457	116.3193	2,349	20	bucket	33.1	0.741	376	0.81	7.21		
Goldenrod 1 (shoshone)	2/20/2016	35.97987	116.27299	1,598	5	visual	19.3	1.408	704	1.56	7.79	--	
Goldenrod 2 (shoshone)	2/20/2016	35.97984	116.27313	1,598	n	visual	18.7	1.569	787	0.25	7.85	--	
Goldenrod 3 (shoshone)	2/20/2016	35.97997	116.27264	1,598	10	visual	18.4	1.552	777	1.35	8.01	--	
Goldenrod 4 (shoshone)	2/20/2016	35.97986	116.27268	1,598	5	visual	20.1	2.193	1,094	0.75	7.59	--	
Grimshaw Well	4/27/2018	35.88814	116.24062	1,343	<1	visual	21.9	4000+	2000+	0.23	21.9		
Historic Spring	2/20/2016	35.98044	116.27367	1,605	13	bucket	32.4	1.398	698	1.42	7.48	--	
Historic Spring	6/4/2016	35.98044	116.27367	1,605	~15	visual	32.9	1.567	784	2.30	7.53	--	
Historic Spring	9/18/2016	35.98044	116.27367	1,605	20	bucket	31.7	1.594	797	nm	7.19	--	
Historic Spring	1/10/2017	35.98044	116.27367	1,605	12	bucket	31.6	1.597	799	2.99	7.44	--	Shoshone Spring Complex
Historic Spring	4/10/2017	35.98044	116.27367	1,605	nm	bucket	32.9	1.564	783	0.64	7.47	--	
Historic Spring	1/17/2018	35.98044	116.27367	1,605	8.2	bucket	32.3	1365	683	1.65	7.48		
Historic Spring	4/27/2018	35.98044	116.27367	1,605	17	bucket	31.8	1483	742	5.37	7.56		
Historic Spring	1/8/2019	35.98044	116.27367	1,605	20	bucket	31.3	1483	740	--	7.64		
Historic Spring	4/23/2019	35.98044	116.27367	1,605	21.8	bucket	31.9	1431	715	4.25	7.48		
Homestead Spring	1/9/2017	35.85437	116.22075	1,401	<1 + 0.1	visual	19.4	1.959	980	3.88	8.25	--	Quite a bit of water in three square bulrush not in low point that is inaccessible
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

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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
Horse Thief Spring	4/30/2012	35.77294	115.88824	4,637	8.8	bucket	16.72	0.429	279	3.96	7.2	62	Located in the Kingston Range
Horse Thief Spring	1/25/2013	35.77294	115.88824	4,637	--	--	16.71	0.540	351	<4	6.7	60	Located in the Kingston Range
Horse Thief Spring	4/18/2013	35.77294	115.88824	4,637	--	--	16.64	0.500	326	2.54	6.47	-108.6	Located in the Kingston Range
Horse Thief Spring	9/24/2013	35.77294	115.88824	4,637	--	--	17.86	0.401	261	1.69	6.84	-218.4	Located in the Kingston Range
Horse Thief Spring	5/4/2014	35.77294	115.88824	4,637	10	visual	16.8	0.4837	--	1.70	6.95	--	Located in the Kingston Range
Horse Thief Spring	12/7/2014	35.77294	115.88824	4,637	7	bucket	12.8	1.186	594	nm	7.19	--	Located in Kingston Range
Horse Thief Spring	12/8/2015	35.77294	115.88824	4,637	1	visual	17.3	0.480	240	3.51	7.05	--	
Horse Thief Spring	5/31/2016	35.77294	115.88824	4,637	3	bucket	21.1	0.501	252	2.75	7.07	--	
Horse Thief Spring	9/15/2016	35.77294	115.88824	4,600	1	visual	18.5	0.439	221	nm	7.56	--	Parameters measured from outflow stream below steel tank; Bee swarm at tank
Horse Thief Spring	1/8/2017	35.77247	115.88913	4,600	1	visual	12.3	0.518	260	0.02	7.08	--	No Flow through water system measured at source
Horse Thief Spring	4/11/2017	35.77294	115.88824	4,600	7.5	bucket	17.7	0.4994	248	2.40	7.27	--	
Horse Thief Spring	1/15/2018	35.77294	115.88824	4,600	2	bucket	12.3	444	222	2.19	7.14		
Horse Thief Spring	4/26/2018	35.77294	115.88824	4,600	--	N/A	--	--	--	--	--		
Horse Thief Spring	10/22/2018	35.77294	115.88824	4,600	5	bucket	17.6	508	254	2.4	7.1		
Horse Thief Spring	4/22/2019	35.77294	115.88824	4,600	11.5	bucket	17.6	462	231	1.87	7.35		
Horse Thief Spring	10/1/2019	35.77294	115.88824	4,600	13.5	bucket	17.7	473	236	1.56	6.81		
Ibex Spring	11/4/2010	35.77211	116.4111	1,133	no flow	visual	18.78	2.486	1,617	0.98	8.76	30.5	
Ibex Spring	4/24/2011	35.77211	116.4111	1,133	no flow	visual	16.35	2.234	1,452	2.99	7.98	114.4	
Ibex Spring	5/11/2014	35.77211	116.4111	1,133	no flow	visual	16.7	1.958	1,515	2.40	8.44	108.3	
Kingston Spring	2010	35.62071	115.96889	2,272	<1	visual	16.07	1.524	1,194	4.01	7.23	--	
Kingston Spring	2/18/2016	35.62071	115.96889	2,272	<1	visual	16.9	1.601	802	2.98	9.17	--	Surface soils fully saturated.
Kingston Spring	9/18/2016	35.62071	115.96889	2,272	0	visual	N/A	N/A	N/A	N/A	N/A	--	Dry, wet ground present. Could easily dig to water. Winter seep; Area dry, seasonal due to plant intake.
Kingston Spring	4/29/2018	35.62071	115.96889	2,272	<1	visual	18.7	1760	891	5.02	7.39		
Old Mormon Spring	2/18/2016	35.51538	116.25577	2,079	<1	visual	nm	nm	nm	nm	nm	--	Fault seep on rangefront may have been dewatered. Trough and pipe (unused now) at site
One Palm Seep	12/7/2015	35.86019	116.22212	1,432	<1	visual	nm	nm	nm	nm	nm	nm	
One Palm Seep	4/27/2018	35.86019	116.22212	1,432	0	visual	nm	nm	nm	nm	nm		
One Palm Seep	10/22/2018	35.86019	116.22212	1,432	0	visual	nm	nm	nm	nm	nm		
Owl Hole Spring	10/15/1917	35.63931	116.64766	1,911	<1	visual	nm	nm	1,804	nm	nm	nm	
Owl Hole Spring	6/15/1953	35.63931	116.64766	1,911	<1	visual	24	2.430	1,540	nm	7.4	nm	
Owl Hole Spring	2/11/1967	35.63931	116.64766	1,911	<1	visual	14	3.060	1,960	nm	8.5	-73	
Owl Hole Spring	11/16/2010	35.63931	116.64766	1,911	<1	visual	17.01	4.098	2,664	0.29	6.86	-73	
Owl Hole Spring	5/11/2014	35.63931	116.64766	1,911	<1	visual	13.7	7.543	4,901	1.06	7.49	116.2	
Owl Hole Spring	2/17/2016	35.63948	116.64758	1,943	<1	visual	14.4	3.357	1,681	0.51	7.00	--	Appears to be excavation encountering local water table. Spring area condition improved since last visit - site cleaned up.
Owl Hole Spring	4/27/2018	35.63948	116.64758	1,943	<1	visual	25.3	2845	1427	10.41	8.34		
Parker Ranch Spring	6/2/2016	36.96480	116.72412	3,603	~45	meter	29.7	1.232	618	1.40	7.43	--	
Parker Ranch TNC #1 (NV)	6/2/2016	36.96725	116.72338	3,594	<1	visual	30.6	1.214	608	1.71	7.48	--	
Parker Ranch TNC #2 (NV)	6/2/2016	36.96751	116.72362	3,594	<1	visual	nm	nm	nm	nm	nm	nm	
Phragmites Seep	2/21/2016	35.97634	116.27470	1,581	<1	visual	10.5	2.639	1,319	10.1	8.44	--	Another spring at head of Phragmites. (Phrag 2)
Phragmites Seep	6/4/2016	35.97634	116.27470	1,581	<1	visual	nm	nm	nm	nm	nm	--	
Phragmites Seep	9/18/2016	35.97634	116.27470	1,581	<1	visual	N/A	N/A	N/A	N/A	N/A	--	
Red Trail Seep	2/21/2016	35.98158	116.26932	1,585	<1	visual	15.2	3.291	1,646	2.71	8.63	--	River edge (above channel) seep, maybe affecte by recent runoff.
Red Trail Seep	6/4/2016	35.98158	116.26932	1,585	<1	visual	20.5	3.717	1,860	5.60	7.77	--	
Red Trail Seep	9/18/2016	35.98158	116.26932	1,585	<1	visual	15.9	3.563	1,792	nm	7.82	--	Water lower in channel than in previous visits, with bench adjacent to depression dry unlike former visits.
Red Trail Seep	1/10/2017	35.98158	116.26932	1,585	<1	visual	17.3	3.445	1,735	5.81	8.37	--	
Resting Spring	1/23/2011	35.87728	116.15757	1,767	150	bucket	26.84	0.923	600	5.62	8.36	157.8	
Revert Spring	6/2/2016	36.91551	116.75311	3,890	311	meter	28.7	0.573	287	3.37	8.48	--	
Riley Spring	12/6/2015	35.95215	116.26620	1,503	0.1	visual	nm	nm	nm	nm	nm	--	Spring site is discharge zone which is impenetrable thricket of mesquite, catclaw and other vegetation; Mesquite is stressed and/or dying.
Rhodes Spring	11/2010	35.93291	116.52482	1,929	N/A	N/A	18.80	1.227	797	1.15	7.67	103.7	
Rhodes Spring	5/10/2014	35.93291	116.52482	1,929	N/A	N/A	24.2	1.730	--	2.0	8.32	--	
Salsberry Spring	1/10/2011	35.93162	116.41820	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

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Amargosa Basin
California/Nevada

Name	Date of Visit	Latitude	Longitude	Elevation (ft amsl)	Flow (gpm)	Flow Measurement Method*	Temp. (deg C)	Elec. Conductivity (uS)	TDS (mg/L)	DO (mg/L)	pH	ORP (mV)	Notes
Salt Spring	1/14/1918	35.62622	116.28041	550	N/A	N/A	nm	nm	5,390	nm	nm	--	
Salt Spring	4/21/1954	35.62622	116.28041	550	N/A	N/A	nm	9.010	5,800	nm	8.0	--	
Salt Spring	5/19/1955	35.62622	116.28041	550	N/A	N/A	27.0	9.520	6,400	nm	7.6	--	
Salt Spring	9/26/1955	35.62622	116.28041	550	N/A	N/A	23.0	9.800	7,300	nm	7.8	--	
Salt Spring	5/22/1956	35.62622	116.28041	550	N/A	N/A	28.0	9.520	nm	nm	8.3	--	
Salt Spring	11/14/1956	35.62622	116.28041	550	N/A	N/A	17.0	11.800	8,540	nm	7.9	--	
Salt Spring	5/9/1957	35.62622	116.28041	550	N/A	N/A	20.0	8.900	nm	nm	7.7	--	
Salt Spring	5/19/1958	35.62622	116.28041	550	N/A	N/A	22.0	9.630	nm	nm	7.9	--	
Salt Spring	5/12/1959	35.62622	116.28041	550	N/A	N/A	31.0	10.100	6,500	nm	7.9	--	
Salt Spring	5/13/1960	35.62622	116.28041	550	N/A	N/A	28.0	12.500	8,210	nm	7.8	--	
Salt Spring	3/25/1963	35.62622	116.28041	550	N/A	N/A	23.0	12.000	8,000	nm	8.1	--	
Salt Spring	5/4/1964	35.62622	116.28041	550	N/A	N/A	25.0	12.400	8,020	nm	8.2	--	
Salt Spring	4/25/1967	35.62622	116.28041	550	N/A	N/A	19.0	10.100	6,700	nm	7.7	--	
Salt Spring	11/5/2010	35.62622	116.28041	550	~1	visual	20.48	6.514	4,235	0.74	7.94	-176.9	
Salt Spring	5/10/2011	35.62622	116.28041	550	~1	visual	19.46	8.944	5,814	5.79	7.7	196.2	
Salt Spring	5/11/2014	35.62622	116.28041	550	~5	visual	26.3	10.690	6,793	8.34	8.30	124.5	
Salt Spring	12/5/2015	35.62622	116.28041	550	~5	visual	10.4	>4.000	>2,000	13.61	8.21	--	
Salt Spring	5/31/2016	35.62614	116.28089	550	<1	visual	24.0	>4.000	>2,000	5.18	8.04	--	
Salt Spring	9/18/2016	35.62614	116.28089	526	<1	visual	N/A	N/A	N/A	N/A	N/A	--	a.k.a "Salt Creek" or "Salt Creek Spring" Dry channels - minor stagnant water not reliable for field parameters due to shallowness for probe and bio debris
Salt Spring	1/10/2017	35.62614	116.28089	526	5	visual	11.1	>4.000	>2,000	11.96	7.96	--	Measured at trail bridge, diffuse surface water where channel(s) intersect w.t.
Salt Spring	4/10/2017	35.62622	116.28041	550	<1	visual	13.4	>4.000	>2,000	7.1	8.16	--	
Salt Spring	1/15/2018	35.62622	116.28041	550	10	visual	13.2	4000+	2000+	10.41	7.96		
Salt Spring	4/27/2018	35.62622	116.28041	550	<1	visual	--	--	--	--	--		
Salt Spring	10/17/2018	35.62622	116.28041	550	0	visual	--	--	--	--	--		
Salt Spring	1/8/19	35.62622	116.28041	550	10	visual	14	4000+	2000+	--	7.08		
Salt Spring	4/23/2019	35.62622	116.28041	550	<1	visual	18	4000+	2000+	4.45	7.57		
Salt Spring	9/30/2019	35.62622	116.28041	550	0	visual							
Saratoga Spring	11/4/2010	35.68090	116.42254	207	unknown	visual	28.8	4.73	3,075	2.49	7.71	259.1	
Scofield Spring	5/31/2016	35.87350	116.12078	2,051	<1	visual	nm	nm	nm	nm	nm	--	First identification of this spring.
Scofield Spring	1/10/2017	35.87357	116.12075	2,051	<1	visual	15.6	1.417	708	4.37	7.43	--	Air temperature greater than water temperature (shaded)
Scofield Spring	10/21/2018	35.87357	116.12075	2,051	<1	visual	22.5	1051	528	0.61	7.29		
Scofield Spring	4/22/2019	35.87357	116.12075	2,051	<1	visual	21.4	992	494	0.57	7.36		
Sheep Creek Spring	10/16/1917	35.58858	116.36027	1,703	nm	N/A	nm	nm	860	nm	nm	--	
Sheep Creek Spring	10/1918	35.58858	116.36027	1,703	nm	N/A	22	nm	nm	nm	nm	--	
Sheep Creek Spring	13/11/1953	35.58858	116.36027	1,703	nm	N/A	nm	nm	860	nm	nm	--	
Sheep Creek Spring	2/10/1967	35.58858	116.36027	1,703	--	N/A	20.0	1.130	801	nm	7.9	--	
Sheep Creek Spring	11/5/2010	35.58858	116.36027	1,703	5	visual	23.10	0.614	400	8.57	9.02	62.5	
Sheep Creek Spring	4/24/2011	35.58858	116.36027	1,703	5	visual	21.40	1.216	789	7.67	7.78	188.2	
Sheep Creek Spring	2/17/2016	35.58863	116.36047	1,719	15	visual	18.6	1.083	541	2.45	8.09	--	Has multiple spring vents feeding creek - flow greatest below confluence.
Sheep Creek Spring	4/29/2018	35.58863	116.36047	1,719	10	visual	21.8	1111	555	0.9	7.61		
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	1,056	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
Shoshone Spring	5/1/2012	35.98056	116.27384	1,611	104***	bucket	33.51	1.477	960	6.77	7.68	16.7	This is from the Shoshone Spring source
Shoshone Spring	1/29/2013	35.98056	116.27384	1,611	--	--	33.31	1.847	1,201	5.85	7.66	30.7	This is from the Shoshone Spring source
Shoshone Spring	5/2/2013	35.98056	116.27384	1,611	--	--	33.47	1.601	1,040	4.5	7.41	-97.1	This is from the Shoshone Spring source
Shoshone Spring	9/25/2013	35.98056	116.27384	1,611	--	--	33.62	1.35	878	2.55	7.23	-182.1	This is from the Shoshone Spring source
Shoshone Spring	5/9/2014	35.98056	116.27384	1,611	250+	N/A	32.3	2.088	--	2.99	7.51	--	
Shoshone Spring	5/12/2014	35.98056	116.27384	1,611	--	--	32.3	1.831	1,190	2.99	7.51	149.4	This is from the Shoshone Spring source
Shoshone Spring (dev)	12/6/2014	35.98056	116.27384	1,611	60	bucket	33.7	1.566	782	--	7.26	--	
Shoshone Spring (undev)	12/6/2014	35.98056	116.27384	1,611	145	meter	31.8	1.586	788	--	7.28	--	
Shoshone Spring	12/6/2014	35.98056	116.27384	1,611	205+	N/A	33.7	1.566	788	nm	7.26	--	
Shoshone Spring	2/21/2016	35.98056	116.27384	1,615	260	pipe meas./visual	32.3	1.416	708	nm	7.64	--	According to R. Sorells, spring does fluctuate.
Wildhorse 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 flow out of spring box
Wildhorse Spring	4/26/2011	35.78814	115.99752	3,066	2-3	visual	--	--	--	--	--	--	Data from flow out of spring box

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Wildhorse Spring	5/9/2014	35.78814	115.99752	3,066	dry	visual	--	--	--	--	--	--	Data from flow out of spring box
Slough Spring	1/28/2013	36.28748	116.37854	2,024	<5	visual	21.17	1.653	1,074	0.97	8.66	--	
Slough Spring	4/24/2013	36.28748	116.37854	2,024	<5	visual	21.56	1.432	930	<1	7.67	--	
Slough Spring	9/23/2013	36.28748	116.37854	2,024	<5	visual	21.94	1.219	792	0.4	8.48	--	
Slough Spring	5/5/2014	36.28748	116.37854	2,024	<5	visual	21.6	1.740	1,131	0.14	8.74	--	
Slough Spring	4/7/2016	36.28748	116.37854	2,024	~2	visual	22.8	2.531	1,251	nm	8.65	--	
Still Spring	6/3/2016	35.95903	116.25961	1,511	<1	visual	nm	nm	nm	nm	nm	--	Former site of a still.
Stormy Spring	12/7/2015	35.85212	116.22059	1,378	<1	visual	7.3	2.726	1,379	2.93	7.95	--	
Tecopa Hot Spring at TNC Trailer	11/11/2010	35.87890	116.23812	1,332	6**	bucket	40.76	4.306	2,799	0.84	8.61	120.7	Sample from Amargosa Conservancy Trailer spring outlet
Tecopa Hot Spring at TNC Trailer	9/21/2011	35.87890	116.23812	1,332	5.1**	bucket	38.85	6.400	4,100	2.74	9.18	-71.1	Sample from Amargosa Conservancy Trailer spring outlet
Tecopa Hot Spring at TNC Trailer	4/30/2012	35.87890	116.23812	1,332	4.9**	bucket	41.2	3.525	2,311	3.54	8.96	20	Sample from Amargosa Conservancy Trailer spring outlet
Tecopa Hot Spring at TNC Trailer	1/29/2013	35.87890	116.23812	1,332	5.4**	bucket	38.02	5.000	3,250	3.48	8.87	32.9	Sample from Amargosa Conservancy Trailer spring outlet
Tecopa Hot Spring at TNC Trailer	9/23/2013	35.87890	116.23812	1,332	5.3**	bucket	41.38	3.675	2,389	1.7	8.43	-237.4	Sample from Amargosa Conservancy Trailer spring outlet
Tecopa Hot Spring at TNC Trailer	5/10/2014	35.87890	116.23812	1,332	5-10	visual	40.6	2.390	2,990	0.23	8.71	60.7	Sample from Amargosa Conservancy Trailer spring outlet
Tecopa Hot Spring at TNC Trailer	12/5/2014	35.87890	116.23812	1,332	~8	bucket	39.6	>4.000	>2,000	nm	8.43	--	Sample from Amargosa Conservancy Trailer spring outlet
Tecopa Hot Spring at TNC Trailer	12/7/2015	35.87890	116.23812	1,332	6	bucket	39.4	>4.000	>2,000	0.09	8.43	--	Water from piped system on property. Discharges to wetland between property and Grimshaw lake. 135+ species of birds have been observed here. Amargosa Vole has been seen here. Coyotes, various lizards, kit fox have also been observed. (Len Warren, 2015).
Tecopa Hot Spring at TNC Trailer	9/14/2016	35.87890	116.23812	1,332	6.6	bucket	41.4	3.850	1,922	nm	8.59	--	
Tecopa Hot Spring (County)	12/7/2015	35.87191	116.232145	1,415	30	bucket	40.2	3.076	1,535	1.56	7.93	--	
Tecopa Hot Spring (County)	1/9/2017	35.87191	116.232145	1,415	~30	visual	40.3	3.295	1,695	nm	7.93	--	
Tecopa Hot Spring (County)	4/10/2017	35.87191	116.23215	1,415	39	bucket	41.5	3.187	1,598	0.55	8.13	--	
Thom Spring	11/11/2010	35.85661	116.22677	1,408	5	visual	24.81	1.571	1,021	2.77	7.63	148.3	Data from flowing water within the vegetation
Thom Spring	4/30/2012	35.85661	116.22677	1,408	~2	visual	24.9	1.478	960	3.66	6.79	74.9	Data from flowing water within the vegetation
Thom Spring	1/28/2013	35.85661	116.22677	1,408	<5	visual	28.63	1.819	1,182	2.8	7.73	32.9	Data obtained near modified outflow
Thom Spring	4/30/2013	35.85661	116.22677	1,408	<5	visual	27.96	1.601	1.040	1.83	7.2	-141.5	Data obtained near modified outflow
Thom Spring	9/25/2013	35.85661	116.22677	1,408	<5	visual	29.09	1.34	871	1.13	7.35	-209.9	Data obtained near modified outflow
Thom Spring	5/5/2014	35.85661	116.22677	1,408	5	visual	27.7	1.965	1,229	1.40	7.63	83	Data obtained near modified outflow
Thom Spring	12/3/2014	35.85661	116.22677	1,408	5	visual	28.5	1.572	787	nm	7.43	--	Data obtained near modified outflow
Thom Spring	12/7/2015	35.85661	116.22677	1,406	1	visual	16.2	1.630	814	6.14	7.75	--	This area is known to be used by Long-eared and Great Horned Owls
Thom Spring	5/31/2016	35.85661	116.22677	1,406	<1	visual	24.8	1.672	829	nm	7.57	--	
Thom Spring	9/15/2016	35.85661	116.22677	1,406	<1	visual	25.9	1.382	691	nm	7.64	--	
Thom Spring	1/9/2017	35.85092	116.22320	1,369	1	visual	23.0	1.876	965	2.21	7.70	--	Parameters measured from immediate source - not same locations as past.
Thom Spring	4/10/2017	35.85609	116.22342	1,408	<1	visual	25.2	1.588	796	3.36	7.75	--	
Thom Spring	1/16/2018	35.85609	116.22342	1,408	<1	visual	17	1425	712	6.76	8.06		
Thom Spring	4/27/2018	35.85609	116.22342	1,408	<1	visual	27.9	1347	676	1.31	7.68		
Thom Spring	10/22/2018	35.85609	116.22342	1,408	<1	visual	21.5	1617	809	2.46	7.94		
Thom Spring	1/8/2019	35.85609	116.22342	1,408	<1	visual	27.5	1351	676	--	7.68		
Thom Spring	4/22/2019	35.85609	116.22342	1,408	<1	visual	27.1	1458	728	3.42	8.08		
Thom Spring	9/30/2019	35.85609	116.22342	1,408	1	visual	17	1362	679	1.82	8.44		
Torrance Rch @ Boardwalk	6/2/2016	37.00390	116.72397	3,665	16	meter	20.9	0.852	424	5.57	8.07	--	
Torrance Rch @ Kiosk	6/2/2016	37.00304	116.72456	3,669	0.1	visual	22.3	1.289	644	2.37	7.89	--	
Tule Spring	11/2010	35.81691	116.0554	2,326	<1	visual	16.43	0.878	571	0.47	7.51	--	
Tule Spring	5/9/2014	35.81691	116.0554	2,326	<1	visual	20	1.031	nm	0.37	7.44	--	
Tule Spring	2/19/2016	35.81691	116.0554	2,326	<1	visual	18.1	0.737	368	0.44	7.53	--	Larvae in pool, water has notable odor.
Tule Spring	5/31/2016	35.81691	116.0554	2,326	<1	visual	nm	nm	nm	nm	nm	--	Water present, but insufficient for data collection
Tule Spring	9/17/2016	35.81691	116.05540	2,326	<1	visual	22.8	1.650	857	nm	7.23	--	
Tule Spring	1/8/2017	35.81691	116.05546	2,326	<1	visual	15.2	0.947	473	0.61	6.91	--	Organic odor when water disturbed
Tule Spring	4/11/2017	35.81691	116.05540	2,326	<1	visual	19.6	0.796	398	1.10	7.56	--	Most water observed during 2010 - present - has been dug-out since last visit.
Tule Spring	1/5/2018	35.81691	116.05540	2,326	<1	visual	18.8	830	415	0.5	7.47		
Tule Spring	4/26/2018	35.81691	116.05540	2,326	<1	visual	23.4	865	435	0.21	7.3		
Tule Spring	10/18/2018	35.81691	116.05540	2,326	<1	visual	19.6	1012	506	0	7.2		
Tule Spring	1/9/2019	35.81691	116.05540	2,326	<1	visual	--	--	--	--	--		
Tule Spring	4/22/2019	35.81691	116.05540	2,326	<1	visual	22.2	1809	1061	0	7.66		

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Tule Spring	10/1/2019	35.81691	116.05540	2,326	<1	visual	nm	nm	nm	nm	nm	nm	
Twelvemile Spring	11/14/2010	36.02172	116.15531	2,240	<1	visual	19.23	0.712	520	1.38	7.66	-141	Data from shallow puddle
Twelvemile Spring	2/19/2016	36.02195	116.15530	2,208	<1	visual	21.9	0.813	411	3.23	7.57	--	Water level data from monitoring well downloaded in December.
Twelvemile Spring	6/1/2016	36.02195	116.15530	2,208	<1	visual	32.2	0.933	463	0.26	7.18	--	
Twelvemile Spring	9/17/2016	36.02195	116.15530	2,208	<1	visual	25.0	0.907	451	nm	7.24	--	Empty plastic water bottle. While driving out followed by likely illegal growers.
Twelvemile Spring	1/8/2017	36.02195	116.15530	2,208	<1	visual	19.3	1.065	522	0.85	7.35	--	Recent footprints/bootprints, approximate size 10 male
Twelvemile Spring	4/11/2017	36.02195	116.15530	2,208	<1	visual	25.9	0.640	320	0.08	7.25	--	
Twelvemile Spring	4/26/2018	36.02195	116.15530	2,208	<1	visual	25.9	640	320	0.08	7.25		
Twelvemile Spring	10/22/2018	36.02195	116.15530	2,208	<1	visual	23.8	813	408	1.35	7.45		
Twelvemile Spring	4/22/2019	36.02195	116.15530	2,208	<1	visual	22.3	716	357	0.08	7.44		
Twelvemile Spring	10/1/2019	36.02195	116.15530	2,208	<1	visual	24.8	701	354	0.13	7.36		
Upper Wild Horse Spring	12/8/2015	35.78515	115.99353	3,369	<1	visual	9.8	0.87	435	2.68	7.59	--	Spring consists of three parallel drainages (shallow) with phragmites. The southernmost has the most surface seepage. Possible fault trending N45E
Vole Spring	12/7/2015	35.85092	16.22320	1,369	5+	visual	18.6	1.809	906	7.26	8.28	--	
Vole Spring	6/3/2016	35.85038	116.22377	1,369	<1	visual	23.0	1.853	927	6.61	8.50	--	
Vole Spring	9/15/2016	35.85032	116.22372	1,369	1	visual	23.0	1.640	826	nm	8.54	--	Numerous pipes in area.
Vole Spring	1/9/2017	35.85092	116.22320	1,369	0.1	visual	17.5	1.853	925	7.46	8.37	--	
Vole Spring	4/10/2017	35.85092	116.22320	1,369	3	visual	21.4	1.831	926	11.60	8.60	--	
Vole Spring	1/16/2018	35.85092	116.22320	1,369	20	visual	19.2	1642	820	7.29	8.63		
Vole Spring	4/27/2018	35.85092	116.22320	1,369	20	visual	22.6	1583	792	10.72	8.71		
Vole Spring	4/23/2019	35.85092	116.22320	1,369	3	visual	23.9	1680	842	8.18	8.48		
West Side Spring	5/6/2014	35.84324	116.22879	1,301	N/A	N/A	18.0	1.322	--	4.91	7.98	--	Taken from channel below the spring source
Wild Bath Spring	11/11/2010	35.87277	116.21932	1,424	1.7	bucket	29.88	1.642	1,067	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	1,083	5.59	7.83	-2.2	Tub located off Furnace Creek Road behind Tecopa Hot Springs
Wild Bath Spring	5/5/2012	35.87277	116.21932	1,424	1.3	bucket	34.89	1.559	1,012	5.64	8.37	16.2	Tub located off Furnace Creek Road behind Tecopa Hot Springs
Wild Bath Spring	1/25/2013	35.87277	116.21932	1,424	<2	visual	36.53	1.906	1,024	4.52	7.94	52.8	Tub covered with plastic tarp
Wild Bath Spring	5/4/2013	35.87277	116.21932	1,424	<2	visual	33.83	1.633	1,061	3.97	7.81	-99.8	Tub located off Furnace Creek Road behind Tecopa Hot Springs
Wild Bath Spring	9/25/2013	35.87277	116.21932	1,424	<2	visual	30.76	1.403	911	5.0	8.07	-178.5	Tub located off Furnace Creek Road behind Tecopa Hot Springs
Wild Bath Spring	5/10/2014	35.87277	116.21932	1,424	~5	visual	35.5	2.249	1,215	3.85	8.2	85.5	Tub located off Furnace Creek Road behind Tecopa Hot Springs
Wild Bath Spring	12/3/2014	35.87277	116.21932	1,424	2.5	bucket	38.8	1.689	848	nm	7.41	--	Tub located off Furnace Creek Road behind Tecopa Hot Springs
Wild Bath Spring	12/7/2015	35.87277	116.21932	1,424	3	bucket	39.8	1.613	802	1.47	7.33	--	
Wild Bath Spring	5/31/2016	35.87277	116.21932	1,411	1.6	bucket	40.2	1.673	834	0.82	7.49	--	Outflow only from NE corner (not NW - so just 1)
Wild Bath Spring	9/15/2016	35.87277	116.21932	1,424	1.5	visual	42.1	1.465	732	nm	7.50	--	
Wild Bath Spring	1/9/2017	35.87277	116.21932	1,411	1.5	visual	41.1	1.658	828	0.65	7.38	--	
Wild Bath Spring	4/11/2017	35.87277	116.21932	1,424	1.5	bucket	41.7	1.635	817	0.36	7.46	--	
Wild Bath Spring	1/16/2018	35.87277	116.21932	1,424	2	bucket	41.8	1433	721	1.61	7.59		
Wild Bath Spring	4/23/2019	35.87277	116.21932	1,424	1.8	bucket	42.1	1507	756	2.48	7.49		
Wild Bath Spring	10/1/2019	35.87277	116.21932	1,424	1.5	bucket	41.2	1503	751	0.91	7.75		
Wildhorse Spring	11/19/2010	35.78804	115.99766	3,108	1	visual	21.41	0.420	293	5.36	7.81	86.9	
Wildhorse Spring	4/26/2011	35.78804	115.99766	3,108	0	visual	nm	nm	nm	nm	nm	nm	
Wildhorse Spring	5/9/2014	35.78804	115.99766	3,108	2.5	visual	nm	nm	nm	nm	nm	nm	
Wildhorse Spring	12/8/2015	35.78804	115.99766	3,108	0.1	visual	12.6	0.466	233	0.11	7.67	--	Spring in fenced area, but gate was down and left open. Closed gate upon completioin of monitoring.
Wildhorse Spring	6/3/2016	35.78804	115.99766	3,108	0.1	visual	23.9	0.461	229	1.60	7.57	--	
Willow Spring 1	11/3/2010	35.80556	116.18284	1,420	28	bucket	23.73	1.453	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 1	5/9/2014	35.80556	116.18284	1,420	N/A	N/A	24.5	1.256	--	3.86	7.46	--	
Willow Spring 1	12/6/2014	35.80556	116.18284	1,420	40	meter	24.0	1.312	664	nm	7.34	--	
Willow Spring 1	12/5/2015	35.80569	116.18264	1,445	>0.1	visual	12.9	1.703	852	3.91	7.55	--	Spring very overgrown in comparison to past visits.
Willow Spring 1	5/31/2016	35.80556	116.18284	1,420	2.5	bucket	25.2	0.986	491	2.73	7.25	--	
Willow Spring 1	9/17/2016	35.80569	116.18264	1,445	20	visual	27.3	1.011	510	nm	7.29	--	
Willow Spring 1	1/9/2017	35.80569	116.18264	1,445	2-3	visual	20.6	1.631	809	3.87	7.64	--	"Willow Creek #1"
Willow Spring 1	4/11/2017	35.80569	116.18264	1,445	~30	visual	21.5	1.147	573	2.58	7.63	--	"Willow Creek #1"
Willow Spring 1	1/16/2018	35.80569	116.18264	1,445	40	visual	21.5	1020	515	2.95	7.71		

Table 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)	Elec. Conductivity (uS)	TDS (mg/L)	DO (mg/L)	pH	ORP (mV)	Notes
Willow Spring 1	4/29/2018	35.80569	116.18264	1,445	15	visual	23.6	893	447	2.86	7.69		
Willow Spring 1	4/25/2019	35.80569	116.18264	1,445	nm	nm	22.6	1008	504	5.46	7.66		
Willow Spring 2	1/18/2011	35.80098	116.19449	1,235	120-130	meter	17.98	1.91	1,241	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
Willow Spring 2	5/1/2012	35.80098	116.19449	1,235	--	--	22.33	1.164	756	8.95	8.09	16.2	Measurement taken at culvert
Willow Spring 2	4/30/2013	35.80098	116.19449	1,235	--	--	22.99	1.154	750	7.12	7.24	-116.8	Measurement taken at culvert
Willow Spring 2	9/25/2013	35.80098	116.19449	1,235	37	meter	23.64	0.837	544	5.6	8	-169.4	Measurement taken at culvert
Willow Spring 2	9/25/2013	35.80098	116.19449	1,235	4.5	USGS	--	--	--	--	--	--	
Willow Spring 2	12/5/2015	35.80098	116.19449	1,235	30	visual	22.7	0.972	486	3.52	7.93	--	Measurement taken at culvert
Willow Spring 2	9/17/2016	35.80097	116.19438	1,236	~25	USGS	24.4	0.991	496	nm	7.91	--	
Willow Spring 2	1/9/2017	35.80097	116.19438	1,236	80-100	USGS	20.1	1.561	780	5.07	7.86	--	USGS Gage, immediately above culvert, upstream use
Willow Spring 2	4/11/2017	35.80097	116.19438	1,236	40	visual	20.9	1.39	684	7.96	7.92	--	"Willow Creek #2"
Willow Spring 3	1/16/2018	35.80097	116.19438	1,236	80	visual	23.4	813	407	2.89	8.08		
Willow Spring 4	4/29/2018	35.80097	116.19438	1,236	220	visual	21.9	871	435	5.83	8.22		
Yerba Mansa Seep	12/6/2015	35.86925	116.22356	1,416	0.1	visual	nm	nm	nm	nm	nm	--	Distinct seeps with Yerba Mansa plants as sole riparian vegetation.
Amargosa River													
Amargosa River/USGS 1	11/3/2010	35.84954	116.23081	1,325	40	USGS	--	--	--	--	--	--	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	31	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 1	4/30/2012	35.84954	116.23081	1,325	117	USGS	17.97	10.806	7,024	10.28	9.36	36.3	At the Tecopa USGS flow station
Amargosa River/USGS 1	1/29/2013	35.84954	116.23081	1,325	162	USGS	5.99	14.25	9,264	17.48	8.71	57.4	At the Tecopa USGS flow station
Amargosa River/USGS 1	4/30/2013	35.84954	116.23081	1,325	45	USGS	17.52	9.69	6,303	10.14	8.34	-172.8	At the Tecopa USGS flow station
Amargosa River/USGS 1	9/25/2013	35.84954	116.23081	1,325	18	USGS	19.4	5.659	3,681	5.4	8.58	-207	At the Tecopa USGS flow station
Amargosa River/USGS 1	5/10/2014	35.84954	116.23081	1,325	130	USGS	19.5	9.499	6,142	7.98	9.2	23.5	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	2,520	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	2,263	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	390	USGS	23.05	3.658	2,378	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
Amargosa River/USGS 2	5/3/2012	35.79042	116.20777	1,094	487.9	meter	19.07	3.899	2,534	12.03	8.69	51.8	At China Ranch USGS flow station
Amargosa River/USGS 2	5/3/2012	35.79042	116.20777	1,094	763	USGS	--	--	--	--	--	--	At China Ranch USGS flow station
Amargosa River/USGS 2	1/27/2013	35.79042	116.20777	1,094	914	meter	11.33	10.56	6,863	15.83	8.57	86	At China Ranch USGS flow station
Amargosa River/USGS 2	1/27/2013	35.79042	116.20777	1,094	539	USGS	--	--	--	--	--	--	At China Ranch USGS flow station
Amargosa River/USGS 2	4/20/2013	35.79042	116.20777	1,094	399	meter	15.96	4.634	3,012	14.04	8	-104.8	At China Ranch USGS flow station
Amargosa River/USGS 2	4/20/2013	35.79042	116.20777	1,094	494	USGS	--	--	--	--	--	--	At China Ranch USGS flow station
Amargosa River/USGS 2	9/24/2013	35.79042	116.20777	1,094	735	meter	15.1	3.263	2,121	6.95	8.32	-184.4	At China Ranch USGS flow station
Amargosa River/USGS 2	9/24/2013	35.79042	116.20777	1,094	1436	USGS	--	--	--	--	--	--	At China Ranch USGS flow station
Amargosa River/USGS 2	5/4/2014	35.79042	116.20777	1,094	527	meter	17.8	4.443	2,886	9.83	8.61	84.4	At China Ranch USGS flow station
Amargosa River/USGS 2	5/4/2014	35.79042	116.20777	1,094	444	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
Willow Creek	5/3/2012	35.78757	116.20039	1,107	37.7	bucket	20.53	1.357	882	10.89	8.8	25.4	Above confluence with Amargosa River
Willow Creek	1/27/2013	35.78757	116.20039	1,107	33	meter/visual	14.28	1.651	1,073	15.49	8.38	69.3	Above confluence with Amargosa River
Willow Creek	4/20/2013	35.78757	116.20039	1,107	47	meter	27.07	1.414	919	9.28	8.15	-107.1	Above confluence with Amargosa River
Willow Creek	9/24/2013	35.78757	116.20039	1,107	dry	visual	--	--	--	--	--	--	Above confluence with Amargosa River
Willow Creek	5/4/2014	35.78757	116.20039	1,107	25	meter/visual	18.1	1.421	923	10.1	8.61	106.1	Above confluence with Amargosa River
Amargosa River at Parker	6/2/2016	36.96539	116.72006	3,546	5	visual	19.9	1.28	629	4.41	8.31		
Amargosa River Confluence	4/29/2011	35.785	116.2023	1,053	662	meter	20.23	3.88	2,523	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	2,748	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	3,677	11.7	8.38	63.6	Confluence with Willow Creek
Amargosa River Confluence	5/3/2012	35.785	116.2023	1,053	395	meter	17.88	4.262	2,770	10.26	8.59	32.2	Confluence with Willow Creek
Amargosa River Confluence	1/27/2013	35.785	116.2023	1,053	561	meter	10.51	7.547	4,905	15.62	7.94	89.9	Confluence with Willow Creek
Amargosa River Confluence	4/20/2013	35.785	116.2023	1,053	563	meter	14.05	5.004	3,253	11.48	8.02	-111.9	Confluence with Willow Creek
Amargosa River Confluence	9/24/2013	35.785	116.2023	1,053	461	meter	14.61	3.54	2,301	7.04	8.43	-147.5	Confluence with Willow Creek

Table 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)	Elec. Conductivity (uS)	TDS (mg/L)	DO (mg/L)	pH	ORP (mV)	Notes
Amargosa River Confluence	5/4/2014	35.785	116.2023	1,053	643	meter	17.3	4.786	3,114	9.21	8.63	111.4	Confluence with Willow Creek
Amargosa River Confluence	12/6/2014	35.785	116.2023	1,053	686	meter	14.9	>4000	>2,000	--	8.51	--	Confluence with Willow Creek
Amargosa River Confluence	6/3/2016	35.785	116.2023	1,053	686	meter		3.845	1,923	6.68	8.17		
Amargosa River Confluence	9/14/2016	35.785	116.2023	1,053	266	meter	17.8	3.520	1,760	nm	8.45	--	
Amargosa River Confluence	1/9/2017	35.785	116.2023	1,053	>1,000	visual	11.0	>4.000	>2,000	15.15	8.67	--	
Amargosa River Confluence	4/11/2017	35.785	116.2023	1,053	2,693	visual	11.6	>4.000	>2,000	8.91	8.63	--	
Amargosa River Confluence	4/12/2017	35.785	116.2023	1,053	3,590	visual	9.6	>4,000	>2,000	14.66	9.08		
Amargosa River Confluence	4/26/2018	35.785	116.2023	1,053	1,795	visual	21.0	3390.000	1699	11.92	8.75		
Amargosa River Confluence	4/23/2019	35.785	116.2023	1,053	500	visual	16.3	3435.000	1717	9.29	8.49		
Amargosa River Confluence	9/30/2019	35.785	116.2023	1,053	50	visual	19.6	2466.000	1218	nm	7.87		
Amargosa River 3	11/16/2010	35.74637	116.22219	846	477	meter	19.08	4.015	2,610	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	2,745	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	2,728	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	2,879	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	2,809	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	3,366	11.3	8.6	130.7	At Sperry Wash
Amargosa River 3	5/4/2012	35.74637	116.22219	846	366	meter	24.22	4.388	2,852	11.75	9.02	22.4	At Sperry Wash
Amargosa River 3	1/26/2013	35.74637	116.22219	846	510	meter	13.02	6.656	4,326	16.55	8.32	76.2	At Sperry Wash
Amargosa River 3	4/18/2013	35.74637	116.22219	846	398	meter	25.66	5.223	3,395	12.37	8.4	-102	At Sperry Wash
Amargosa River 3	9/23/2013	35.74637	116.22219	846	275	meter	22.71	4.171	2,711	8.34	8.69	-157.7	At Sperry Wash
Amargosa River 3	5/4/2014	35.74637	116.22219	846	588	meter	26.2	4.831	3,140	12.72	8.93	29.8	At Sperry Wash
Amargosa River 3	12/5/2014	35.74637	116.22219	846	550	meter	19.2	>4000	>2000	--	8.69	--	At Sperry Wash
Amargosa River 3	9/14/2016	35.74637	116.22219	846	233	meter	30.2	3.647	1,823	nm	8.85	--	At Sperry Wash; Channel changed due to flooding. Old Cattail/rushes now high and
Amargosa River 4	4/29/2011	35.69609	116.25082	649	70	meter	15.67	4.472	2,904	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
Amargosa River 4	12/21/2011	35.69609	116.25082	649	136	meter	3.79	4.727	3,073	12.35	8.6	214.1	At crossing of Dumont Dunes Road
Amargosa River 4	5/4/2012	35.69609	116.25082	649	44	meter	27.23	4.617	3,003	9.07	9.22	22.5	At crossing of Dumont Dunes Road
Amargosa River 4	1/26/2013	35.69609	116.25082	649	171	meter	12.06	6.025	3,916	15.34	8.49	76.4	At crossing of Dumont Dunes Road
Amargosa River 4	4/18/2013	35.69609	116.25082	649	0	visual	--	--	--	--	--	--	At crossing of Dumont Dunes Road
Amargosa River 4	9/23/2013	35.69609	116.25082	649	<50	visual	16.54	5.134	3,338	6.8	8.95	-195.2	At crossing of Dumont Dunes Road
Amargosa River 4	5/4/2014	35.69609	116.25082	649	<50	visual	25.4	5.926	3,854	7.9	9.15	79.1	At crossing of Dumont Dunes Road
Amargosa River 4	12/5/2014	35.69609	116.25082	649	224	meter	20.7	>4000	>2000	--	8.76	--	At crossing of Dumont Dunes Road
Amargosa River 4	1/10/2017	35.69894	116.24766	646	~12	visual	8.0	>4.000	>2,000	15.76	8.94	--	At Dumon Dunes Road (2WD)
Amargosa River 4	4/10/2017	35.69894	116.24766	646	1,300	visual	15.2	>4.000	>2,000	12.18	9.18	--	
Amargosa River 4	1/15/2018	35.69894	116.24766	646	430	visual	13.8	>4,000	>2000	11.87	9.03		
Amargosa River 4	1/9/2019	35.69894	116.24766	646	84	visual	16.0	>4,000	>2000	nm	9.14		
Amargosa River 4	4/23/2019	35.69894	116.24766	646	280	visual	24.0	>4,000	>2000	5.83	8.84		
Amargosa River 4	10/1/2019	35.69894	116.24766	646	0	visual	nm	nm	nm	nm	nm	nm	
Amargosa River 2	11/16/2010	35.66418	116.29722	443	256	meter	21.4	4.295	2,793	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	visual	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	5/5/2011	35.66418	116.29722	443	dry	visual	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	9/23/2011	35.66418	116.29722	443	dry	visual	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	12/21/2011	35.66418	116.29722	443	dry	visual	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	5/4/2012	35.66418	116.29722	443	dry	visual	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	1/26/2013	35.66418	116.29722	443	dry	visual	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	4/18/2013	35.66418	116.29722	443	dry	visual	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	9/23/2013	35.66418	116.29722	443	dry	visual	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	5/4/2013	35.66418	116.29722	443	<50	visual	--	--	--	--	--	--	At rt 127 crossing south of Dumont Dunes
Amargosa River 2	1/10/2017	35.66326	116.29811	440	~10	visual	7.3	>4.001	>2,001	16.15	8.97	--	At Highway 126
Amargosa River 2	1/15/2018	35.66326	116.29811	440	2,000+	visual	13.5	>4.001	>2,001	11.29	9.12	--	At Highway 127
Amargosa River 2	10/1/2019	35.66326	116.29811	440	0	visual	--	--	--	--	--	--	At Highway 127

Table 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)	Elec. Conductivity (uS)	TDS (mg/L)	DO (mg/L)	pH	ORP (mV)	Notes
Wells					**Depth to Water (ft from top of casing)**								
ARHS-1	5/25/2012	36.0773	116.2953	1,780	111.72	dtw meter	35	2.941	1,910	2.04	8.26	107.3	At rt 127, 6 miles north of Shoshone, CA
ARHS-1	4/24/2013	36.0773	116.2953	1,780	111.88	dtw meter	--	--	--	--	--	--	At rt 127, 6 miles north of Shoshone, CA
ARHS-1	12/3/2014	36.0773	116.2953	1,780	112.03	dtw meter	--	--	--	--	--	--	At rt 127, 6 miles north of Shoshone, CA
ARHS-1	12/15/2015	36.0773	116.2953	1,780	112.00	dtw meter	24.39	2.95	1,898	4.75	7.9	-42.9	At rt 127, 6 miles north of Shoshone, CA
ARHS-1	9/17/2016	36.0773	116.2953	1,780	N/A	dtw meter	nm	nm	nm	nm	nm	--	
ARHS-1	1/8/2017	36.0773	116.2953	1,780	N/A	dtw meter	27.312	N/A	N/A	N/A	N/A	--	
ARHS-1	4/10/2017	36.0773	116.2953	1,780	N/A	dtw meter	27.3	N/A	N/A	N/A	N/A	--	
ARHS-1	1/15/2018	36.0773	116.2953	1,780	112.69	dtw meter							
ARHS-1	1/8/2019	36.0773	116.2953	1,780	112.65	dtw meter							
ARHS-1	4/26/2019	36.0773	116.2953	1,780	112.61	dtw meter							
ARHS-1	10/2/2019	36.0773	116.2953	1,780	112.96	dtw meter							
ARHS-2	5/25/2012	35.8054	116.1825	1,430	5.79	dtw meter	24.36	0.912	593	4.2	7.54	129.8	At China Ranch
ARHS-2	1/25/2013	35.8054	116.1825	1,430	5.94	dtw meter	23.73	1.095	714	5.52	7.6	36.9	At China Ranch
ARHS-2	4/30/2013	35.8054	116.1825	1,430	6.83	dtw meter	--	--	--	--	--	--	At China Ranch
ARHS-2	9/24/2013	35.8054	116.1825	1,430	6.39	dtw meter	25.73	0.798	519	3.41	7.25	-178.8	At China Ranch
ARHS-2	5/9/2014	35.8054	116.1825	1,430	5.69	dtw meter	24.5	1.27	826	3.86	7.46	-178.4	At China Ranch
ARHS-2	12/8/2014	35.8054	116.1825	1,430	7.18	dtw meter	--	--	--	--	--	--	At China Ranch
ARHS-2	12/13/2015	35.8054	116.1825	1,430	5.25	dtw meter	24.89	1.02	656	3.73	7.44	-27.1	At China Ranch
ARHS-2	9/17/2016	35.80569	116.18264	1,445			27.3	1.011	510	nm	7.29	--	Willow #1 Spring
ARHS-2	1/9/2017	35.80569	116.18264	1,445			20.6	1.631	809	3.87	7.64	--	"Willow Creek #1"
ARHS-2	4/11/2017	35.80569	116.18264	1,445	N/A	N/A	24.39	N/A	N/A	N/A	N/A	--	
ARHS-2	4/12/2017	35.80569	116.18264	1,445									
ARHS-2	1/16/2018	35.80569	116.18264	1,445	6.24	dtw meter							
ARHS-2	1/9/2019	35.80569	116.18264	1,445	nm								
ARHS-2	4/25/2019	35.80569	116.18264	1,445	5.39	dtw meter							
ARHS-3	4/24/2013	36.0216	116.1554	2,205	18.64	dtw meter	24.6	0.77	500	5.48	6.86	-101.2	Located adjacent to 12 Mile Spring
ARHS-3	9/24/2013	36.0216	116.1554	2,205	19.34	dtw meter	24.63	0.647	421	3.72	7.42	-182.7	Located adjacent to 12 Mile Spring
ARHS-3	5/5/2014	36.0216	116.1554	2,205	19.13	dtw meter	24.3	1.087	709	5.5	7.68	81.1	Located adjacent to 12 Mile Spring
ARHS-3	12/8/2014	36.0216	116.1554	2,205	19.85	dtw meter	--	--	--	--	--	--	Located adjacent to 12 Mile Spring
ARHS-3	12/15/2015	36.0216	116.1554	2,205	19.04	dtw meter	24.61	0.76	494	4.16	7.55	-41.6	Located adjacent to 12 Mile Spring
ARHS-3	9/17/2016	36.02195	116.15530	2,208	20.01	dtw meter	25.0	0.907	451	nm	7.24	--	Empty plastic water bottle. While driving out followed by likely illegal growers.
ARHS-3	10/1/2019	36.02195	116.15530	2,208	20.41								
ARHS-4	9/18/2016	36.02195	116.15530	2,208									
ARHS-4	9/18/2016	36.02195	116.15530	2,208									
ARHS-4	9/24/2013	35.7999	116.1035	2,072	12.5	dtw meter	24.08	0.656	427	4.1	7.5	-171.6	Located adjacent to Married Man's Camp
ARHS-4	5/9/2014	35.7999	116.1035	2,072	11.94	dtw meter	22.6	1.106	722	4.96	7.52	149.6	Located adjacent to Married Man's Camp
ARHS-4	5/10/2014	35.7999	116.1035	2,072	12.86	dtw meter	--	--	--	--	--	--	Located adjacent to Married Man's Camp
ARHS-4	12/15/2015	35.7999	116.1035	2,072	11.77	dtw meter	24.28	0.77	500	5.05	7.73	-11.5	
ARHS-4	9/17/2016	35.7999	116.1035	2,072	N/A	--	nm	nm	nm	N/A	nm	--	Located adjacent to Married Man's Camp; Match locks
ARHS-4	1/8/2017	35.79990	116.10347	2,072	N/A	visual	24.874	N/A	N/A	N/A	N/A	--	
ARHS-4	4/11/2017	35.79990	116.10347	2,072	N/A	N/A	N/A	N/A	N/A	N/A	N/A	--	
ARHS-4	4/12/2017	35.79990	116.10347	2,072	13.53	dtw meter							
ARHS-4	4/13/2017	35.79990	116.10347	2,072	12.63	dtw meter							
ARHS-4	10/1/2019	35.79990	116.10347	2,072	12.55	dtw meter							
ARHS-5	2/15/2018	35.69530	116.2512	669	74.6	dtw meter							
ARHS-5	1/9/2019	35.69530	116.2512	669	106.68	dtw meter							
ARHS-5	10/1/2019	35.69530	116.2512	669	106.65	dtw meter							
ARHS-6	2/7/2018	35.81399	116.05242	2,302	12.4	dtw meter							
ARHS-6	1/9/2019	35.81399	116.05242	2,302	nm	dtw meter							
ARHS-6	4/22/2019	35.81399	116.05242	2,302	14.35	dtw meter							
ARHS-8	2/17/2018	36.14688	116.31758	1,871	180	dtw meter							

Table 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)	Elec. Conductivity (uS)	TDS (mg/L)	DO (mg/L)	pH	ORP (mV)	Notes
ARHS-8	1/8/2019	36.14688	116.31758	1,871	178.13	dtw meter							
ARHS-8	4/26/2019	36.14688	116.31758	1,871	178.14	dtw meter							
ARHS-8	10/1/2019	36.14688	116.31758	1,871	178.14	dtw meter							
ARHS-9	2/15/2018	36.16347	116.12998	2,478	36.5	dtw meter							
ARHS-9	1/9/2019	36.16347	116.12998	2,478	55.66	dtw meter							
ARHS-9	4/22/2019	36.16347	116.12998	2,478	56.7	dtw meter							
ARHS-9	10/1/2019	36.16347	116.12998	2,478	55.95	dtw meter							
ARHS-10	2/15/2018	35.85807	116.04934	2,451	46.68	dtw meter							
ARHS-10	1/9/2019	35.85807	116.04934	2,451	46.03	dtw meter							
ARHS-10	4/22/2019	35.85807	116.04934	2,451	46.1	dtw meter							
ARHS-10	9/30/2019	35.85807	116.04934	2,451	46.11	dtw meter							
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
Cynthia's Well	5/5/2012	35.8461	116.20478	1,447	40.22	dtw meter	22.31	1.163	756	3	8.36	33.9	Located in Tecopa Heights
Cynthia's Well	1/27/2013	35.8461	116.20478	1,447	39	dtw meter	--	--	--	--	--	--	Located in Tecopa Heights
Cynthia's Well	4/25/2013	35.8461	116.20478	1,447	40.95	dtw meter	23.06	1.251	813	2.75	7.36	-113.8	Located in Tecopa Heights
Cynthia's Well	5/12/2014	35.8461	116.20478	1,447	41.16	dtw meter	23.8	1.151	748	6.2	7.86	76	Located in Tecopa Heights
Cynthia's Well	12/3/2014	35.8461	116.20478	1,447	40.63	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	2,177	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
Eagle Mountain Well	4/30/2012	36.24987	116.3953	2,007	14.94	dtw meter	19.79	3.251	2,112	7.39	8.42	36.5	Located west of Eagle Mountain
Eagle Mountain Well	1/24/2013	36.24987	116.3953	2,007	15	dtw meter	21.23	4.043	2,628	7.98	8.45	41.1	Located west of Eagle Mountain
Eagle Mountain Well	4/24/2013	36.24987	116.3953	2,007	14.97	dtw meter	20.08	3.487	2,267	7.05	7.93	-112.4	Located west of Eagle Mountain
Eagle Mountain Well	9/23/2013	36.24987	116.3953	2,007	14.75	dtw meter	22.8	2.984	1,938	5.9	8.09	-181.4	Located west of Eagle Mountain
Eagle Mountain Well	5/9/2014	36.24987	116.3953	2,007	14.92	dtw meter	20	3.864	--	6.6	8.56	--	Located west of Eagle Mountain
Eagle Mountain Well	12/8/2014	36.24987	116.3953	2,007	14.99	dtw meter	--	--	--	--	--	--	Located west of Eagle Mountain
Good / Barnes Well	12/8/2015	35.84216	116.20419	1,474	N/A	--	22.2	0.969	484	nm	7.36	--	511 Grimshaw Tecopa Heights; Domestic well house
Married Man's Well	11/19/2011	35.80038	116.10177	2,096	25.82	dtw meter	--	--	--	--	--	--	Locate at head of Willow Creek Wash
Married Man's Well	4/30/2012	35.80038	116.10177	2,096	25.49	dtw meter	23.96	1.255	816	3.61	7.59	-114.5	Locate at head of Willow Creek Wash
Married Man's Well	1/25/2013	35.80038	116.10177	2,096	25.51	dtw meter	--	--	--	--	--	--	Locate at head of Willow Creek Wash
Junior's Well	1/16/2011	35.8512	116.24252	1,346	NA	NA	24.29	2.04	1,326	6.63	8.33	69	Located west of Amargosa River (opposite of Tecopa)
Hog Farm Well	1/28/2013	36.28748	116.37854	2,017	<5	visual	21.17	1.653	1,074	0.97	8.66	39.9	Located southeast of Death Valley Junction
Hog Farm Well	4/24/2013	36.28748	116.37854	2,017	<5	visual	21.56	1.432	930	<1	7.67	-180.7	Located southeast of Death Valley Junction
Hog Farm Well	9/23/2013	36.28748	116.37854	2,017	<5	visual	21.94	1.219	792	0.4	8.48	-258	Located southeast of Death Valley Junction
Hog Farm Well	5/5/2014	36.28748	116.37854	2,017	<5	visual	21.6	1.74	1,131	0.14	8.74	31.3	Located southeast of Death Valley Junction
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
Tule Spring Well	4/30/2012	35.81178	116.04909	1,989	10.01	dtw meter	19.37	0.827	537	1.76	7.87	26.8	Data from well. No smell from well.
Tule Spring Well	1/25/2013	35.81178	116.04909	1,989	10	dtw meter	17.44	0.981	638	<2.5	7.35	66.5	Data from well. No smell from well.
Tule Spring Well	4/21/2013	35.81178	116.04909	1,989	9.83	dtw meter	17.38	0.91	591	1.35	6.9	-160.6	Data from well. Moderate odor of decay
Tule Spring Well	9/24/2013	35.81178	116.04909	1,989	10.8	dtw meter	20.91	0.728	473	0.37	7.42	-272.3	Data from well. Moderate odor of decay
Tule Spring Well	5/9/2014	35.81178	116.04909	1,989	9.98	dtw meter	19.2	1.099	800	0.5	7.4	59.9	Data from well. Moderate odor of decay
Tule Spring Well	2/19/2016	35.81174	116.04908	2,297	0.1	visual	N/A	N/A	N/A	N/A	N/A	--	"Artist House"; Well present, depth to water ~ 10 ft; No PFC report taken; Adjacent site with similar characteristics; 8" PVC well (moist at bottom ~10 ft)

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

Table 2
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

Table 2
Mean Annual Flow
Amargosa River
California/Nevada

Year	Discharge (cfs)				
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**
2004	ND	1.26	ND	ND	ND
2005	ND	11.1	ND	ND	ND
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	5.04	ND	ND	ND
2012	ND	0.370	ND	ND	ND
2013	ND	0.688	ND	ND	ND
2014	ND	0.608	ND	ND	ND
2015	ND	0.607	ND	ND	ND
2016	ND	8.960	ND	ND	ND
2017	ND	3.110	ND	ND	ND
2018	ND	0.711	ND	ND	ND
2019	ND	0.859	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.

FIGURES

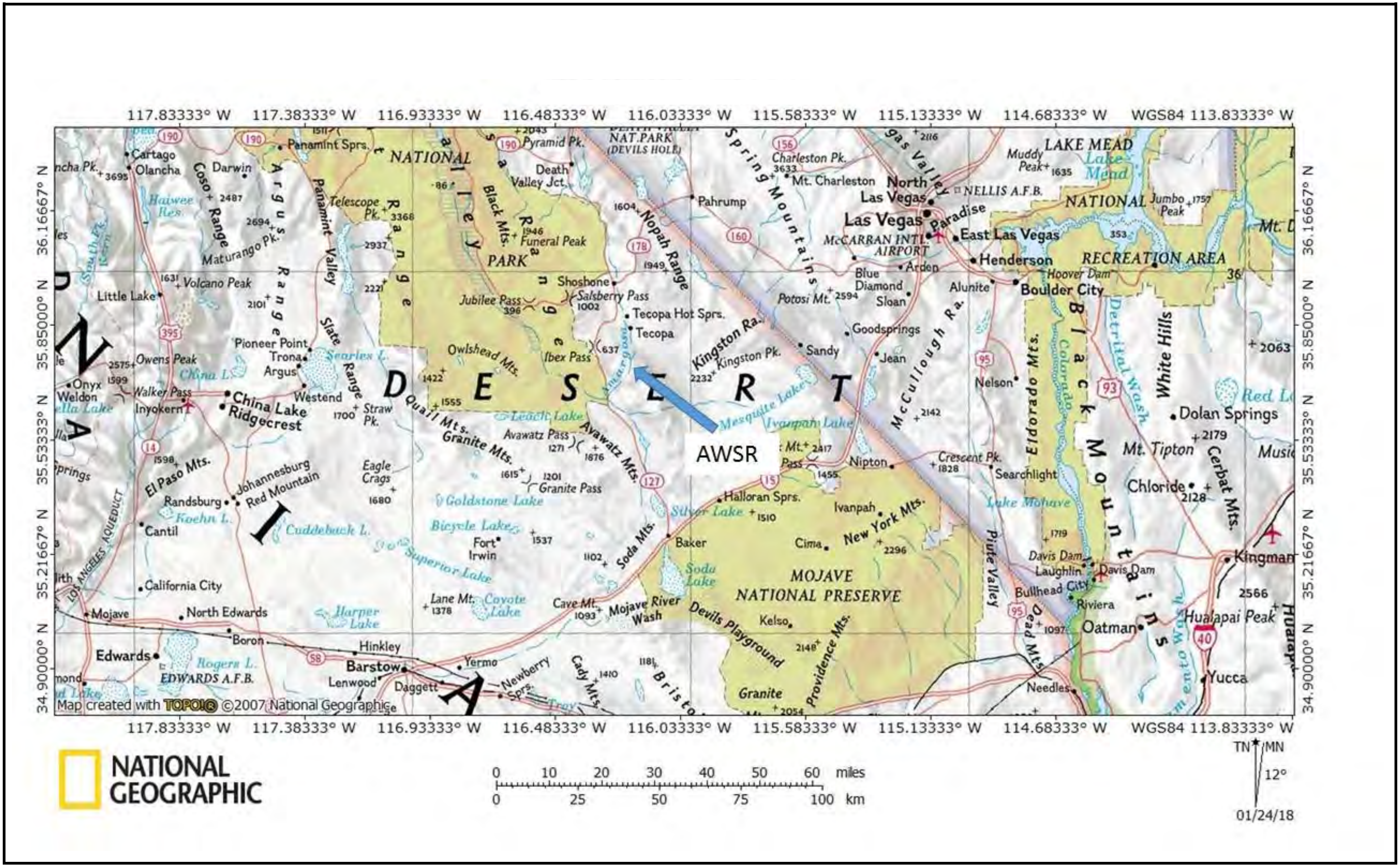
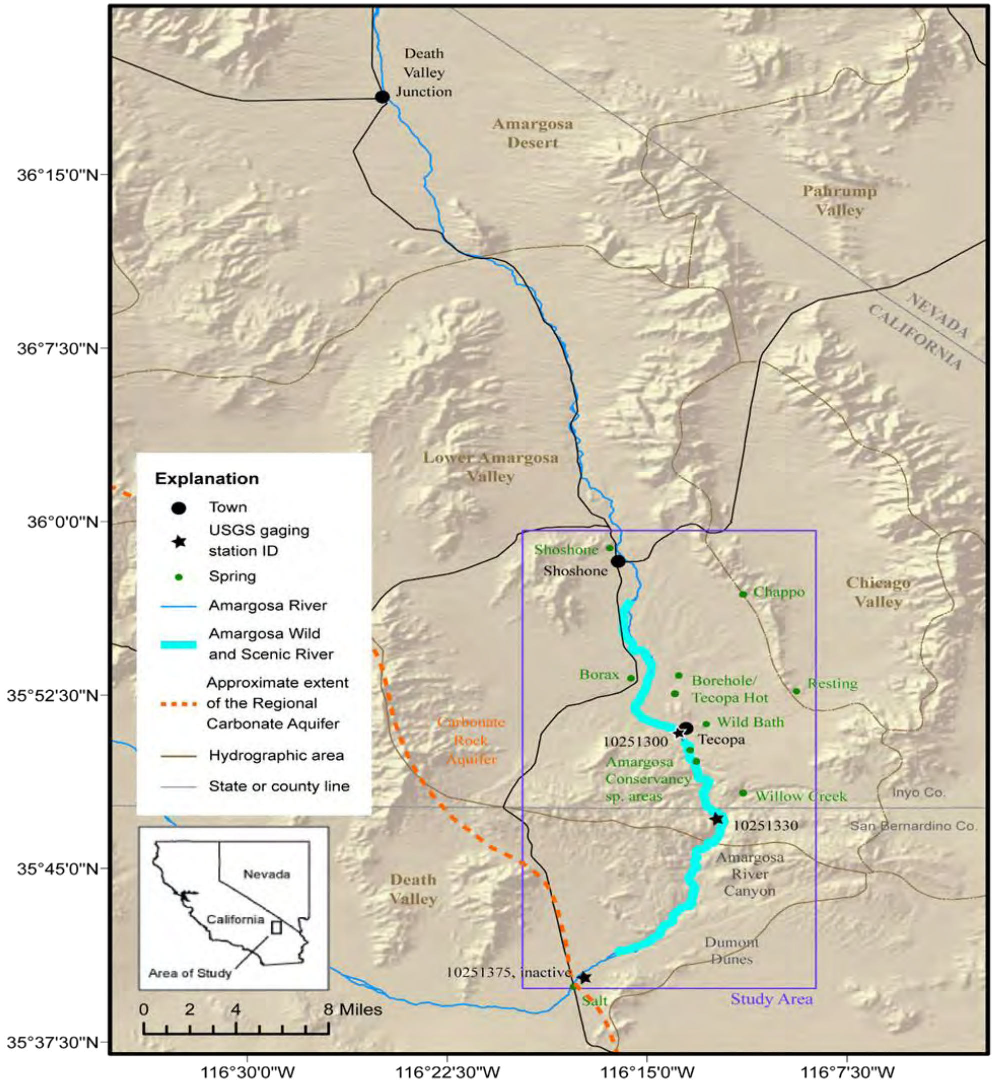


FIGURE 1: LOCATION MAP

Project No. SM16-175861



Adapted from USGS, 2015

FIGURE 2: AWSR LOCATION

Project No. SM16-175861

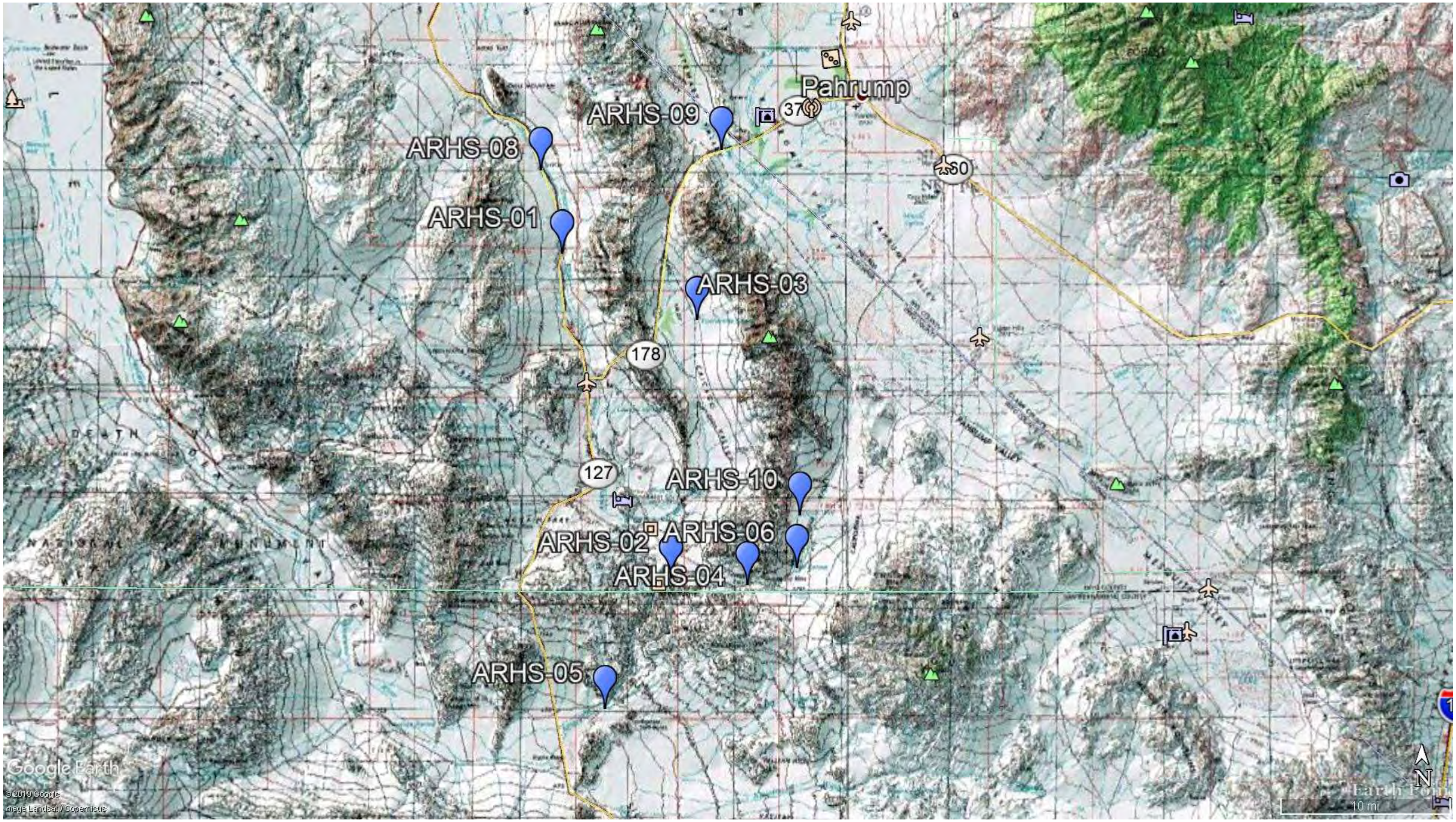
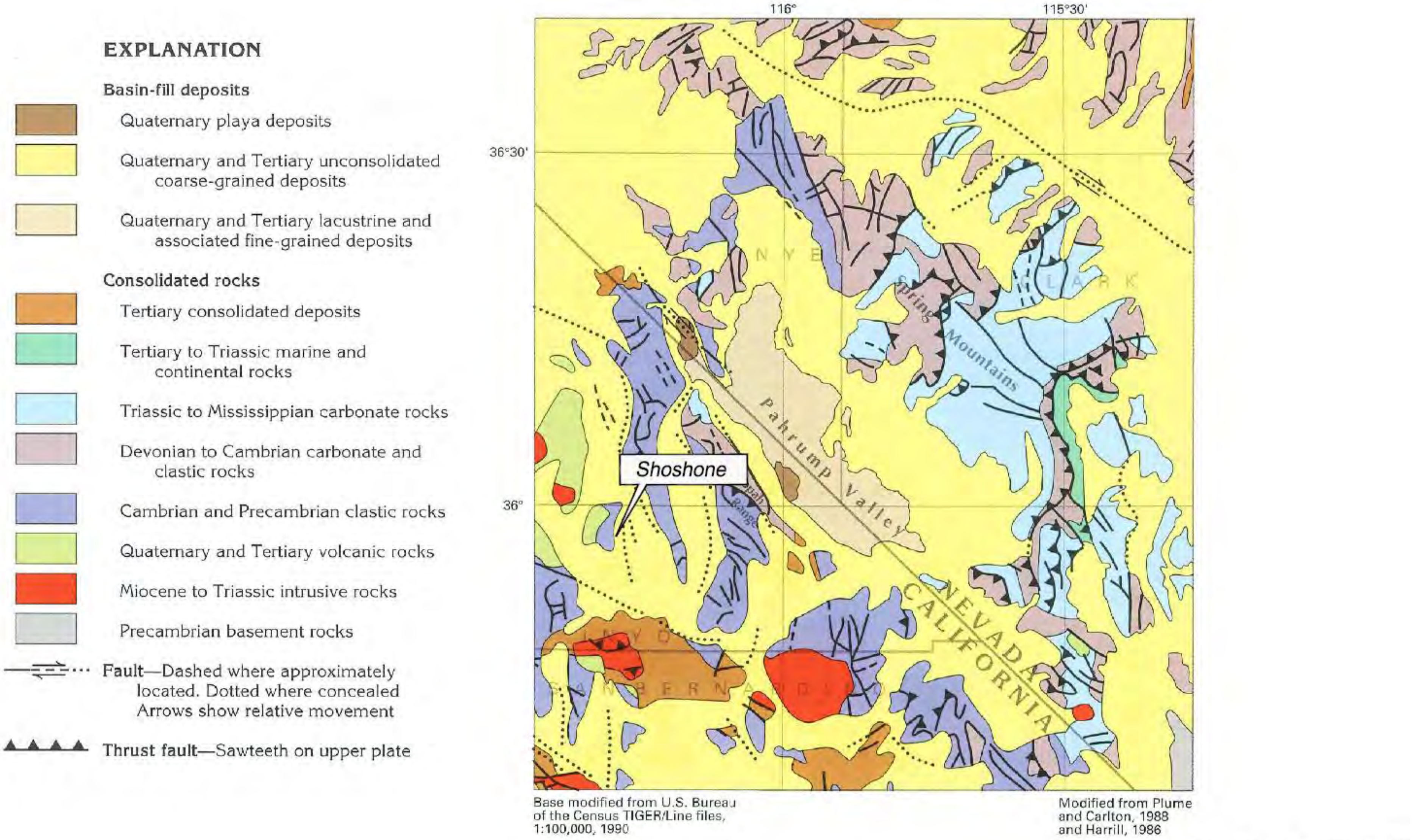


FIGURE 3: MONITORING WELL LOCATIONS

Project No. SM16-175861



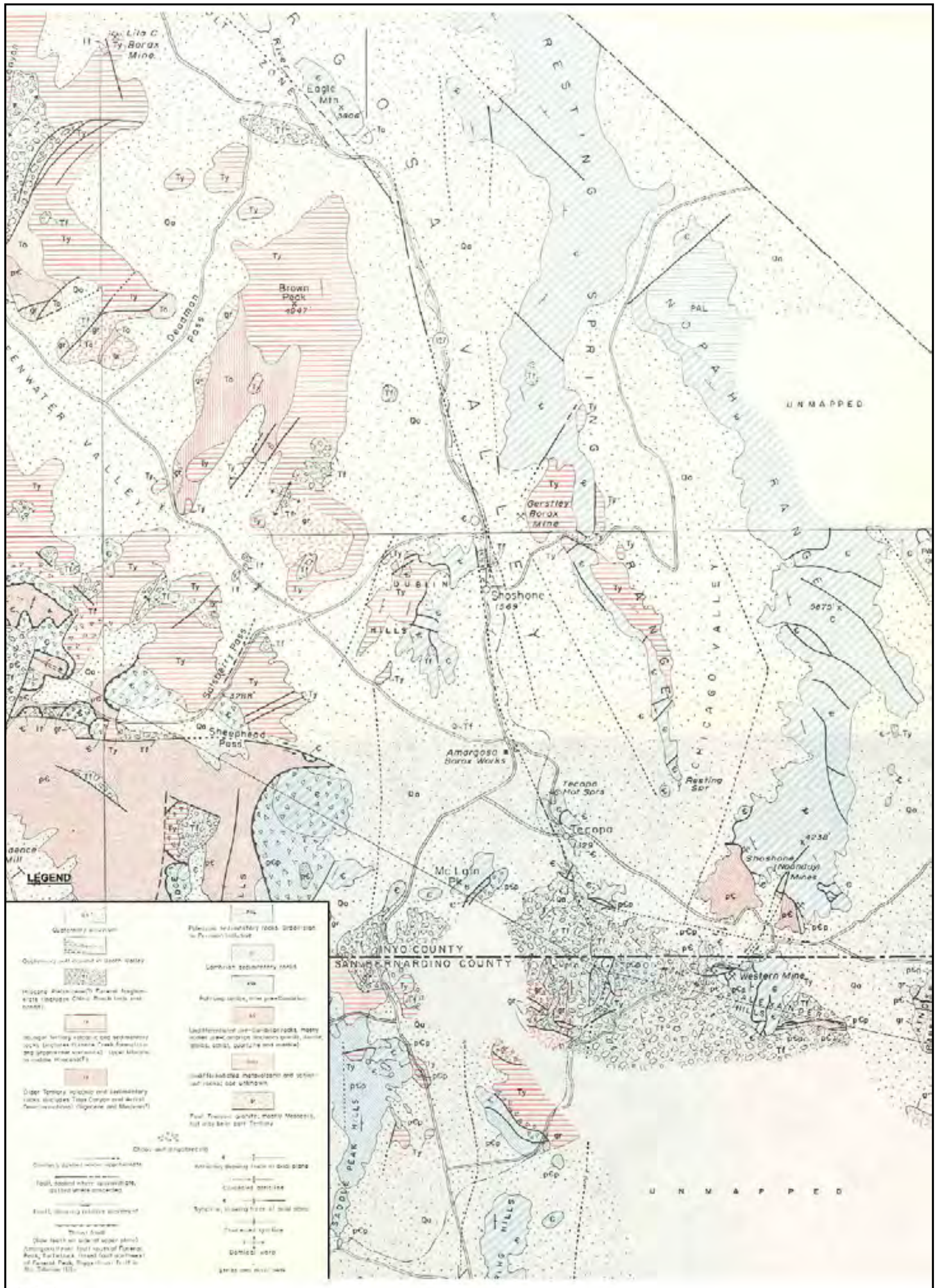
Base modified from U.S. Bureau of the Census TIGER/Line files, 1:100,000, 1990

Modified from Plume and Carlton, 1988 and Harrill, 1986

Source: Planert and Williams, 1995

FIGURE 4: REGIONAL GEOLOGIC MAP

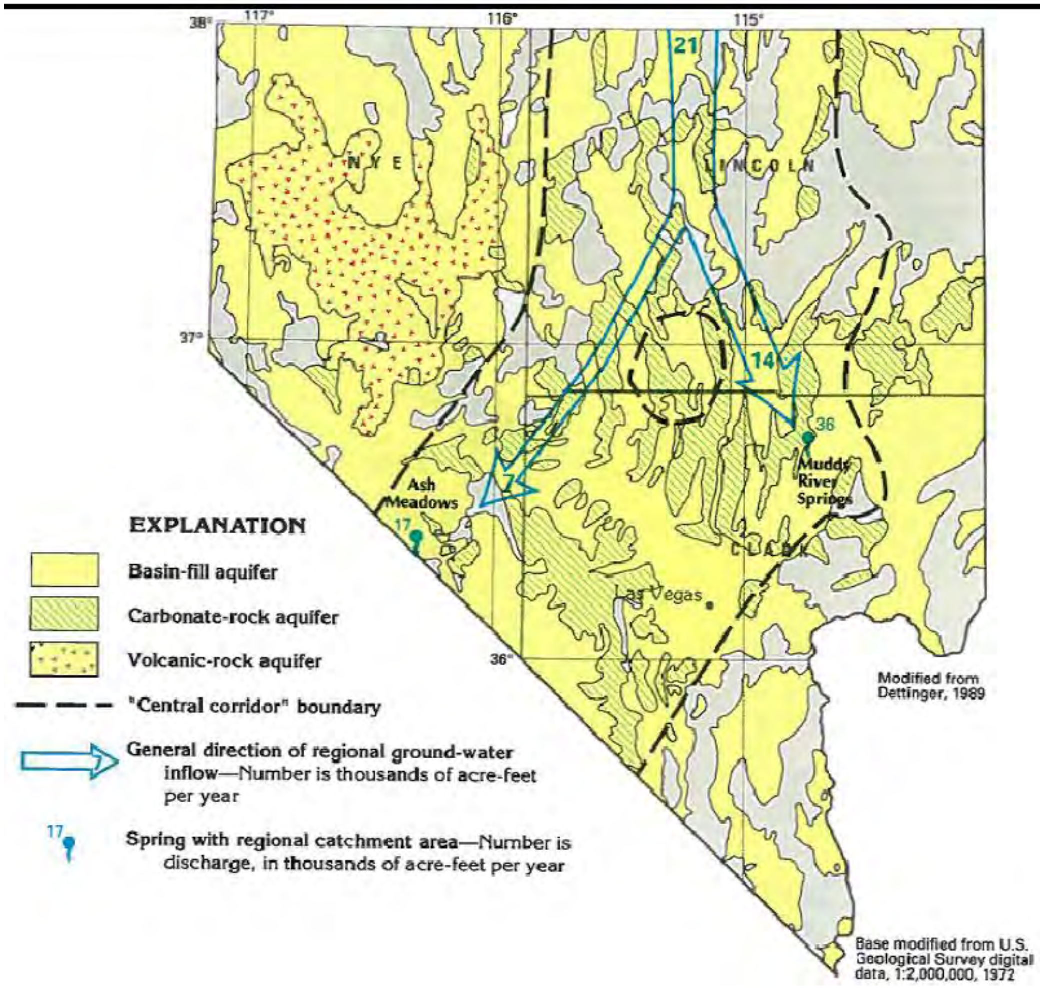
Project No. SM16-175861



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

FIGURE 5: AWSR AREA GEOLOGY

Project No. SM16-175861



Source: Planert and Williams, 1995

FIGURE 6: REGIONAL FLOW PATHS

Project No. SM16-175861

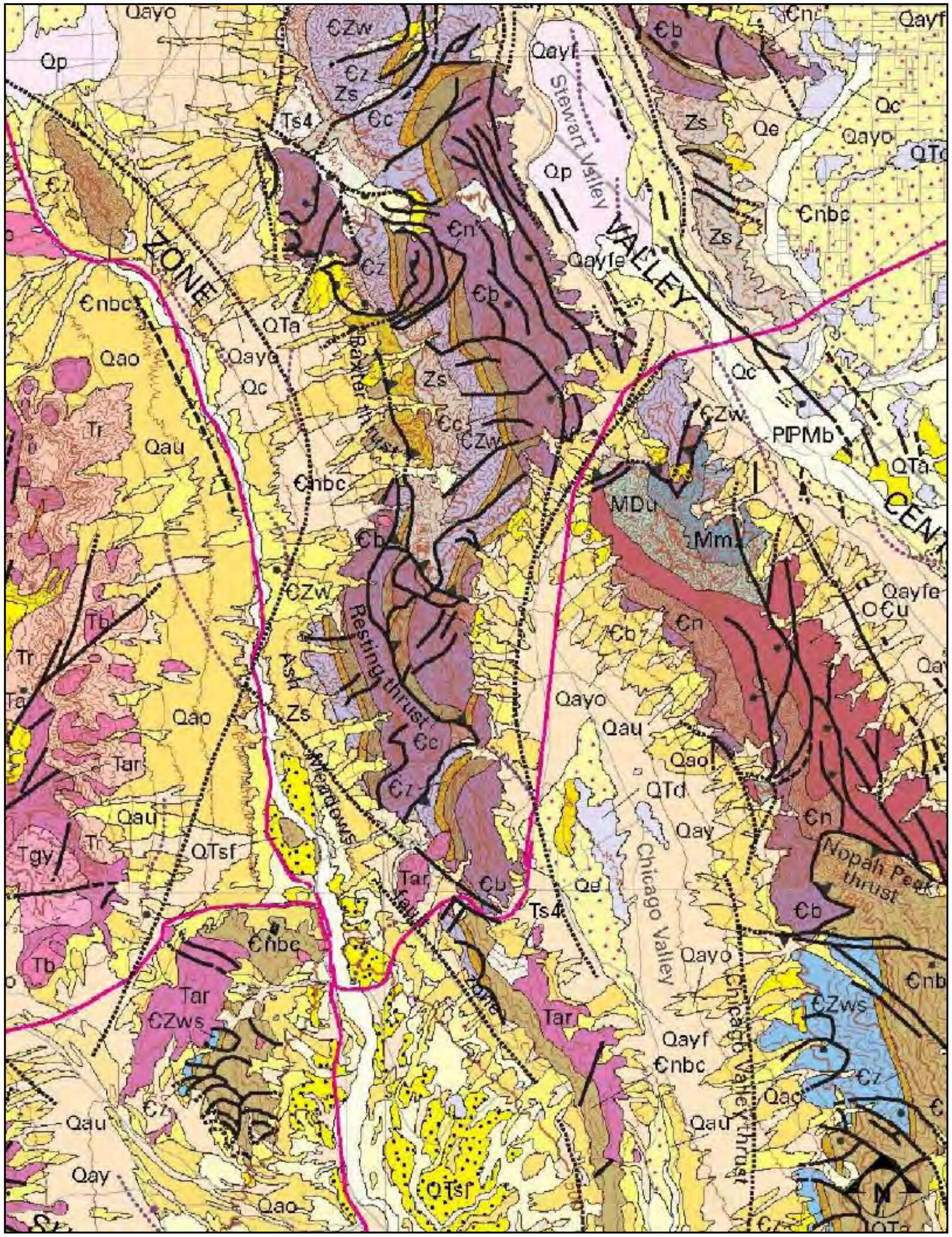


FIGURE 7: GEOLOGIC MAP

Project No. SM16-175861

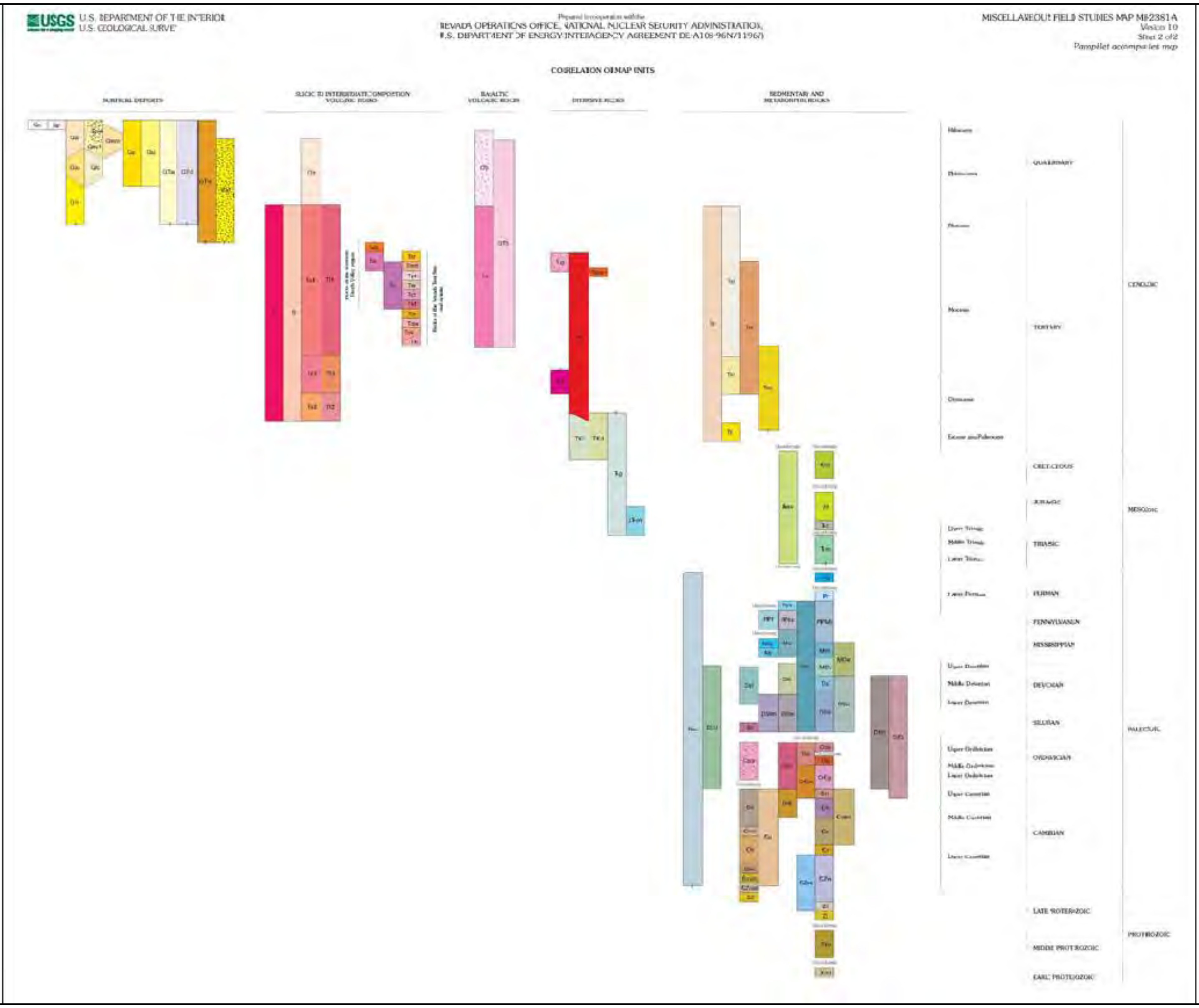


FIGURE 8: GEOLOGIC MAP - LEGEND

Project No. SM16-175861

PARTNER

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 finegrained alluvium (Holocene to latest Pleisocene?)
[illegible]	Evaporite surface crust of salts and (or) carbonate (Holocene to latest Pleistocene?)
[illegible]	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)
[illegible]	Old alluvial, paludal, or lacustrine sediments (Pleistocene to late Tertiary)
Qao	Old alluvium (late to middle Pleistocene)
Qol	Old lacustrine deposits (late to middle Pleistocene)
QTa	Oldest alluvium (middle Pleistocene to late Tertiary)

BEDROCK UNITS

SILICIC TO INTERMEDIATE COMPOSITION VOLCANIC ROCKS

Qi	Young intermediate-composition lava flows, undivided (Pleistocene)
Tv	Volcanic rocks, undivided (Pliocene to Oligocene)
Tr	Felsic-composition lava flows, undivided (Pliocene to Oligocene)
Ti4	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)
[illegible]	Greenwater Volcanics
Tcv	Intermediate- to felsic-composition lava flows of the central Death Valley volcanic field
Tsv	Intermediate- to felsic-composition lava flows of the southern Death Valley-Kingston Range volcanic belt
	Rocks of the Nevada Test Site and vicinity (Miocene)
[illegible]	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
Tlr	Lithic Ridge Tuff, rhyolite of Picture Rock, Tunnel Formation, and comendite of Quartet Dome, undivided
Tqm	Volcanic rocks of Quartz Mountain
Tot	Older ash-flow tuffs and lava sequences, undivided
Tbr	Lava flows of the Belted Range
Ti3	Intermediate-composition lava flows, unit 3 (Miocene and Oligocene)
Tt3	Ash-flow tuffs and interbedded air-fall tuffs, unit 3 (Miocene and Oligocene)
Ti2	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

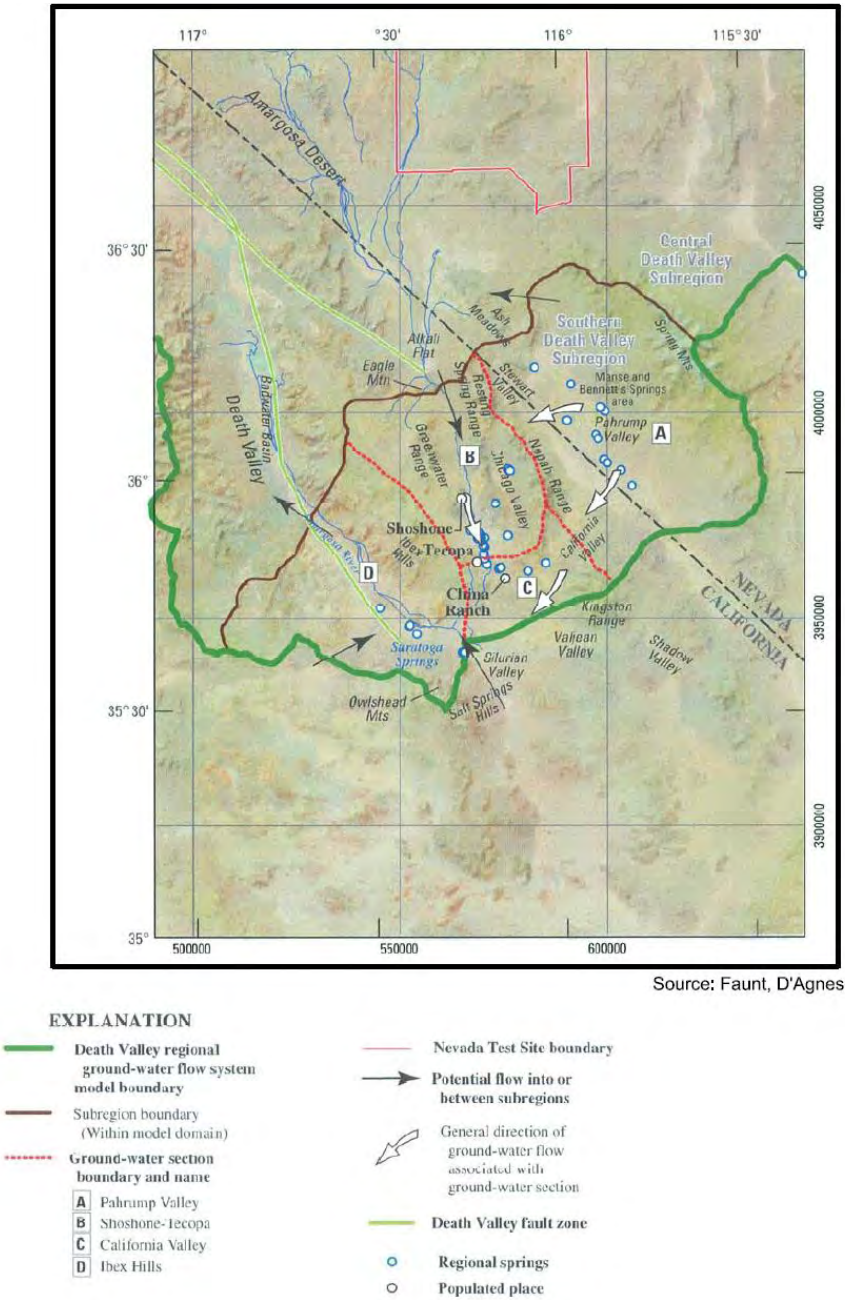
Tgy	Young granitic intrusive rocks (Miocene)
[illegible]	Younger intermediate-composition intrusive rocks (Miocene to Oligocene)
[illegible]	Gabbro to diorite intrusive rocks of Willow Springs (Miocene)
[illegible]	Older granitic intrusive rocks (Miocene? to Oligocene)
TKi	Older intermediate-composition intrusive rocks (Oligocene to Cretaceous)
TKd	Mafic intrusive rocks (Oligocene to Cretaceous)
[illegible]	Oldest granitic intrusive rocks (Tertiary? to Triassic)
[illegible]	[illegible] 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)
[illegible]	Landslide and mega-breccia deposits (Miocene to Oligocene)
[illegible]	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)
[illegible]	Sedimentary and volcanic rocks, undivided (Mesozoic)
[illegible]	Lavinia Wash sequence (Upper and Lower Cretaceous)
Ja	Aztec Sandstone (Jurassic)
[illegible]	Chinle Formation (Upper Triassic)
[illegible]	Moenkopi Formation (Middle? and Lower Triassic)
[illegible]	Sedimentary rocks, undivided (Paleozoic)
[illegible]	Kaibab and Toroweap Formations, undivided (Lower Permian)
Pr	Redbeds (Lower Permian)
Pov	Owens Valley Group (Lower Permian)
[illegible]	Sedimentary rocks, undivided (Permian to Silurian)
[illegible]	Bird Spring (Lower Permian and Pennsylvanian) and Indian Springs Formations (Upper Mississippian)
[illegible]	Tippipah Limestone (Lower Permian and Pennsylvanian)
[illegible]	Keeler Canyon Formation (Lower Permian to Middle Pennsylvanian)
[illegible]	Sedimentary rocks, undivided (Upper and Lower Mississippian)
[illegible]	Scotty Wash Quartzite (Upper Mississippian) and Chainman Shale (Upper and Lower Mississippian), undivided
[illegible]	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)
[illegible]	Lost Burro Formation (Upper and Middle Devonian)
[illegible]	Dolomite and limestone, undifferentiated (Devonian to Upper Cambrian)
[illegible]	Slope-facies carbonate rocks (Upper to Lower Devonian)
Ds	Simonson Dolomite (Middle Devonian)
DSu	Sedimentary rocks, undivided (Devonian and Silurian)
[illegible]	Mountain Springs Formation (Middle Devonian, Lower Ordovician, and Upper Cambrian)
[illegible]	Mountain Springs (Middle Devonian, Lower Ordovician, and Upper Cambrian) and Nopah Formations (Upper Cambrian), undivided
[illegible]	Sevy (Middle and Lower Devonian) and Laketown (Upper and Middle Silurian) Dolomites, undivided
[illegible]	Lone Mountain Dolomite (Lower Devonian and Silurian)
[illegible]	Hidden Valley Dolomite (Lower Devonian and Silurian)
[illegible]	Roberts Mountains Formation (Silurian)
[illegible]	Palmetto Formation (Upper, Middle, and Lower Ordovician)
[illegible]	Sedimentary rocks, undivided (Ordovician and Upper Cambrian)
[illegible]	Ely Springs Dolomite (Upper Ordovician) and Eureka Quartzite (Upper and Middle Ordovician), undivided
[illegible]	Ely Springs Dolomite (Upper Ordovician)
Oe	Eureka Quartzite (Upper and Middle Ordovician)
[illegible]	Pogonip Group (Middle and Lower Ordovician and Upper Cambrian) and Nopah Formation (Upper Cambrian), undivided
[illegible]	Pogonip Group (Middle and Lower Ordovician and Upper Cambrian)
[illegible]	Emigrant Formation (Upper and Middle Cambrian)
[illegible]	Sedimentary rocks, undivided (Upper to Lower Cambrian)
[illegible]	Nopah (Upper Cambrian) and Bonanza King Formations (Upper and Middle Cambrian), undivided
[illegible]	Nopah Formation (Upper Cambrian)
[illegible]	Nopah (Upper Cambrian), Bonanza King (Upper and Middle Cambrian), and Carrara Formations (Middle and Lower Cambrian), undivided
[illegible]	Bonanza King Formation (Upper and Middle Cambrian)
[illegible]	Carrara Formation (Middle and Lower Cambrian)
[illegible]	Mule Spring Limestone (Lower Cambrian)
[illegible]	Harkless Formation (Lower Cambrian)
[illegible]	Zabriskie Quartzite (Lower Cambrian)
[illegible]	Wood Canyon Formation (Lower Cambrian and Late Proterozoic) and Stirling Quartzite (Late Proterozoic), undivided
[illegible]	Wood Canyon Formation (Lower Cambrian and Late Proterozoic)
[illegible]	Poleta Formation (Lower Cambrian)
	Campito Formation (Lower Cambrian and Late Proterozoic)
[illegible]	Montenegro Member (Lower Cambrian)
[illegible]	Andrews Mountain Member (Lower Cambrian and Late Proterozoic)
[illegible]	Deep Spring Formation (Late Proterozoic)
[illegible]	Stirling Quartzite and Reed Dolomite, undivided (Late Proterozoic)
[illegible]	Johnnie and Wyman Formations, undivided (Late Proterozoic)
[illegible]	Pahrump Group (Late and Middle Proterozoic)
[illegible]	Metamorphic and igneous rocks, undifferentiated (Early Proterozoic)

FIGURE 9: GEOLOGIC MAP - LEGEND

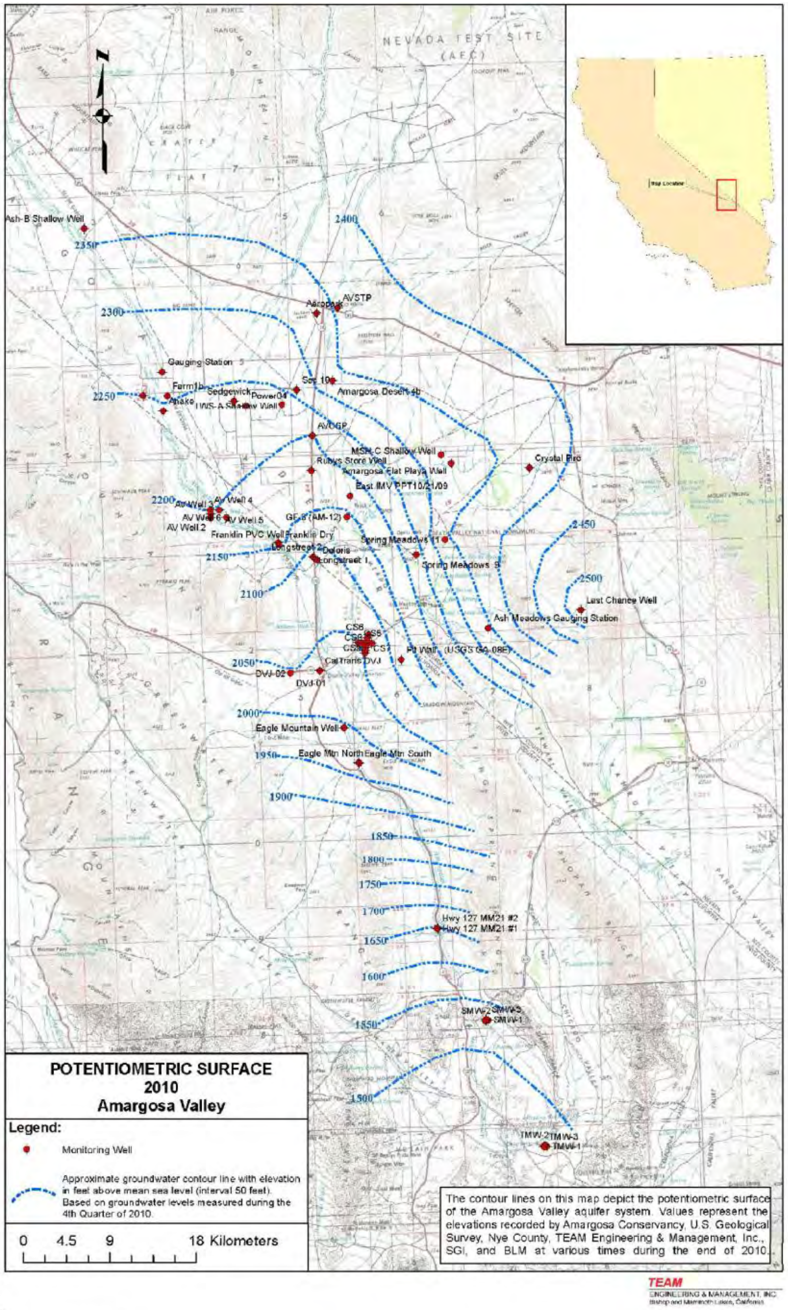
Project No. SM16-175861



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

FIGURE 10: USGS FLOW PATHS

Project No. SM16-175861



SOURCE:
TEAM ENGINEERING & MANAGEMENT, INC

FIGURE 11: GROUNDWATER SURFACE

Project No. SM16-175861

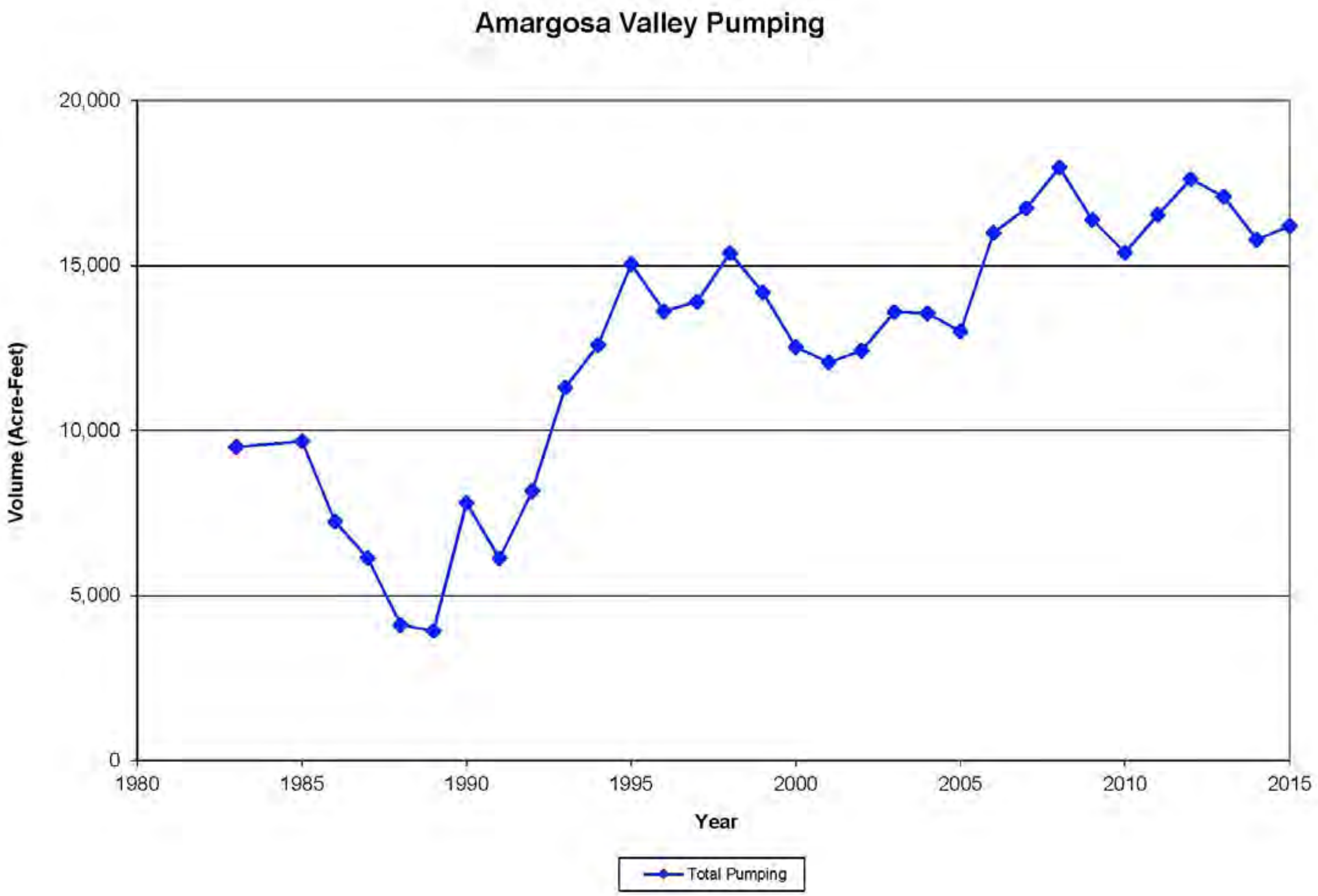


FIGURE 12: AMARGOSA VALLEY PUMPING

Project No. SM16-175861

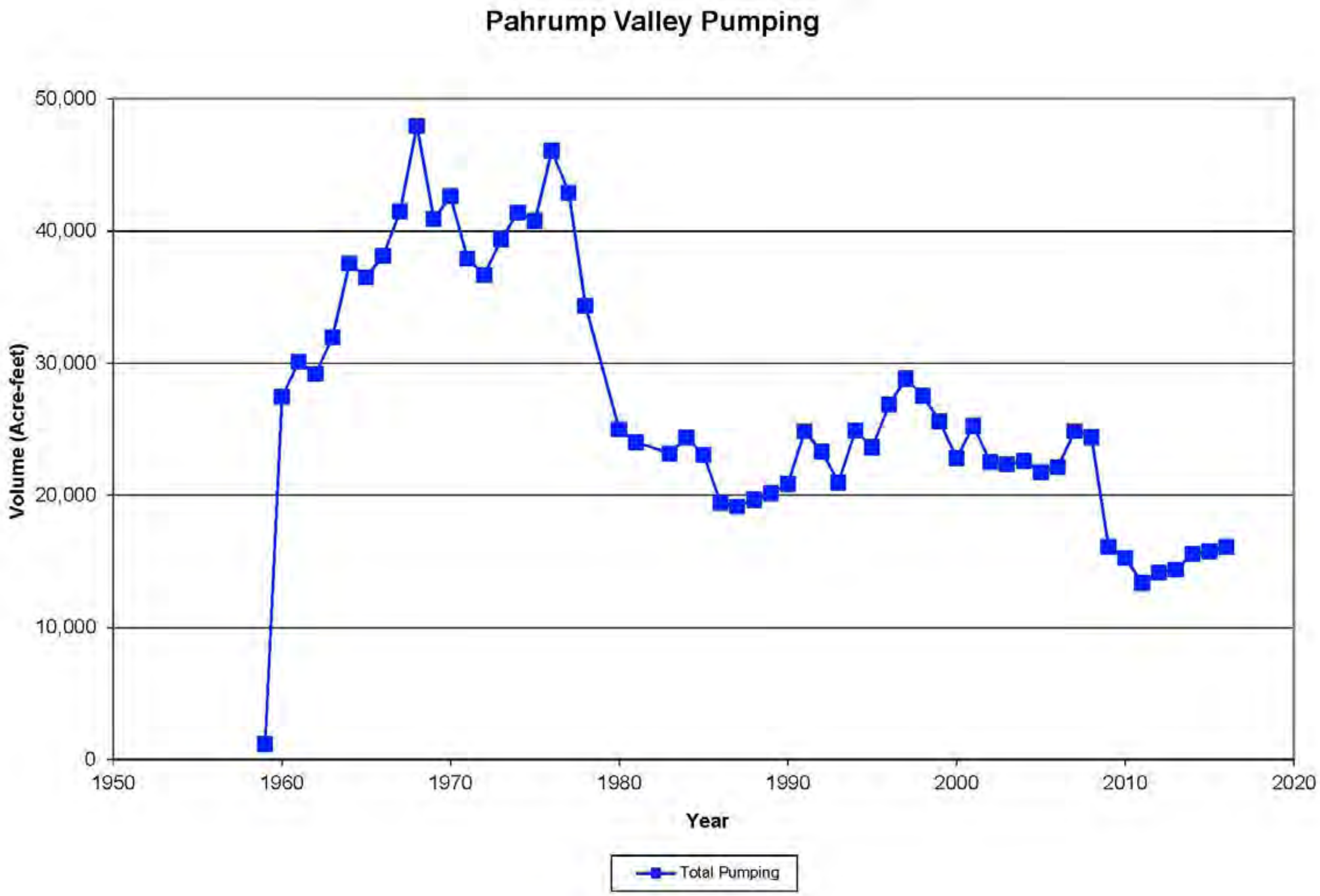


FIGURE 13: PAHRUMP VALLEY PUMPING

Project No. SM16-175861

FIGURE 14: AMARGOSA RIVER CANYON (AWSR)

FIGURE 15 BORAX SPRING

Project No. SM16-175861

FIGURE 16: BOREHOLE SPRING

Project No. SM16-175861

FIGURE 17: DODGE CITY SPRING

Project No. SM16-175861

FIGURE 18: THOM SPRING

Project No. SM16-175861

FIGURE 19: VOLE SPRING

Project No. SM16-175861

FIGURE 20: HOMESTEAD SPRING

Project No. SM16-175861

FIGURE 21: STORMY SPRING

Project No. SM16-175861

PARTNER

FIGURE 22: WEST-SIDE SPRING

Project No. SM16-175861

FIGURE 23 CHRISTIAN SPRING

FIGURE 24: AMARGOSA CANYON SPG 4

Project No. SM16-175861

FIGURE 25: WILLOW CREEK #1

Project No. SM16-175861

FIGURE 26: WILLOW CREEK #2

Project No. SM16-175861

APPENDIX A:

APPENDIX B:

BORING LOG

BORING: **ARHS - 10**

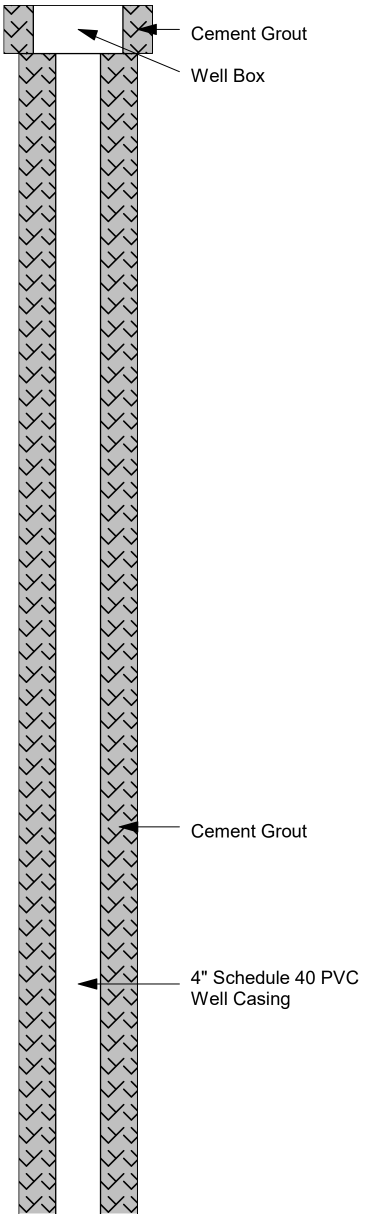
TOTAL DEPTH: **60'**

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	45.68'
LOCATION:	California Valley, Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Mesquite Valley Road - Davis Well	METHOD OF DRILLING:	Sonic Drilling
	N35.85807, W-116.04934, Elevation 2,451 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/14/2018-2/15/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE
0		NM	N/A		SP	Poorly-graded SAND (SP), fine to medium grained, with silt, dark yellowish brown, moist
5					SM	Silty fine SAND (SM), trace clay (powder-like)
10					ML	SILT (ML) with fine sand, trace clay; poorly to moderately indurated, evaporite crust Increasing moisture
15 20					SM	Silty fine SAND (SM) with caliche clasts, white Increasing caliche clasts to 2-inches Increasing evaporite/caliche clasts
					SILT-STONE	SILTSTONE (poorly indurated)
25						

BORING COMPLETION | WELL DESCRIPTION



NOTES: Depth to water, 5/3/2018, 45.88 feet

BORING LOG

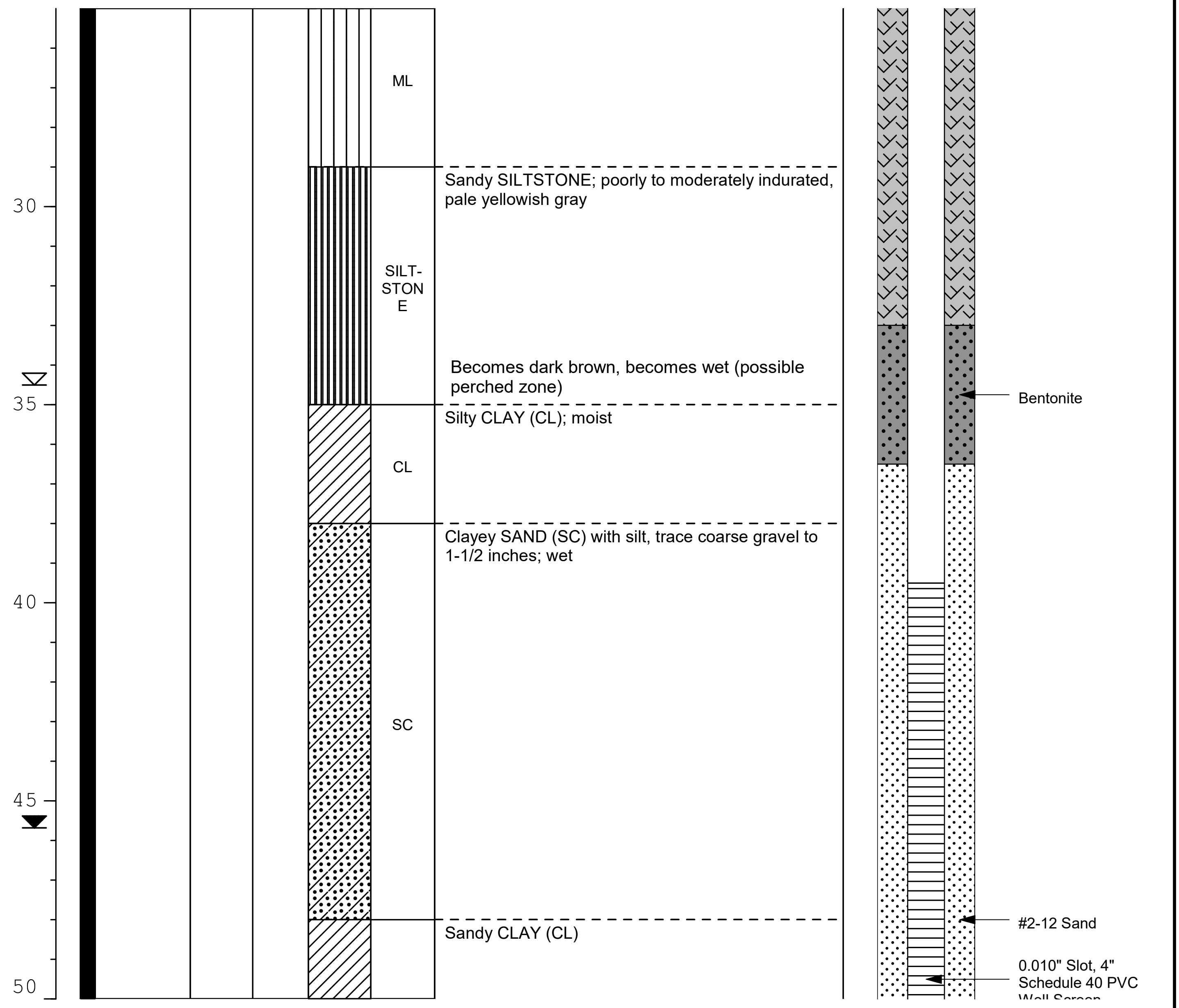
BORING: **ARHS - 10**

TOTAL DEPTH: **60'**

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	45.68'
LOCATION:	California Valley, Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Mesquite Valley Road - Davis Well	METHOD OF DRILLING:	Sonic Drilling
	N35.85807, W-116.04934, Elevation 2,451 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/14/2018-2/15/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION



Sandy SILTSTONE; poorly to moderately indurated, pale yellowish gray

Becomes dark brown, becomes wet (possible perched zone)

Silty CLAY (CL); moist

Clayey SAND (SC) with silt, trace coarse gravel to 1-1/2 inches; wet

Sandy CLAY (CL)

NOTES: Depth to water, 5/3/2018, 45.88 feet

BORING LOG

BORING: **ARHS - 10**

TOTAL DEPTH: **60'**

PARTNER Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

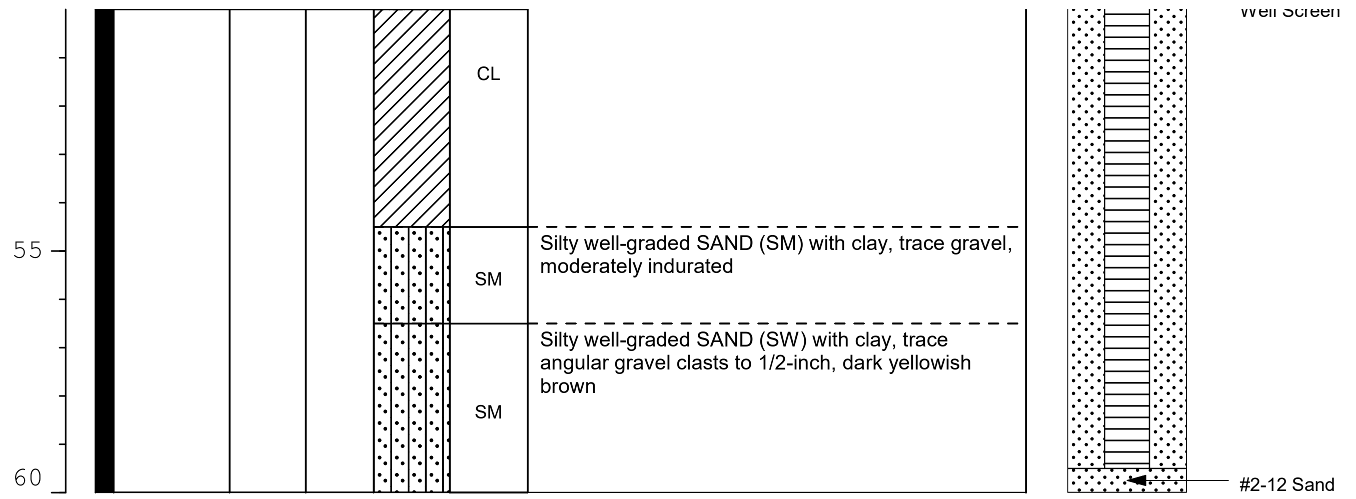
PROJECT INFORMATION

PROJECT: Amargosa River Basin
LOCATION: California Valley, Inyo County, California
SITE ADDRESS: Mesquite Valley Road - Davis Well
N35.85807, W-116.04934, Elevation 2,451 feet
JOB NO.: SM16-175861 T2
DATES DRILLED: 2/14/2018-2/15/2018

DRILLING INFORMATION

DEPTH TO GROUNDWATER: 45.68'
RIG TYPE: Sonic - Gregg Drilling
METHOD OF DRILLING: Sonic Drilling
SAMPLING METHODS: Eijkelkamp SonicSampDrill
BORING DIAMETER: 8"
FIELD TECHNICIAN: AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION



Silty well-graded SAND (SM) with clay, trace gravel, moderately indurated

Silty well-graded SAND (SW) with clay, trace angular gravel clasts to 1/2-inch, dark yellowish brown

NOTES: Depth to water, 5/3/2018, 45.88 feet

BORING LOG

BORING: **ARHS - 09**

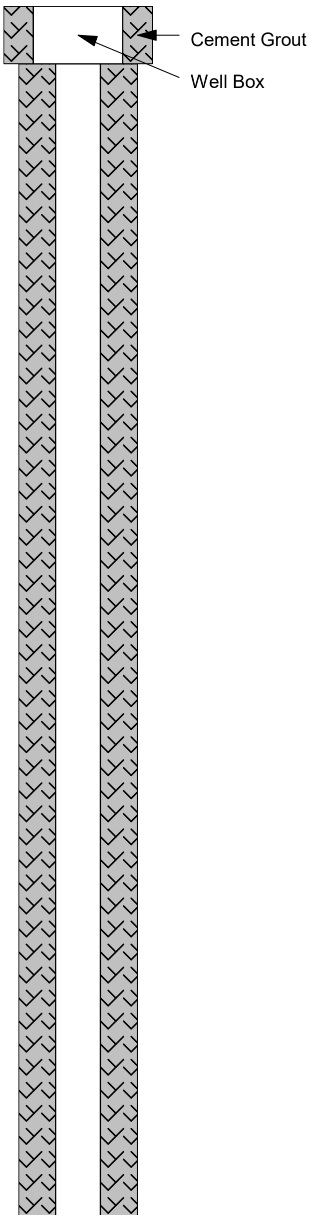
TOTAL DEPTH: **80'**

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	36.5'
LOCATION:	Stewart Valley, Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Highway 178	METHOD OF DRILLING:	Sonic Drilling
	N36.16347, W-116.12998, Elevation 2,478 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/14/2018-2/15/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE
0		NM	N/A			SILT (ML) trace sand, gravel (primarily carbonate) clasts, rounded to subangular, yellowish brown, moist
5					ML	
						Increased induration with spotty evaporite crust
10					SM	Silty well-graded SAND (SM), trace gravel, clay, lakebed siltstone chips
						Sandy SILT; poorly indurated (playa deposit), trace clay, gravel, pale yellowish gray
15					SILT STET	Increasing gravel (carbonate clasts) to 1-1/2 inches
20					GM	Silty GRAVEL (GM) with sand, trace clay
						SILT STET, poorly to moderately indurated,

BORING COMPLETION / WELL DESCRIPTION



NOTES: Depth to groundwater, 5/3/2018, 55.40 feet

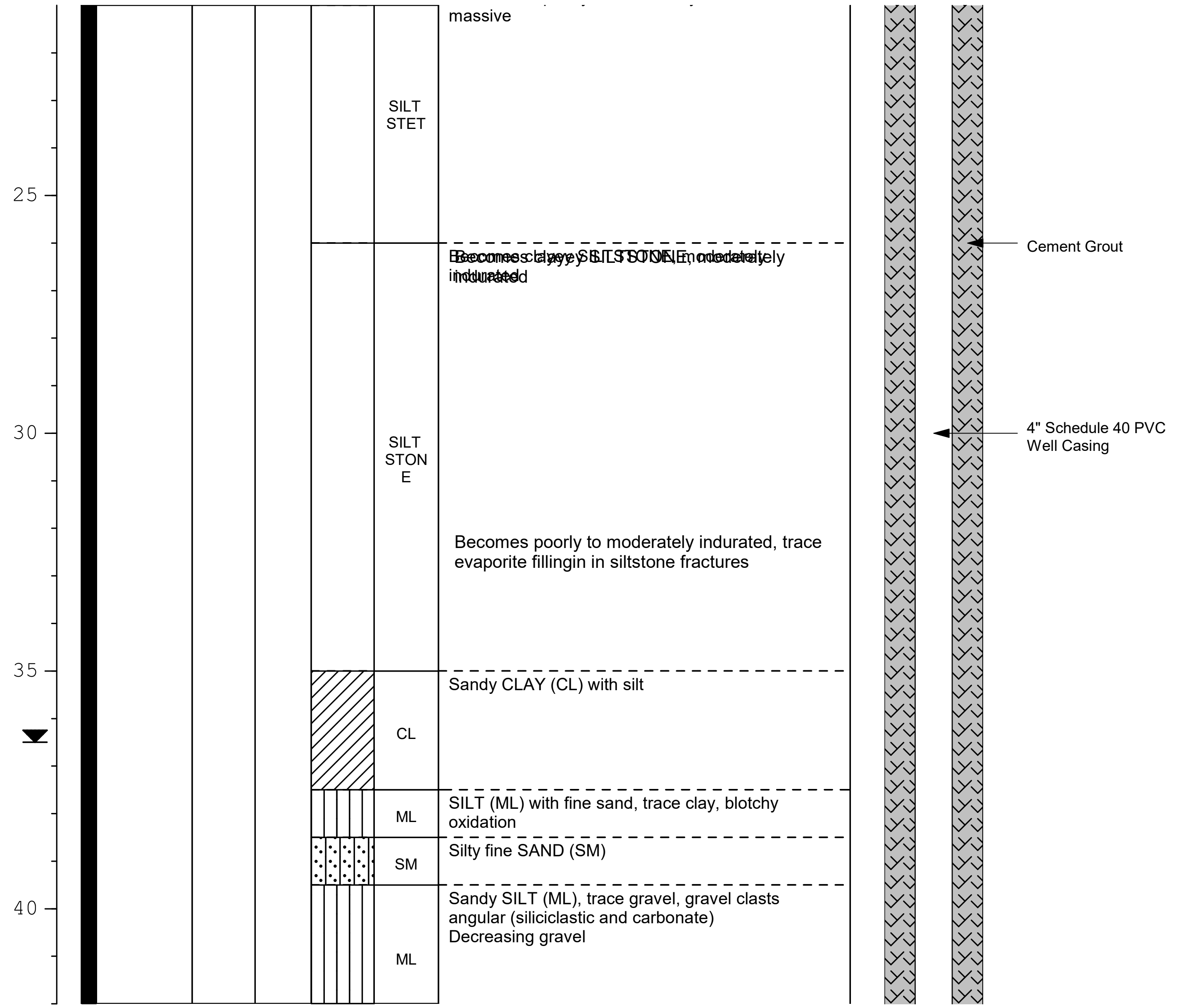
BORING LOG

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

BORING:	ARHS - 09
TOTAL DEPTH:	80'

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	36.5'
LOCATION:	Stewart Valley, Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Highway 178	METHOD OF DRILLING:	Sonic Drilling
	N36.16347, W-116.12998, Elevation 2,478 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/14/2018-2/15/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION



SOIL TYPE	SOIL TYPE
SILT STET	massive
SILT STONE	Becomes clayey SILTSTONE, moderately indurated Becomes poorly to moderately indurated, trace evaporite fillingin in siltstone fractures
CL	Sandy CLAY (CL) with silt
ML	SILT (ML) with fine sand, trace clay, blotchy oxidation
SM	Silty fine SAND (SM)
ML	Sandy SILT (ML), trace gravel, gravel clasts angular (siliciclastic and carbonate) Decreasing gravel

NOTES: Depth to groundwater, 5/3/2018, 55.40 feet

BORING LOG

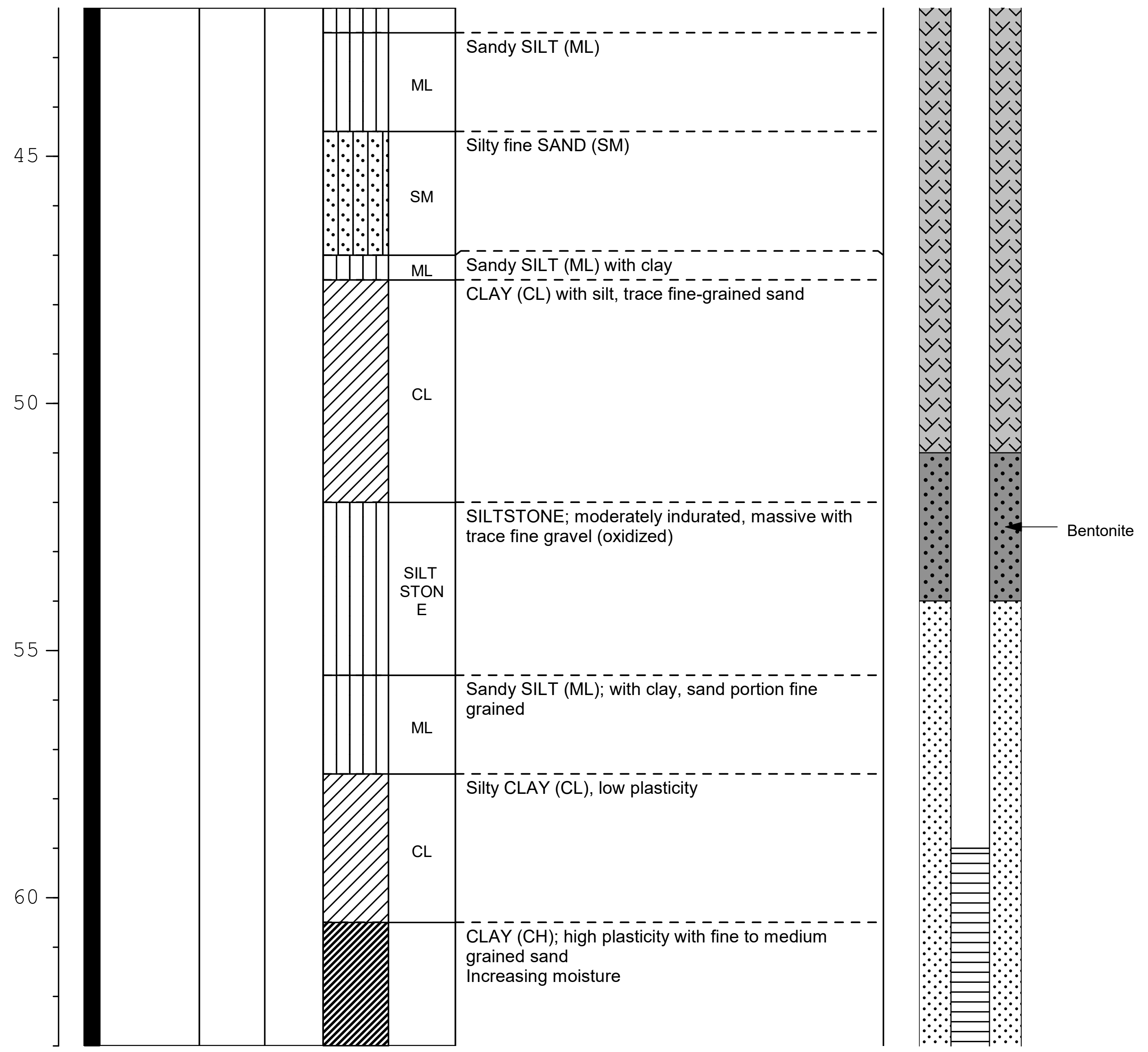
BORING: **ARHS - 09**

TOTAL DEPTH: **80'**

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	36.5'
LOCATION:	Stewart Valley, Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Highway 178	METHOD OF DRILLING:	Sonic Drilling
	N36.16347, W-116.12998, Elevation 2,478 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/14/2018-2/15/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION



Sandy SILT (ML)

Silty fine SAND (SM)

Sandy SILT (ML) with clay

CLAY (CL) with silt, trace fine-grained sand

SILTSTONE; moderately indurated, massive with trace fine gravel (oxidized)

Sandy SILT (ML); with clay, sand portion fine grained

Silty CLAY (CL), low plasticity

CLAY (CH); high plasticity with fine to medium grained sand
Increasing moisture

NOTES: Depth to groundwater, 5/3/2018, 55.40 feet

BORING LOG

BORING: **ARHS - 09**

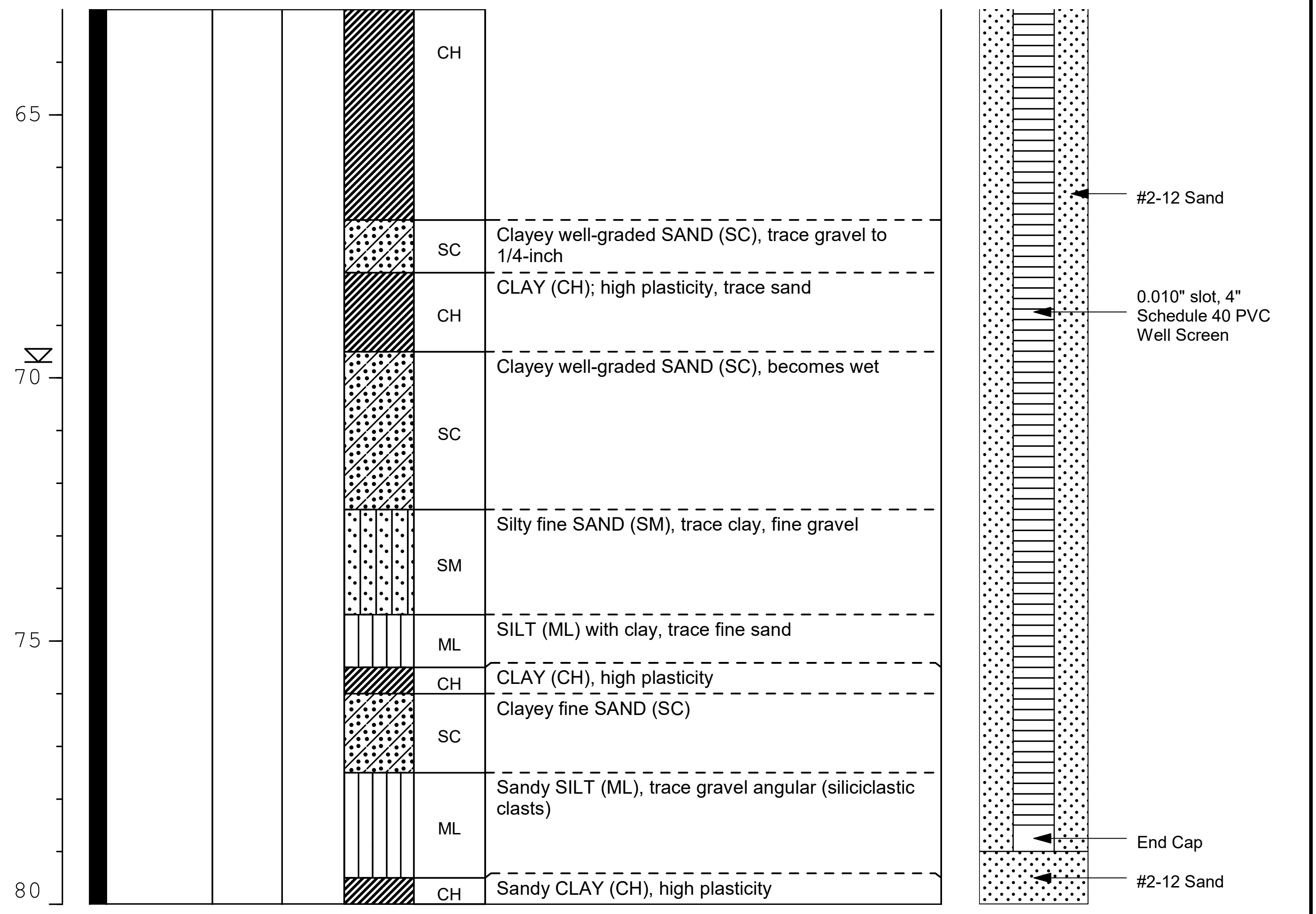
TOTAL DEPTH: **80'**

PARTNER Engineering and Science, Inc.

2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	36.5'
LOCATION:	Stewart Valley, Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Highway 178	METHOD OF DRILLING:	Sonic Drilling
	N36.16347, W-116.12998, Elevation 2,478 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/14/2018-2/15/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION



Clayey well-graded SAND (SC), trace gravel to 1/4-inch

CLAY (CH); high plasticity, trace sand

Clayey well-graded SAND (SC), becomes wet

Silty fine SAND (SM), trace clay, fine gravel

SILT (ML) with clay, trace fine sand

CLAY (CH), high plasticity

Clayey fine SAND (SC)

Sandy SILT (ML), trace gravel angular (siliciclastic clasts)

Sandy CLAY (CH), high plasticity

NOTES: Depth to groundwater, 5/3/2018, 55.40 feet

BORING LOG

BORING: ARHS - 08

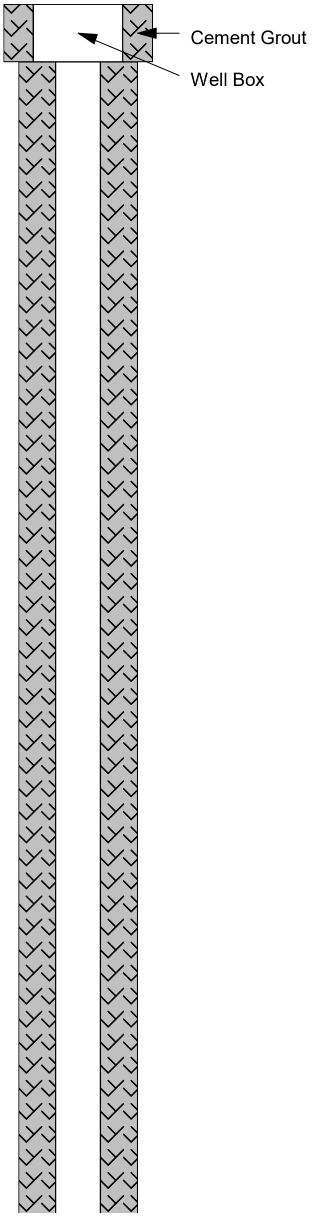
TOTAL DEPTH: 201'

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	180'
LOCATION:	Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Highway 127 - Evelyn Siding	METHOD OF DRILLING:	Sonic Drilling
	N36.14688, W-116.31758, Elevation 1,871 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/15/2018-2/17/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE
0		NM	N/A		SM	Silty well-graded SAND (SM); trace gravel to 1-inch, pale yellowish brown Increasing gravel
5					SW	Well-graded SAND (SW) with SILT; trace mud chips to 1/4-inch thick by 1-inch diameter
					SW	Well-graded SAND (SW) with silt, gravel to 2 inches
					GW	Well-graded GRAVEL (GW) with well-graded sand; yellowish gray
10					SW	Well-graded SAND (SW) with silt, trace gravel
					GW	GRAVEL (GW) well-graded to 2 inches, with well-graded sand clasts, mixed lithologies (carbonate, granitic, quartzite), subrounded to angular
15					SM	Silty well-graded SAND (SM); trace gravel to 1-inch; dark yellowish brown Becomes light yellowish brown
					ML	Sandy SILT (ML), trace clay
20					SM	Silty fine-grained SAND (SM), with gravel to 1-inch, subangular to subrounded
						Well-graded SAND (SW) with gravel to 2 inches;

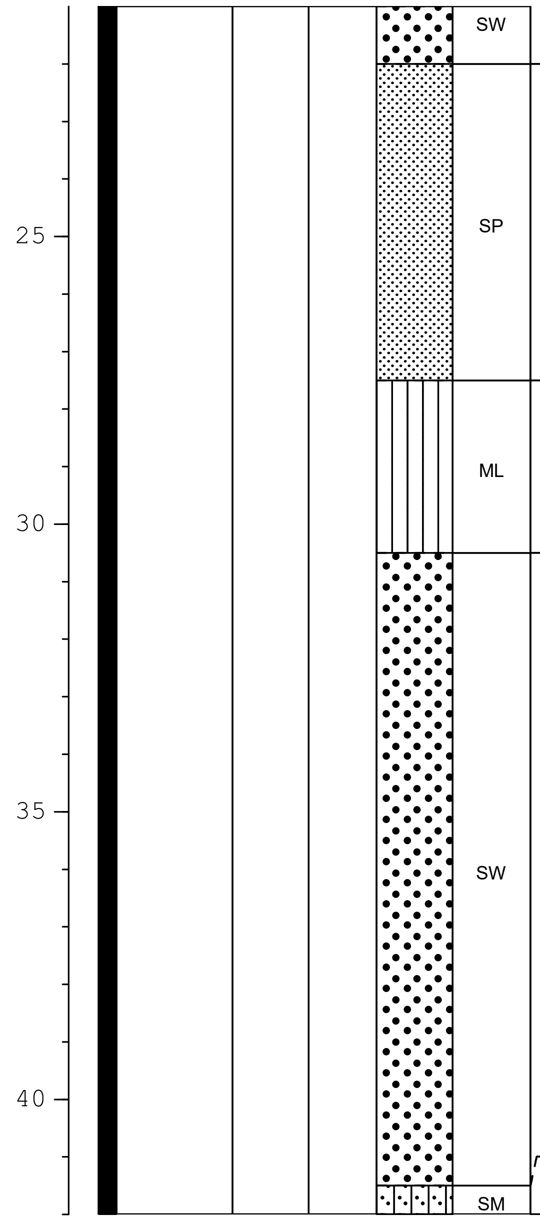
BORING COMPLETION / **WELL DESCRIPTION**



NOTES: Depth to water, 5/2/2018, 178.11 feet

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	180'
LOCATION:	Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Highway 127 - Evelyn Siding	METHOD OF DRILLING:	Sonic Drilling
	N36.14688, W-116.31758, Elevation 1,871 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/15/2018-2/17/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION



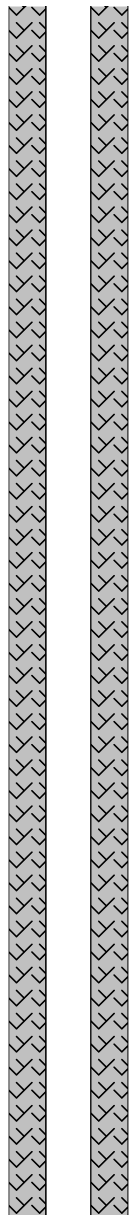
brown

Poorly-graded SAND (SP), fine to medium grained, with SILT, trace gravel to 3/4-inch, carbonate clasts to 3 inches, light yellowish gray

Sandy SILT (ML) with gravel, trace claystone fragments, poorly indurated

Silty well-graded SAND (SW), trace gravel to 3/4-inch; gravel clasts carbonate dominant, siltstone clasts poorly indurated/friable

Silty poorly-graded SAND (SM), fine grained with medium sand, trace coarse sand



NOTES: Depth to water, 5/2/2018, 178.11 feet

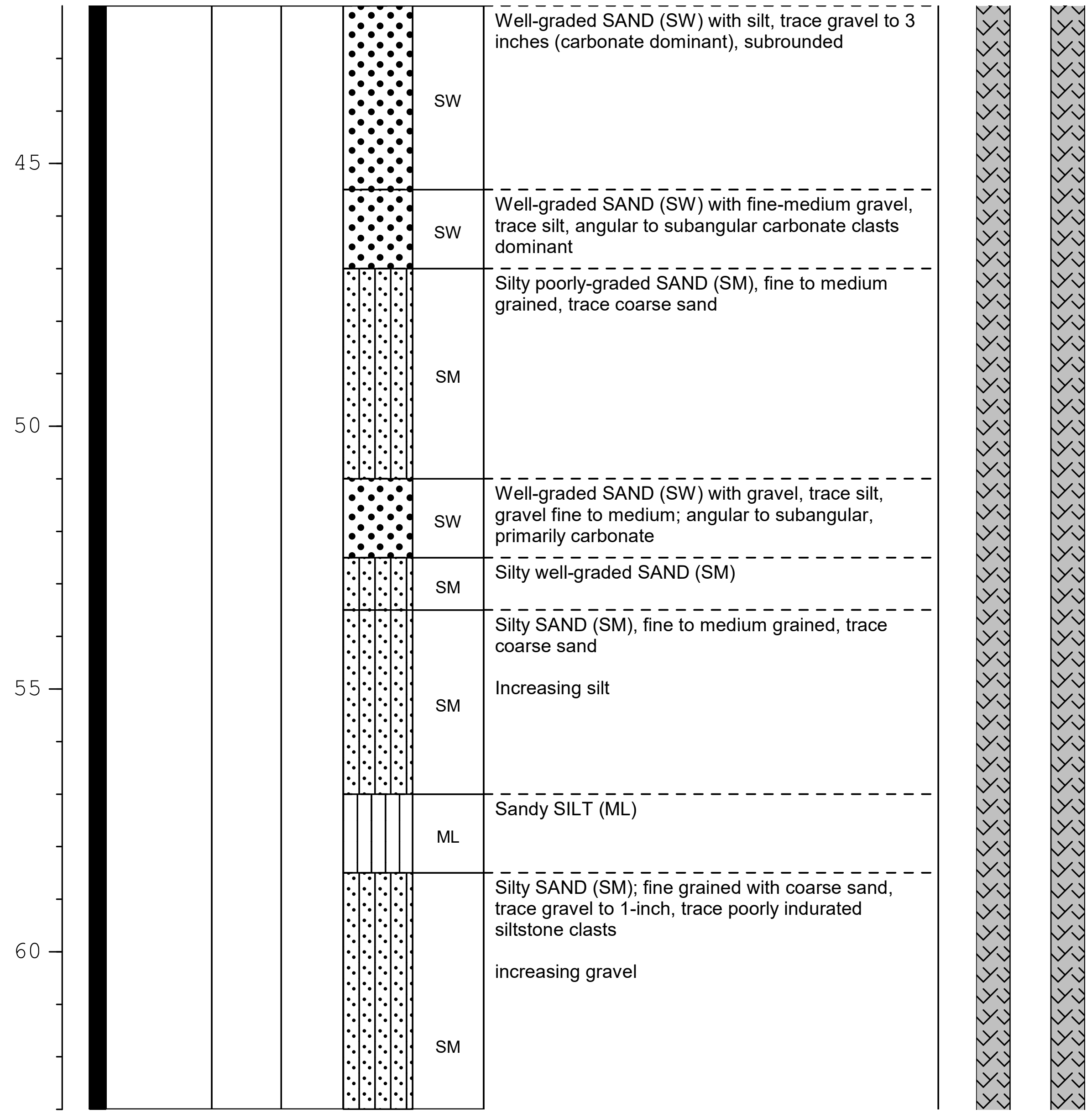
BORING LOG

BORING: **ARHS - 08**

TOTAL DEPTH: **201'**

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	180'
LOCATION:	Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Highway 127 - Evelyn Siding	METHOD OF DRILLING:	Sonic Drilling
	N36.14688, W-116.31758, Elevation 1,871 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/15/2018-2/17/2018	FIELD TECHNICIAN:	AZ



DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION
					SW	Well-graded SAND (SW) with silt, trace gravel to 3 inches (carbonate dominant), subrounded		
					SW	Well-graded SAND (SW) with fine-medium gravel, trace silt, angular to subangular carbonate clasts dominant		
					SM	Silty poorly-graded SAND (SM), fine to medium grained, trace coarse sand		
					SW	Well-graded SAND (SW) with gravel, trace silt, gravel fine to medium; angular to subangular, primarily carbonate		
					SM	Silty well-graded SAND (SM)		
					SM	Silty SAND (SM), fine to medium grained, trace coarse sand Increasing silt		
					ML	Sandy SILT (ML)		
					SM	Silty SAND (SM); fine grained with coarse sand, trace gravel to 1-inch, trace poorly indurated siltstone clasts increasing gravel		

NOTES: Depth to water, 5/2/2018, 178.11 feet

BORING LOG

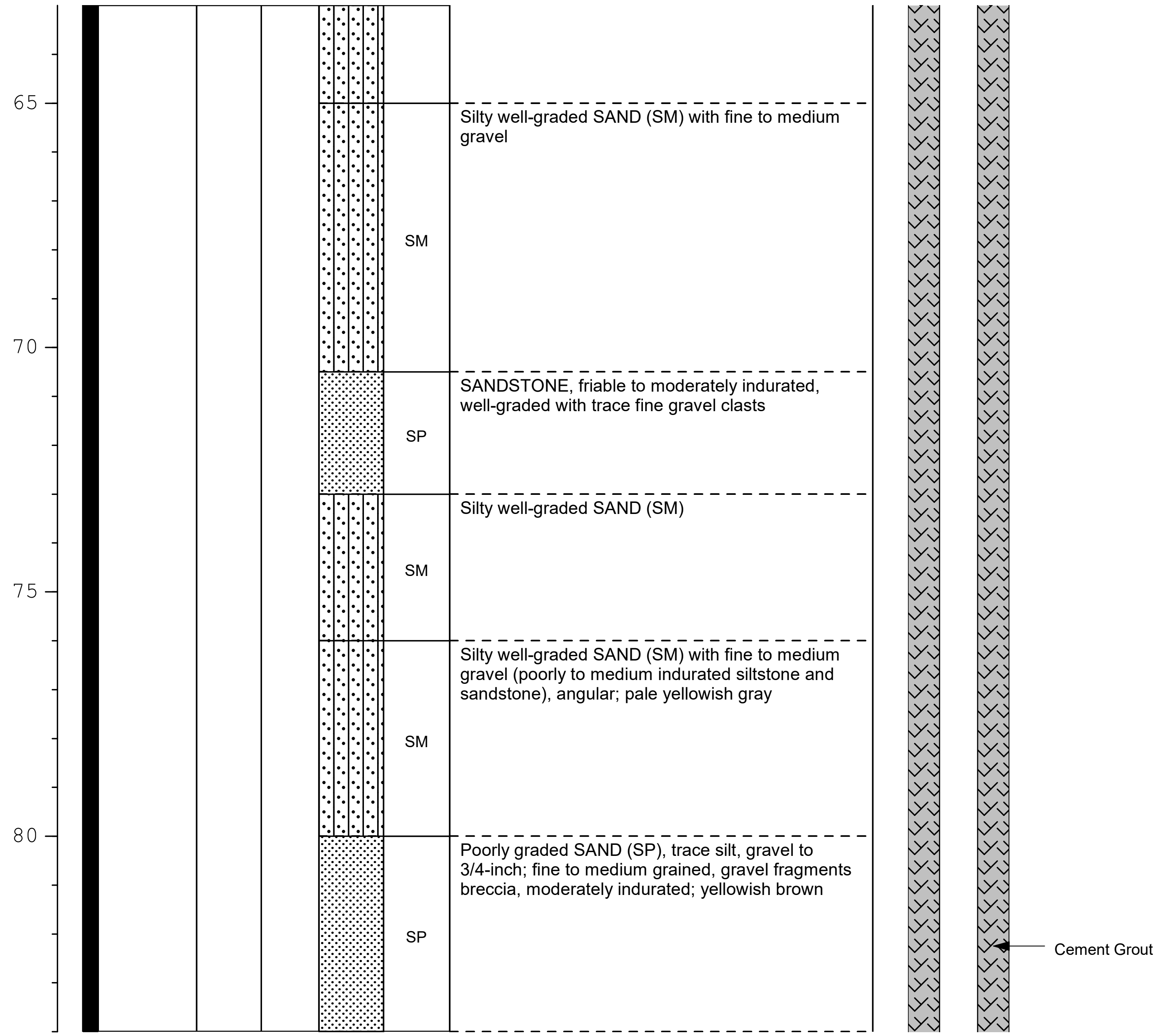
BORING: **ARHS - 08**

TOTAL DEPTH: **201'**

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	180'
LOCATION:	Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Highway 127 - Evelyn Siding	METHOD OF DRILLING:	Sonic Drilling
	N36.14688, W-116.31758, Elevation 1,871 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/15/2018-2/17/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION



Silty well-graded SAND (SM) with fine to medium gravel

SANDSTONE, friable to moderately indurated, well-graded with trace fine gravel clasts

Silty well-graded SAND (SM)

Silty well-graded SAND (SM) with fine to medium gravel (poorly to medium indurated siltstone and sandstone), angular; pale yellowish gray

Poorly graded SAND (SP), trace silt, gravel to 3/4-inch; fine to medium grained, gravel fragments breccia, moderately indurated; yellowish brown

NOTES: Depth to water, 5/2/2018, 178.11 feet

BORING LOG

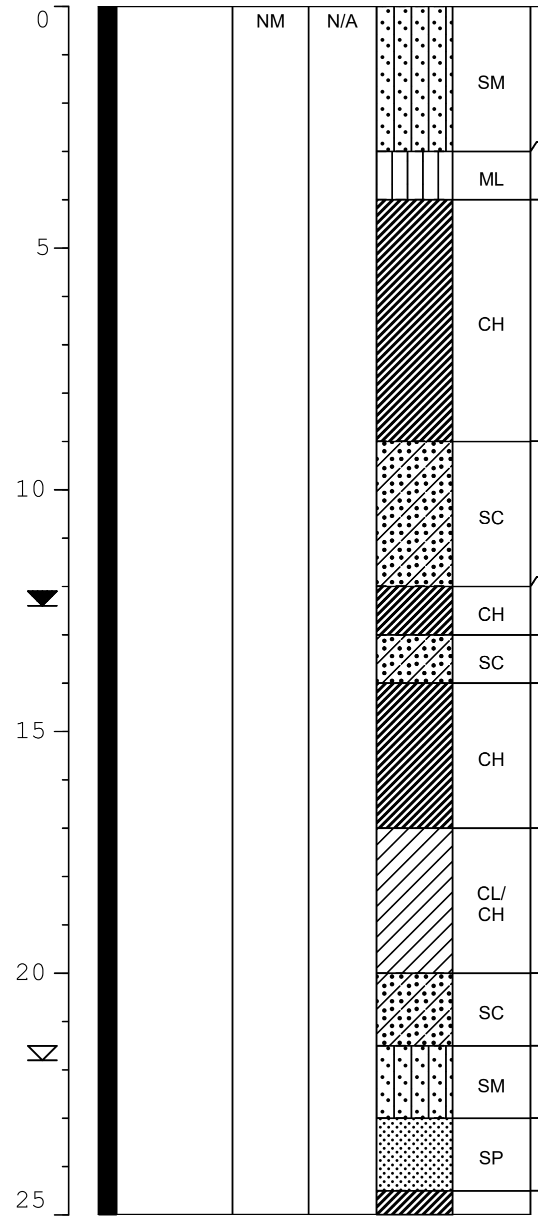
BORING: **ARHS - 06**

TOTAL DEPTH: **30'**

PARTNER Engineering and Science, Inc.

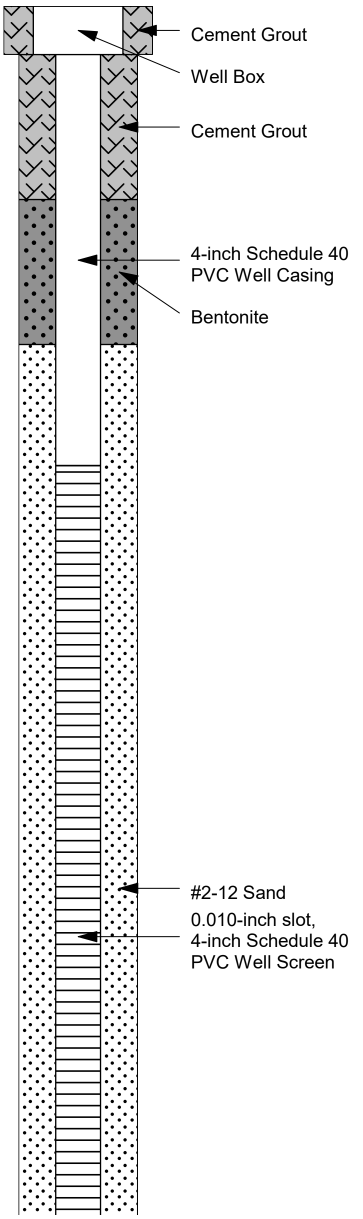
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	12.4'
LOCATION:	California Valley - Tule Well, Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Mesquite Valley Road	METHOD OF DRILLING:	Sonic Drilling
	N35.81399, W-116.05242, Elevation -2,302 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/7/2018	FIELD TECHNICIAN:	AZ



DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE
		NM	N/A		SM	Silty, poorly-graded SAND (SM); fine grained with medium sand, trace clay, pale yellowish brown; moist
					ML	SILT (ML) with sand, sand content fine to medium grained
					CH	Sandy CLAY (CH), medium to high plasticity, sand fine to medium grained, trace coarse sand
					SC	Clayey SAND (SC); fine to medium grained; clay fraction high plasticity
					CH	CLAY (CH) with fine to medium grained sand, medium to high plasticity; dark yellowish brown
					SC	Clayey SAND (SC)
					CH	CLAY (CH); medium to high plasticity
					CL/ CH	CLAY (CL/CH); medium plastic, with fine grained sand; mottled dark yellowish brown and dark reddish brown
					SC	Clayey SAND (SC); fine to medium grained; dark yellowish brown with mottled dark reddish brown
					SM	Silty fine to medium SAND (SM); dark yellowish brown, becomes wet
					SP	Poorly-graded SAND (SP); fine to medium grained, trace gravel to 1-inch

BORING COMPLETION | WELL DESCRIPTION



NOTES: Depth to water, 5/3/2018, 14.52 feet

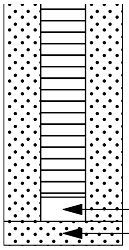
BORING LOG

BORING: **ARHS - 06**

TOTAL DEPTH: **30'**

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	12.4'
LOCATION:	California Valley - Tule Well, Inyo County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Mesquite Valley Road	METHOD OF DRILLING:	Sonic Drilling
	N35.81399, W-116.05242, Elevation -2,302 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/7/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION
	■			▨	CH	mottling (organic material)		
30	■			▨	SC	Clayey SAND (SC) with silt, grayish olive		End Cap #2-12 Sand

NOTES: Depth to water, 5/3/2018, 14.52 feet

BORING LOG

BORING: ARHS - 05

TOTAL DEPTH: 110'

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION

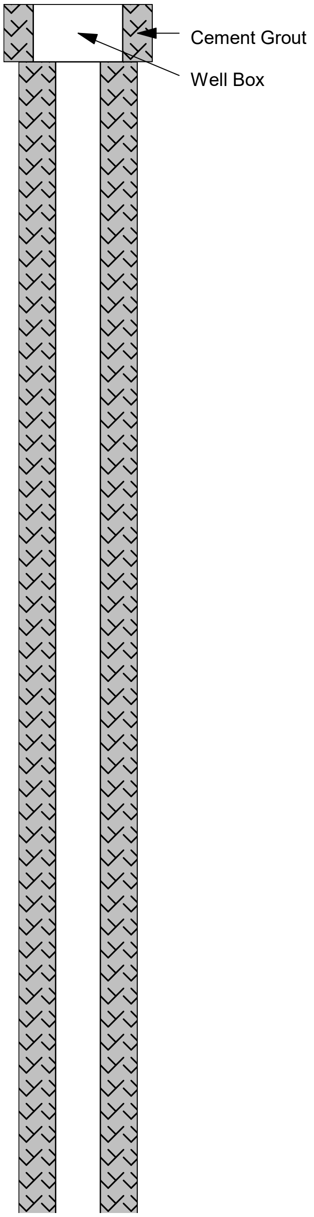
PROJECT: Amargosa River Basin
LOCATION: San Bernardino County, California
SITE ADDRESS: Dumont Dunes Road
N35.69529, W-116.25121, Elevation 631 feet
JOB NO.: SM16-175861 T2
DATES DRILLED: 2/15/2018

DRILLING INFORMATION

DEPTH TO GROUNDWATER: 74.60'
RIG TYPE: Sonic - Gregg Drilling
METHOD OF DRILLING: Sonic Drilling
SAMPLING METHODS: Eijkelkamp SonicSampDrill
BORING DIAMETER: 8"
FIELD TECHNICIAN: AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE
0		NM	N/A		SW	Well-graded SAND (SW) with gravel, trace silt; loose, yellowish brown; moist Color consistent to 25 feet below ground surface (bgs).
5 10					SW	Well-graded SAND (SW) with gravel, trace cobbles to greater than 3 inches; subangular to subrounded, mixed-lithology clasts.
					GP	Poorly-graded GRAVEL (GP) with sand, gravel fine to coarse, loose
					SP	Poorly-graded SAND (SP), fine to medium grained; loose
15					SW	Well-graded SAND with gravel; trace silt; loose
					SP	Poorly-graded SAND (SP), fine to medium grained; trace coarse sand, gravel, silt, loose
20						Silty well-graded SAND (SM) with gravel

BORING COMPLETION / WELL DESCRIPTION



NOTES: Depth to water, 5/3/2018, 104.71 feet at top of casing

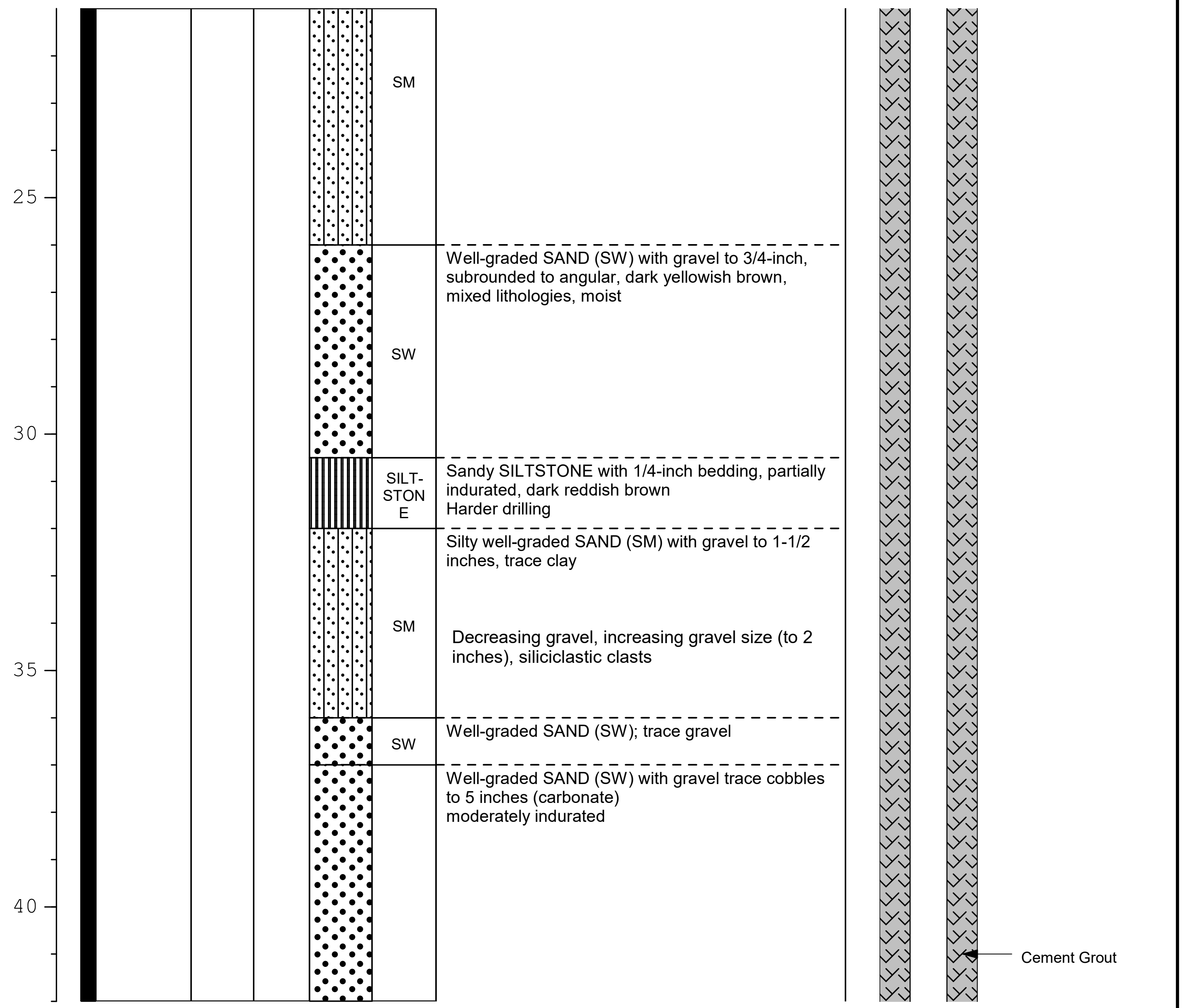
BORING LOG

BORING: **ARHS - 05**

TOTAL DEPTH: **110'**

PARTNER Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	74.60'
LOCATION:	San Bernardino County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Dumont Dunes Road	METHOD OF DRILLING:	Sonic Drilling
	N35.69529, W-116.25121, Elevation 631 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/15/2018	FIELD TECHNICIAN:	AZ



DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION
					SM			
					SW	Well-graded SAND (SW) with gravel to 3/4-inch, subrounded to angular, dark yellowish brown, mixed lithologies, moist		
					SILT-STONE	Sandy SILTSTONE with 1/4-inch bedding, partially indurated, dark reddish brown Harder drilling		
					SM	Silty well-graded SAND (SM) with gravel to 1-1/2 inches, trace clay Decreasing gravel, increasing gravel size (to 2 inches), siliciclastic clasts		
					SW	Well-graded SAND (SW); trace gravel		
						Well-graded SAND (SW) with gravel trace cobbles to 5 inches (carbonate) moderately indurated		

NOTES: Depth to water, 5/3/2018, 104.71 feet at top of casing

BORING LOG

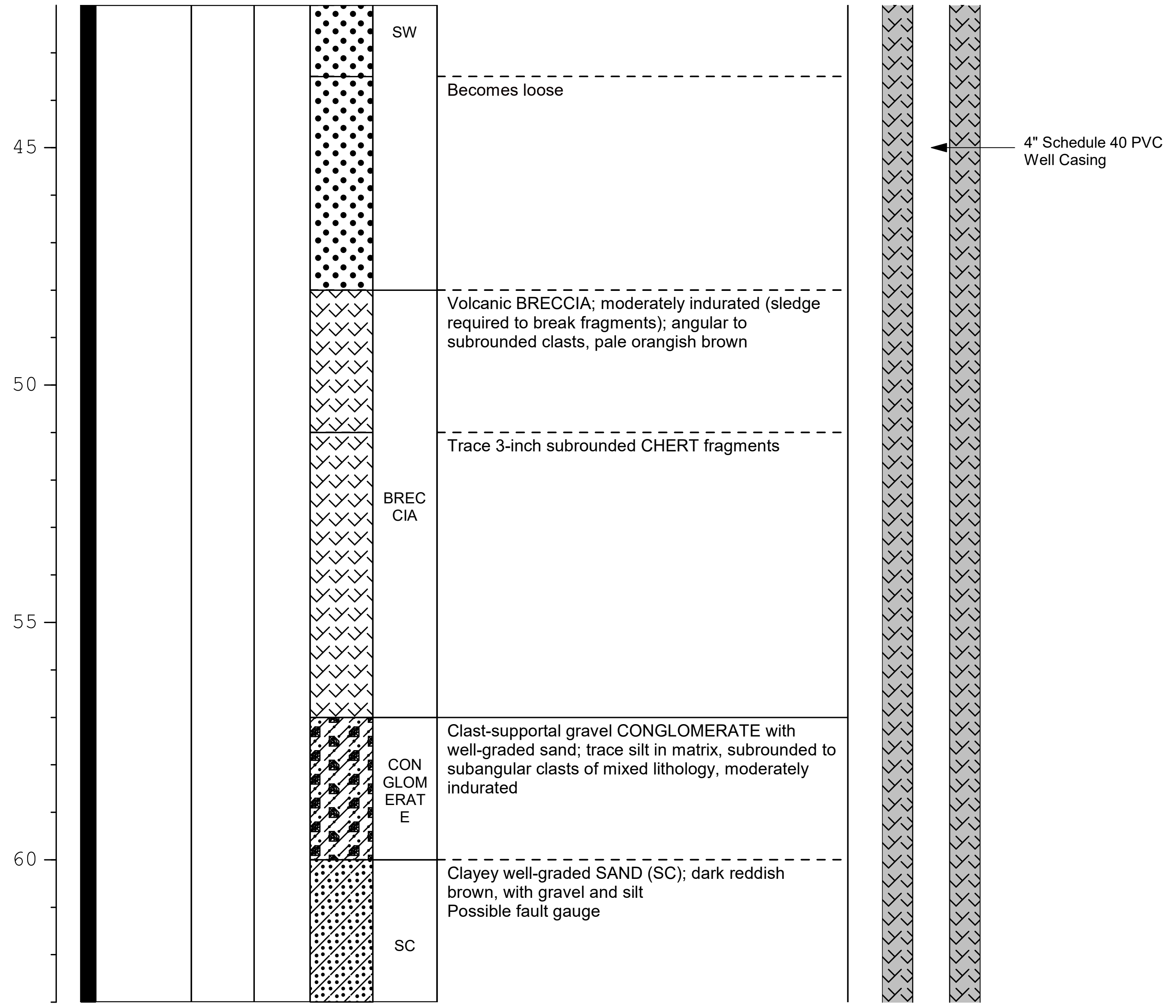
BORING: **ARHS - 05**

TOTAL DEPTH: **110'**

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	74.60'
LOCATION:	San Bernardino County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Dumont Dunes Road	METHOD OF DRILLING:	Sonic Drilling
	N35.69529, W-116.25121, Elevation 631 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/15/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION



Becomes loose

Volcanic BRECCIA; moderately indurated (sledge required to break fragments); angular to subrounded clasts, pale orangish brown

Trace 3-inch subrounded CHERT fragments

Clast-supportal gravel CONGLOMERATE with well-graded sand; trace silt in matrix, subrounded to subangular clasts of mixed lithology, moderately indurated

Clayey well-graded SAND (SC); dark reddish brown, with gravel and silt
Possible fault gauge

NOTES: Depth to water, 5/3/2018, 104.71 feet at top of casing

BORING LOG

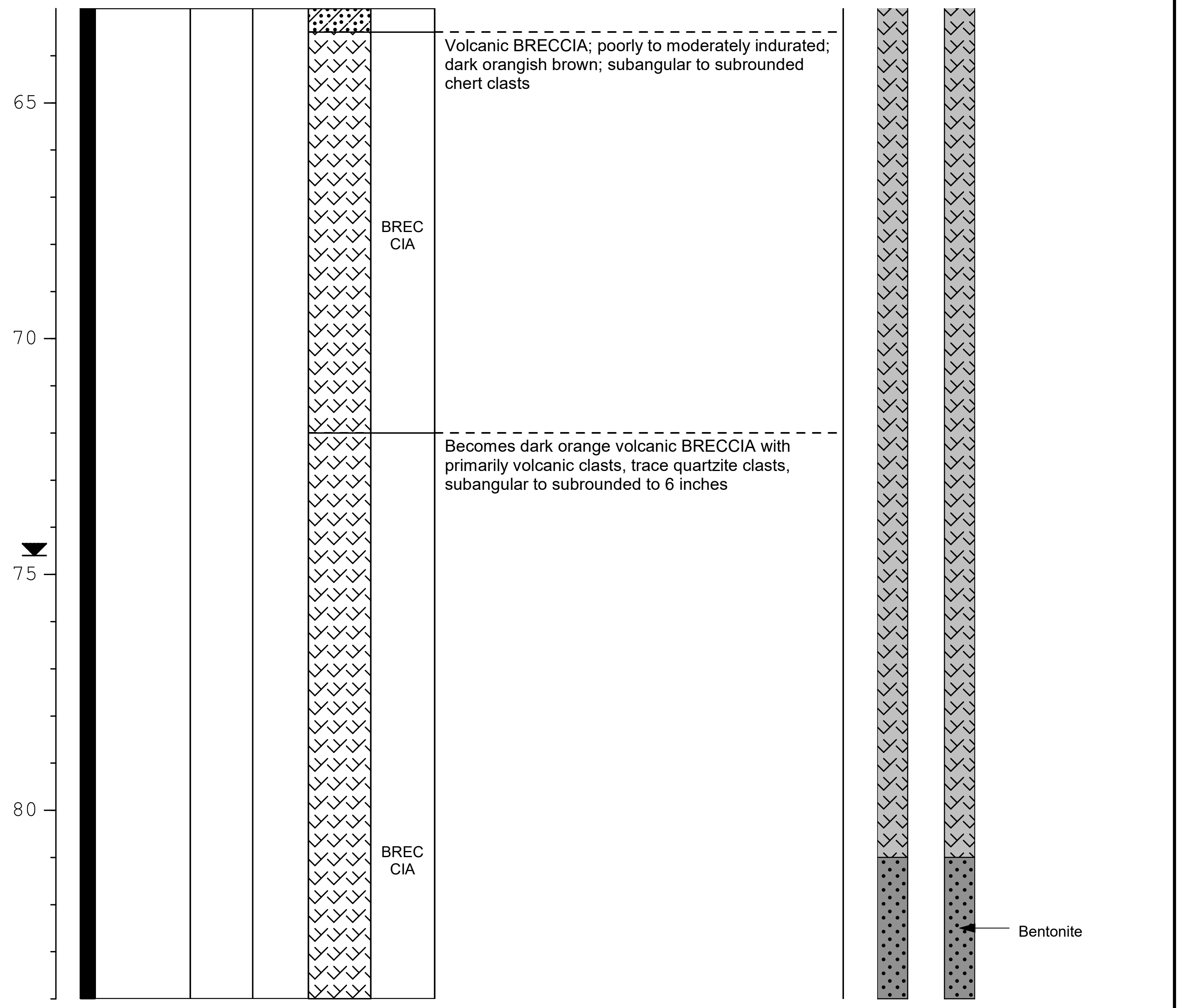
BORING: **ARHS - 05**

TOTAL DEPTH: **110'**

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	74.60'
LOCATION:	San Bernardino County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Dumont Dunes Road	METHOD OF DRILLING:	Sonic Drilling
	N35.69529, W-116.25121, Elevation 631 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/15/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION



Volcanic BRECCIA; poorly to moderately indurated; dark orangish brown; subangular to subrounded chert clasts

Becomes dark orange volcanic BRECCIA with primarily volcanic clasts, trace quartzite clasts, subangular to subrounded to 6 inches

NOTES: Depth to water, 5/3/2018, 104.71 feet at top of casing

BORING LOG

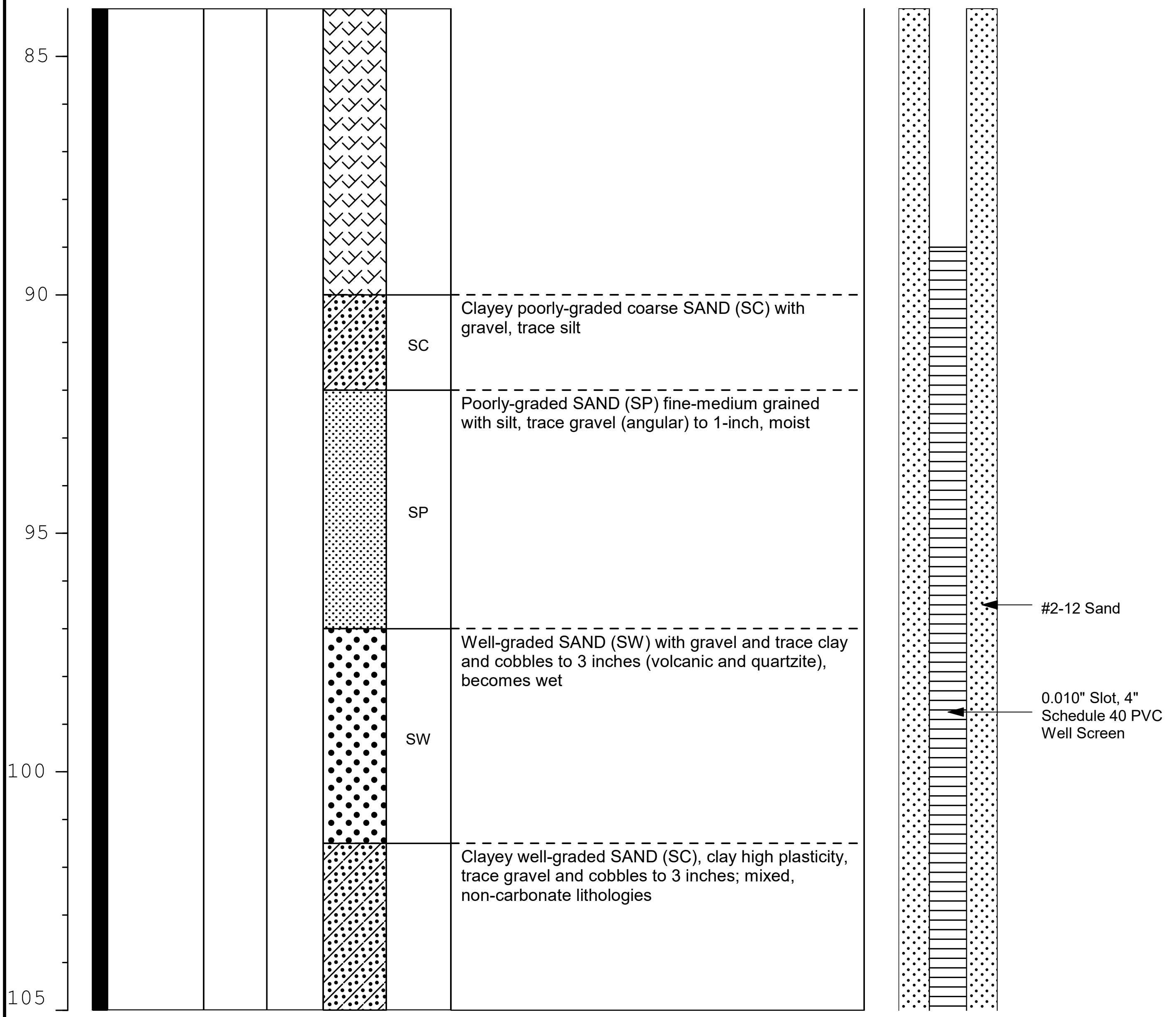
BORING: ARHS - 05

TOTAL DEPTH: 110'

PARTNER
Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	74.60'
LOCATION:	San Bernardino County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Dumont Dunes Road	METHOD OF DRILLING:	Sonic Drilling
	N35.69529, W-116.25121, Elevation 631 feet	SAMPLING METHODS:	Eijkelkamp SonicSampDrill
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/15/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION



Clayey poorly-graded coarse SAND (SC) with gravel, trace silt

Poorly-graded SAND (SP) fine-medium grained with silt, trace gravel (angular) to 1-inch, moist

Well-graded SAND (SW) with gravel and trace clay and cobbles to 3 inches (volcanic and quartzite), becomes wet

Clayey well-graded SAND (SC), clay high plasticity, trace gravel and cobbles to 3 inches; mixed, non-carbonate lithologies

NOTES: Depth to water, 5/3/2018, 104.71 feet at top of casing

BORING LOG

BORING: ARHS - 05

TOTAL DEPTH: 110'

PARTNER Engineering and Science, Inc.
2154 Torrance Boulevard, Suite 200
Torrance, California 90501

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Amargosa River Basin	DEPTH TO GROUNDWATER:	74.60'
LOCATION:	San Bernardino County, California	RIG TYPE:	Sonic - Gregg Drilling
SITE ADDRESS:	Dumont Dunes Road	METHOD OF DRILLING:	Sonic Drilling
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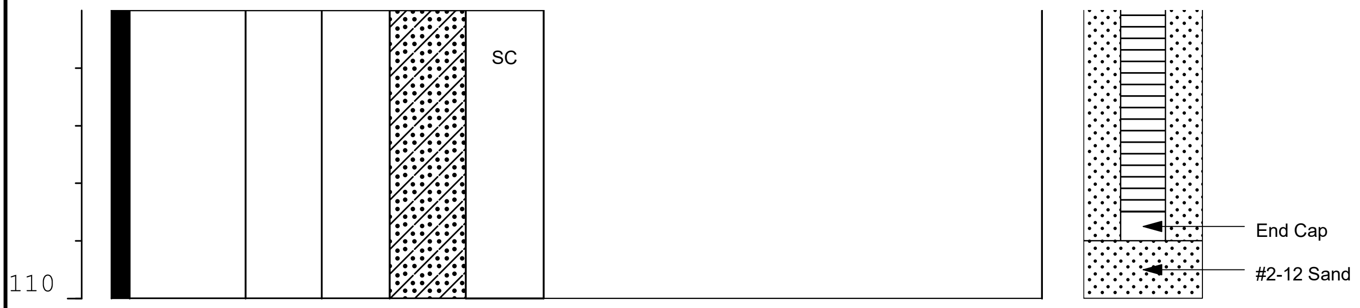
JOB NO.:	SM16-175861 T2	BORING DIAMETER:	8"
DATES DRILLED:	2/15/2018	FIELD TECHNICIAN:	AZ

DEPTH	SAMPLE	PID (ppm)	BLOW COUNT	USCS	SOIL TYPE	SOIL TYPE	BORING COMPLETION	WELL DESCRIPTION



NOTES: Depth to water, 5/3/2018, 104.71 feet at top of casing

INYO COUNTY ENVIRONMENTAL HEALTH SERVICES

P. O. Box 427, Independence, CA 93526
(760) 878-0238 • Fax (760) 878-0239

207 W. South Street, Bishop, CA 93514
(760) 873-7866 • Fax (760) 873-3236

WELL PERMIT APPLICATION

ARHS-10

Permit No. ______________

TYPE OF WORK (Check)

New Well ☑
Repair or Modification ☐
Destruction ☐

USE

Domestic ☐ Test Well ☐
Irrigation ☐ Municipal ☐
Monitoring ☑ Other ☐

EQUIPMENT (Check)

Rotary ☑
Cable Tool ☐
Other ☑
Sonic

PROPOSED WELL DEPTH

30 Feet

PROPOSED CASING

Steel ☐ Other PVC Diameter 4" Wall or Gage SCH 40

PROPOSED SEALING ZONE

From 0 to 18 Feet

SEALING MATERIAL (Check)

Neat Cement ☐ Bentonite Clay ☐
Cement Grout ☑ Concrete ☐

PHYSICAL SITE ADDRESS:
None. See attached map. Appx location N35.81397, W-116.05249.

ASSESSOR'S PARCEL NO.
None.

DATE OF WORK

Start ______________

Completion ______________

NAME OF WELL OWNER:
Amargosa Conservancy

MAILING ADDRESS:
2121 N California Blvd., Suite 290

PHONE NUMBER:

NAME OF WELL DRILLER:

BUSINESS ADDRESS:

PHONE NUMBER:

(FOR OFFICE USE ONLY)
DISPOSITION OF APPLICATION

☐ APPROVED ☐ DENIED

☐ APPROVED WITH CONDITIONS LISTED:

☐ Minimum ________ft. seal of annular space(minimum 2 inches) is required and must be witnessed by Inyo County Environmental Health Services.

☐ A concrete pad shall be placed around the well casing that extends at least two feet laterally in all directions from the outside of the well boring and is a minimum of 4 inches thick.The pad must be sloped away from the well casing.

☐ Well driller's log shall be submitted to Inyo County Environmental Health Services within 30 days of completion of the well.

☐ ______________________________

____

____

Inyo County Environmental Health Services recommends that an acceptable bacteriological sample be obtained after the well is completed.

C-57 LICENSE NUMBER:
____

Cash Deposit ☐
Bond Posted ☐

$__________ Fee paid on ________ Receipt No. __________

I hereby agree to comply with all regulations of the Department of Environmental Health Services and with all ordinances and laws of Inyo County and of the State of California pertaining to well construction, repair, modification and destruction at the time of commencement of work.

____
LICENSED WELL DRILLER'S SIGNATURE

____
DATE

____
Site Approval/Permit Application Approval *Date*

____
Construction Inspection *Date*

____
Final Approval *Date*


127
Well ARHS-08
Well ARHS-09
37
Pahrump
160
178
Well ARHS-07
Well ARHS-10
Well ARHS-06
Sandy Valley
Well ARHS-05
16.07 mi
© 2016 Google
Image Landsat
Google earth

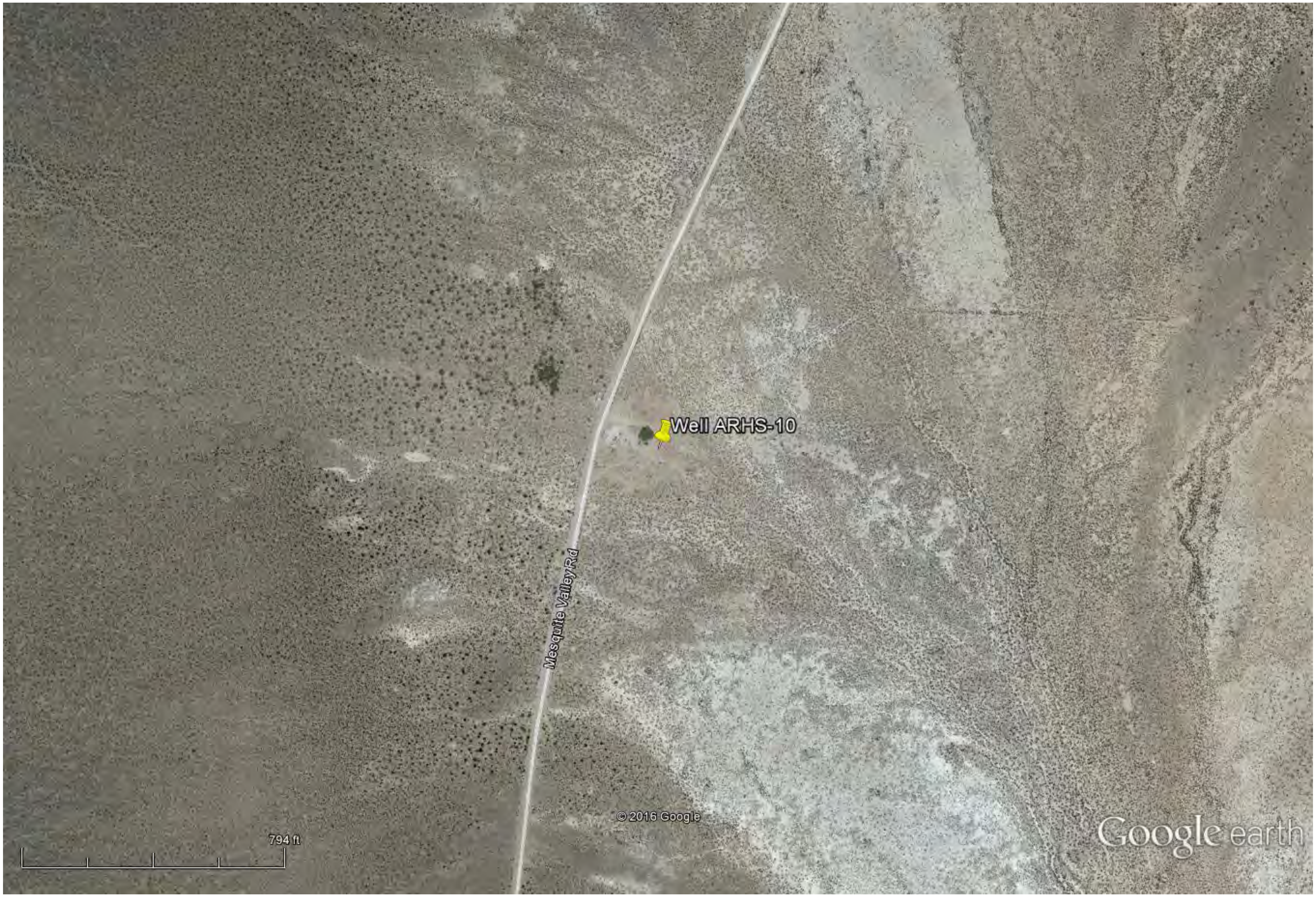

Well ARHS-10
Mesquite Valley Rd
794 ft
© 2016 Google
Google earth

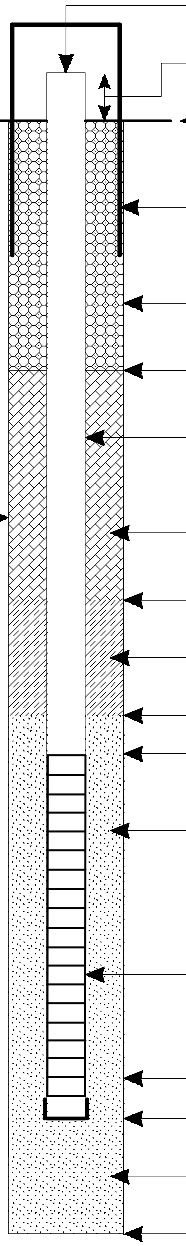
Photo 5: Proposed monitoring well location for ARHS-10.

Project:
Project Location:
Project Number:

CONSTRUCTION LOG FOR WELL IN BORING ARHS-10

Location:
Date(s) Installed:
Installed By:
Observed By:
Total Depth (ft bgs):
Method of Installation:
Screened Interval:
Completion Zone:
Remarks:

NOTE: DIAGRAM IS NOT TO SCALE



Boring Diameter: 8 **inches**

Elevation of Top of Riser Pipe: ______ **ft MSL**

Height of Riser Above Ground: ______ **ft**

Ground Elevation: ______ **ft MSL**

ID/Type of Surface Casing: Above Ground Vault

Type of Grouting/Conductor Casing: Cement Grout

Depth of Grouting/Conductor Casing: 20 **ft**

ID/Type of Riser Pipe: 4" Sch 40

Type of Backfill: NA

Depth of Seal: 36 **ft**

Type of Seal: Bentonite

Depth of Top of Filter Pack: 38 **ft**

Depth of Top of Screen: 40 **ft**

Type of Filter Pack: #1 Sand

ID/Type of Screen: 4" Sch 40

Screen Slot Size: 0.010 inch

Depth of Bottom of Screen: 60 **ft**

Depth of Bottom of Plugged Blank Casing: 60 **ft**

Type/Depth of Backfill/Seal Below Well: NA

Total Depth of Boring: 60 **ft**

INYO COUNTY ENVIRONMENTAL HEALTH SERVICES

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(760) 878-0238 • Fax (760) 878-0239

207 W. South Street, Bishop, CA 93514
(760) 873-7866 • Fax (760) 873-3236

WELL PERMIT APPLICATION

ARHS-09

Permit No. ____________

TYPE OF WORK (Check)

- New Well ☑
- Repair or Modification ☐
- Destruction ☐

USE

- Domestic ☐
- Irrigation ☐
- Monitoring ☑
- Test Well ☐
- Municipal ☐
- Other ☐

EQUIPMENT (Check)

- Rotary ☑
- Cable Tool ☐
- Other ☑

Sonic

PROPOSED WELL DEPTH

30 Feet

PROPOSED CASING

Steel ☐ Other PVC Diameter 4" Wall or Gage SCH 40

PROPOSED SEALING ZONE

From 0 to 18 Feet

SEALING MATERIAL (Check)

- Neat Cement ☐
- Cement Grout ☑
- Bentonite Clay ☐
- Concrete ☐

PHYSICAL SITE ADDRESS:

None. See attached map. Appx location N35.81397, W-116.05249.

ASSESSOR'S PARCEL NO.

None.

DATE OF WORK

Start ____________

Completion ____________

NAME OF WELL OWNER:

Amargosa Conservancy

MAILING ADDRESS:

2121 N California Blvd., Suite 290

PHONE NUMBER:

NAME OF WELL DRILLER:

BUSINESS ADDRESS:

PHONE NUMBER:

C-57 LICENSE NUMBER:

____

- Cash Deposit ☐
- Bond Posted ☐

$__________ Fee paid on __________ Receipt No. __________

(FOR OFFICE USE ONLY)
DISPOSITION OF APPLICATION

☐ APPROVED ☐ DENIED

☐ APPROVED WITH CONDITIONS LISTED:

☐ Minimum ________ft. seal of annular space(minimum 2 inches) is required and must be witnessed by Inyo County Environmental Health Services.

☐ A concrete pad shall be placed around the well casing that extends at least two feet laterally in all directions from the outside of the well boring and is a minimum of 4 inches thick.The pad must be sloped away from the well casing.

☐ Well driller's log shall be submitted to Inyo County Environmental Health Services within 30 days of completion of the well.

☐ ____________________

____

____

Inyo County Environmental Health Services recommends that an acceptable bacteriological sample be obtained after the well is completed.

I hereby agree to comply with all regulations of the Department of Environmental Health Services and with all ordinances and laws of Inyo County and of the State of California pertaining to well construction, repair, modification and destruction at the time of commencement of work.

____
LICENSED WELL DRILLER'S SIGNATURE

____
DATE

____
Site Approval/Permit Application Approval *Date*

____
Construction Inspection *Date*

____
Final Approval *Date*


127
Well ARHS-08
Well ARHS-09
37
Pahrump
160
178
Well ARHS-07
Well ARHS-10
Well ARHS-06
Sandy Valley
Well ARHS-05
16.07 mi
© 2016 Google
Image Landsat
Google earth


Well ARHS-09
178
© 2016 Google
760 ft
Google earth

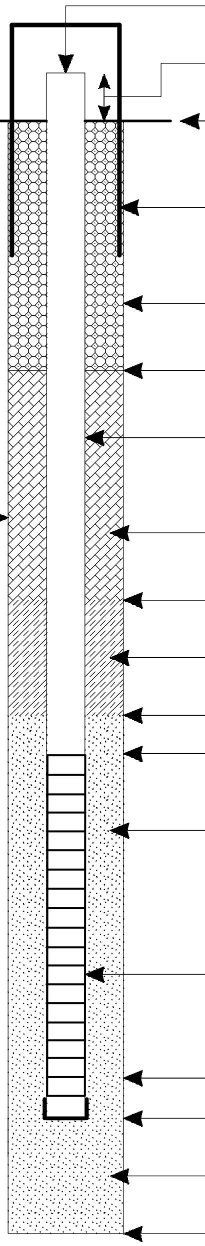
Photo 4: Proposed monitoring well location for ARHS-09.

Project:
Project Location:
Project Number:

CONSTRUCTION LOG FOR WELL IN BORING ARHS-09

Location:		Date(s) Installed:
Installed By:	Observed By:	Total Depth (ft bgs):
Method of Installation:		
Screened Interval:	Completion Zone:	
Remarks:		

NOTE: DIAGRAM IS NOT TO SCALE



Boring Diameter: ______ **inches**

Elevation of Top of Riser Pipe: ______ **ft MSL**

Height of Riser Above Ground: ______ **ft**

Ground Elevation: ______ **ft MSL**

ID/Type of Surface Casing: Above Ground Vault

Type of Grouting/Conductor Casing: Cement Grout

Depth of Grouting/Conductor Casing: 20 **ft**

ID/Type of Riser Pipe: 4" Sch 40

Type of Backfill: NA

Depth of Seal: 36 **ft**

Type of Seal: Bentonite

Depth of Top of Filter Pack: 38 **ft**

Depth of Top of Screen: 40 **ft**

Type of Filter Pack: #1 Sand

ID/Type of Screen: 4" Sch 40

Screen Slot Size: 0.010 inch

Depth of Bottom of Screen: 60 **ft**

Depth of Bottom of Plugged Blank Casing: 60 **ft**

Type/Depth of Backfill/Seal Below Well: NA

Total Depth of Boring: 60 **ft**

INYO COUNTY ENVIRONMENTAL HEALTH SERVICES

P. O. Box 427, Independence, CA 93526
(760) 878-0238 • Fax (760) 878-0239

207 W. South Street, Bishop, CA 93514
(760) 873-7866 • Fax (760) 873-3236

WELL PERMIT APPLICATION

ARHS-08

Permit No. ____________

TYPE OF WORK (Check)

New Well ☑
Repair or Modification ☐
Destruction ☐

USE

Domestic ☐
Irrigation ☐
Monitoring ☑
Test Well ☐
Municipal ☐
Other ☐

EQUIPMENT (Check)

Rotary ☑
Cable Tool ☐
Other ☑
Sonic

PROPOSED WELL DEPTH

30 Feet

PROPOSED CASING

Steel ☐ Other PVC Diameter 4" Wall or Gage SCH 40

PROPOSED SEALING ZONE

From 0 to 18 Feet

SEALING MATERIAL (Check)

Neat Cement ☐
Cement Grout ☑
Bentonite Clay ☐
Concrete ☐

PHYSICAL SITE ADDRESS:

None. See attached map. Appx location N35.81397, W-116.05249.

ASSESSOR'S PARCEL NO.

None.

DATE OF WORK

Start ____________

Completion ____________

NAME OF WELL OWNER:

Amargosa Conservancy

MAILING ADDRESS:

2121 N California Blvd., Suite 290

PHONE NUMBER:

NAME OF WELL DRILLER:

BUSINESS ADDRESS:

PHONE NUMBER:

(FOR OFFICE USE ONLY)
DISPOSITION OF APPLICATION

☐ APPROVED ☐ DENIED

☐ APPROVED WITH CONDITIONS LISTED:

☐ Minimum ________ft. seal of annular space(minimum 2 inches) is required and must be witnessed by Inyo County Environmental Health Services.

☐ A concrete pad shall be placed around the well casing that extends at least two feet laterally in all directions from the outside of the well boring and is a minimum of 4 inches thick.The pad must be sloped away from the well casing.

☐ Well driller's log shall be submitted to Inyo County Environmental Health Services within 30 days of completion of the well.

☐ ____________________

____

____

Inyo County Environmental Health Services recommends that an acceptable bacteriological sample be obtained after the well is completed.

C-57 LICENSE NUMBER:

____

Cash Deposit ☐
Bond Posted ☐

$__________ Fee paid on ________ Receipt No. __________

I hereby agree to comply with all regulations of the Department of Environmental Health Services and with all ordinances and laws of Inyo County and of the State of California pertaining to well construction, repair, modification and destruction at the time of commencement of work.

____
LICENSED WELL DRILLER'S SIGNATURE

____
DATE

____
Site Approval/Permit Application Approval *Date*

____
Construction Inspection *Date*

____
Final Approval *Date*


127
Well ARHS-08
Well ARHS-09
37
Pahrump
160
178
Well ARHS-07
Well ARHS-10
Well ARHS-06
Sandy Valley
Well ARHS-05
16.07 mi
© 2016 Google
Image Landsat
Google earth


Well ARHS-08
© 2016 Google
747 ft
127
Google earth

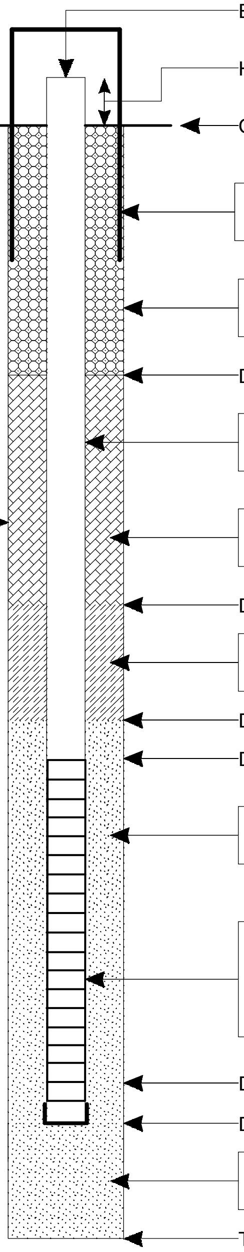
Photo 3: Proposed monitoring well location for ARHS-08.

Project:
Project Location:
Project Number:

CONSTRUCTION LOG FOR WELL IN BORING ARHS-08

Location:		Date(s) Installed:
Installed By:	Observed By:	Total Depth (ft bgs):
Method of Installation:		
Screened Interval:	Completion Zone:	
Remarks:		

NOTE: DIAGRAM IS NOT TO SCALE



Boring Diameter: 8 **inches**

Elevation of Top of Riser Pipe: ______ **ft MSL**

Height of Riser Above Ground: ______ **ft**

Ground Elevation: ______ **ft MSL**

ID/Type of Surface Casing: Above Ground Vault

Type of Grouting/Conductor Casing: Cement Grout

Depth of Grouting/Conductor Casing: 20 **ft**

ID/Type of Riser Pipe: 4" Sch 40

Type of Backfill: NA

Depth of Seal: 156 **ft**

Type of Seal: Bentonite

Depth of Top of Filter Pack: 158 **ft**

Depth of Top of Screen: 160 **ft**

Type of Filter Pack: # Sand

ID/Type of Screen: 4" Sch 40

Screen Slot Size: 0.010 inch

Depth of Bottom of Screen: 180 **ft**

Depth of Bottom of Plugged Blank Casing: 180 **ft**

Type/Depth of Backfill/Seal Below Well:

Total Depth of Boring: 180 **ft**

INYO COUNTY ENVIRONMENTAL HEALTH SERVICES

P. O. Box 427, Independence, CA 93526
(760) 878-0238 • Fax (760) 878-0239

207 W. South Street, Bishop, CA 93514
(760) 873-7866 • Fax (760) 873-3236

WELL PERMIT APPLICATION

ARHS-06

Permit No. ______

TYPE OF WORK (Check)

New Well ☑
Repair or Modification ☐
Destruction ☐

USE

Domestic ☐
Irrigation ☐
Monitoring ☑
Test Well ☐
Municipal ☐
Other ☐

EQUIPMENT (Check)

Rotary ☑
Cable Tool ☐
Other ☑
Sonic

PROPOSED WELL DEPTH

30 Feet

PROPOSED CASING

Steel ☐ Other PVC Diameter 4" Wall or Gage SCH 40

PROPOSED SEALING ZONE

From 0 to 18 Feet

SEALING MATERIAL (Check)

Neat Cement ☐
Cement Grout ☑
Bentonite Clay ☐
Concrete ☐

PHYSICAL SITE ADDRESS:
None. See attached map. Appx location N35.81397, W-116.05249.

ASSESSOR'S PARCEL NO.
None.

DATE OF WORK

Start ______

Completion ______

NAME OF WELL OWNER:
Amargosa Conservancy

MAILING ADDRESS:
2121 N California Blvd., Suite 290

PHONE NUMBER:

NAME OF WELL DRILLER:

BUSINESS ADDRESS:

PHONE NUMBER:

(FOR OFFICE USE ONLY)
DISPOSITION OF APPLICATION

☐ APPROVED ☐ DENIED

☐ APPROVED WITH CONDITIONS LISTED:

☐ Minimum ______ft. seal of annular space(minimum 2 inches) is required and must be witnessed by Inyo County Environmental Health Services.

☐ A concrete pad shall be placed around the well casing that extends at least two feet laterally in all directions from the outside of the well boring and is a minimum of 4 inches thick.The pad must be sloped away from the well casing.

☐ Well driller's log shall be submitted to Inyo County Environmental Health Services within 30 days of completion of the well.

☐ ______

______

______

Inyo County Environmental Health Services recommends that an acceptable bacteriological sample be obtained after the well is completed.

C-57 LICENSE NUMBER:

______

Cash Deposit ☐
Bond Posted ☐

$______ Fee paid on ______ Receipt No. ______

I hereby agree to comply with all regulations of the Department of Environmental Health Services and with all ordinances and laws of Inyo County and of the State of California pertaining to well construction, repair, modification and destruction at the time of commencement of work.

______
LICENSED WELL DRILLER'S SIGNATURE

______
DATE

______
Site Approval/Permit Application Approval *Date*

______
Construction Inspection *Date*

______
Final Approval *Date*


127
Well ARHS-09
37
Pahrump
160
Well ARHS-08
178
Well ARHS-07
Well ARHS-10
Well ARHS-06
Sandy Valley
Well ARHS-05
16.07 mi
© 2016 Google
Image Landsat
Google earth


Well ARHS-06
Mesquite Valley Rd
Mesquite-Valley
© 2016 Google
777 ft
Google earth

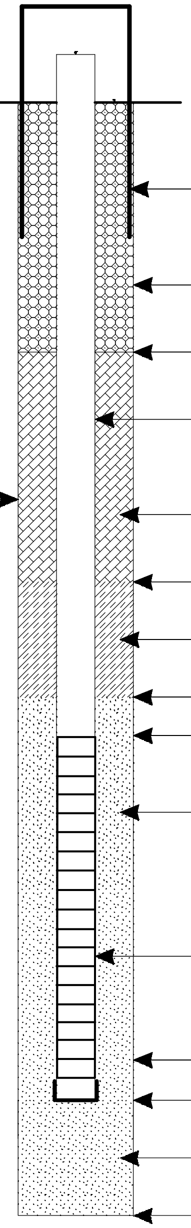
Photo 1: Proposed monitoring well location for ARHS-06.

Project:
Project Location:
Project Number:

CONSTRUCTION LOG FOR
WELL IN BORING ARHS-06

Location:		Date(s) Installed:
Installed By:	Observed By:	Total Depth (ft bgs):
Method of Installation:		
Screened Interval:	Completion Zone:	
Remarks:		

NOTE: DIAGRAM IS NOT TO SCALE



Boring Diameter: 8 **inches**

ID/Type of Surface Casing: Above Ground Vault

Type of Grouting/Conductor Casing: Cement Grout

Depth of Grouting/Conductor Casing: 18 **ft**

ID/Type of Riser Pipe: 4" Sch 40

Type of Backfill: NA

Depth of Seal: NA **ft**

Type of Seal: NA

Depth of Top of Filter Pack: 18 **ft**

Depth of Top of Screen: 20 **ft**

Type of Filter Pack: #1 Sand

ID/Type of Screen: 4" Sch 40

Screen Slot Size: 0.010 inch

Depth of Bottom of Screen: 30 **ft**

Depth of Bottom of Plugged Blank Casing: 30 **ft**

Type/Depth of Backfill/Seal Below Well: NA

Total Depth of Boring: 30 **ft**

Andy Zdon & Associates, Inc.

SAN BERNARDINO COUNTY

Public Health
Environmental Health Services

www.SBCounty.gov
www.sbcounty.gov/dph/dehs
Phone: (800) 442-2283

ARHS-05

APPLICATION FOR WELL PERMIT

THIS SECTION TO BE COMPLETED BY APPLICANT • HEALTH PERMITS ARE NOT TRANSFERABLE

1 – PROPERTY INFORMATION

Property Owner None.			Phone Number
Site Address See Map Attached. See latitude and longitude.	City	State	Zip
Assessor's Parcel Number None.	Email None.		
Township · N/S Tier 19N	E/W Range 7E	Section S32	
Well Head · Latitude (decimal) 35.69542	Longitude (decimal) -116.25118		
Property Owner's Mailing Address	City	State	Zip

2 – CONSULTANT INFORMATION

Name of Consultant Andy Zdon & Associates, Inc.	Email andy@ndyzdon.net		Phone Number (909) 212-7917
Address 2121 N California Blvd., Suite 290	City Walnut Creek	State CA	Zip 94596

3 – REGISTERED WELL DRILLER INFORMATION

Name of Driller		Phone Number
Email		C-57 License Number

Return well permit to ☐ Well Driller ☒ Consultant ☐ Property Owner

Return by ☐ Mail ☒ Email

4 – TYPE OF WORK

☒ New ☐ Reconstruction ☐ Destruction

Date of Work	Start Date	Completion Date

5 – WELL TYPE

☐ Agriculture
☐ Cathodic
☐ Community/PWS/City – **Specify Use Below**
Use:

☐ Geothermal
☐ Horizontal
☐ Residential – cannot be used as a community well

☐ Industrial
☒ Monitoring/Observation
☐ Test
☐ Other

6 – ANNULAR SEAL

Seal Depth (ft.) 20 feet

☒ Driven Conductor Diameter (in.) 8 ☒ Wall (gauge) (in.) 0.4

☒ Sealing Material Cement Grout ☐ Thickness (in.)

Sealing material shall be placed in one continuous pour. Annular seal thickness must be at least 3 inches for public water supply wells.

ITEMS 7 THROUGH 10 TO BE ESTIMATED FOR NEW WELLS, EXACT FOR ALL OTHER WELLS

7 – DIMENSIONS

Proposed Depth of Well (ft.) 40	Existing Depth of Well (ft.)	Diameter of Bore (in.) 8

8 – CASING INSTALLED

☐ Steel ☒ Plastic ☐ Standard Casing ☐ Other ☐ No Casing

From (ft.)	To (ft.)	Diameter (in.)	Wall (Gauge)
0	18	4	Sch 40

Gravel Pack ☐ Yes	☒ No	From (ft.)	To (ft.)
Specify Other Backfill Material #1 Sand		From (ft.) 18	To (ft.) 40

9 – PERFORATIONS (list all if applicable)

From (ft.) 20	To (ft.) 40	Pumping Rate (gpm)

10 – SEALED ZONES (list all if applicable)

From (ft.) 0	To (ft.) 20

11 – PLOT PLAN

a) In perspective to the well site, sketch and label the following items **on a separate paper**: well lot property lines, other wells (include abandoned wells), sewage disposal systems (sewers, septic tanks, leaching fields, seepage pits, cesspools), lakes and ponds, watercourses and animals or fowl kept.

b) Indicate the distance, in **feet**, of any of the above which are within 500 ft. of the well site. The plot plan needs to be drawn to scale (½ inch = 100 feet). Show the approximate drainage pattern of the property and show access roads to the well site within 500 feet.

c) ☒ None of the above is within 500 feet.

d) Solid or Liquid Disposal Site within Two Miles ☐ Yes ☒ No Location

12 – METHOD OF CONSTRUCTION OR DESTRUCTION

Provide the method of construction/destruction in the space below or as an attachment if more space is needed. The method shall be in accordance with the standards recommended in the California Department of Water Resources Bulletin No. 74-81 and 74-90. Title 22 standards shall also be followed for public water supply wells.

Please see example well construction log attached to this permit.

13 – AGREEMENT AND SIGNATURE

I have read this application and agree to comply with all laws regulating the type of work being performed.

Property Owner's Signature X	Date
Print Property Owner's Name	
C-57 Contractor's Signature X	Date
Print Contractor's Name	

For Office Use Only DISPOSITION OF PERMIT For Office Use Only DISPOSITION OF PERMIT

Permit Number:	
Expiration Date:	
WP Number:	

☐ Sent to Water Agency

☐ Water Agency conditions or recommendations attached

☐ Denied

☐ Approved subject to the following:

A. ☐ Notify the Division's Safe Drinking Water Program at (800) 442-2283 at least seventy two (72) hours in advance to make an inspection of the following operations: (Inspections are conducted Monday – Friday between 8:00 AM to 5:00 PM). Failure to cancel or reschedule appointments may result in an additional hourly fee.

- ☐ Prior to sealing of the annular space or filling of the conductor casing.
- ☐ After installation of the surface protective slab and pumping equipment.
- ☐ After installation of the surface features.
- ☐ During destruction of wells, prior to pouring the sealing material.

B. ☐ Submit to the Division, within thirty (30) days after completion of work, a copy of:

☐ Water Well Driller's Report	☐ Bacterial Analysis	☐ Inorganic Chemical Analysis	☐ General Physical
☐ Radiological Analysis	☐ Nitrate	☐ Organic Chemical Analysis	☐ General Mineral

Comments

For Office Use Only For Office Use Only For Office Use Only For Office Use Only For Office Use Only

Fee:	FA Number:	Record ID:	PE Number:
Late Fee: ☐ Y ☐ N	Designated Employee:	Received By:	Date:
Check One: ☐ New ☐ Transfer ☐ Reactivate		Changes (please specify):	


127
Well ARHS-09
37
Pahrump
Well ARHS-08
160
178
Well ARHS-07
Well ARHS-10
Well ARHS-06
Sandy Valley
Well ARHS-05
16.07 mi
© 2016 Google
Image Landsat
Google earth

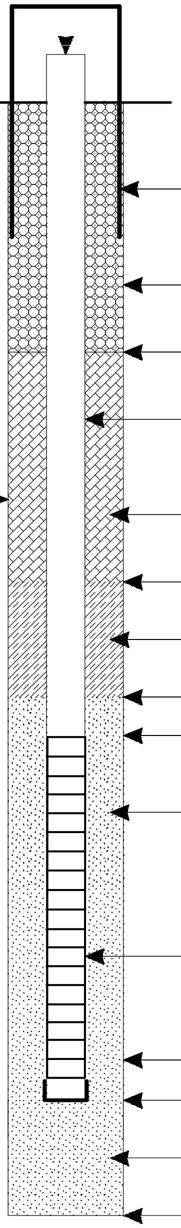

Death Valley Rd
127
Well ARHS-05
5649 ft
Google earth

Project:
Project Location:
Project Number:

CONSTRUCTION LOG FOR
WELL IN BORING ARHS-05

Location:		Date(s) Installed:
Installed By:	Observed By:	Total Depth (ft bgs):
Method of Installation:		
Screened Interval:	Completion Zone:	
Remarks:		

NOTE: DIAGRAM IS NOT TO SCALE



Boring Diameter: 8 **inches**

ID/Type of Surface Casing: Above Ground Vault

Type of Grouting/Conductor Casing: Cement Grout

Depth of Grouting/Conductor Casing: 18 **ft**

ID/Type of Riser Pipe: Sch 40

Type of Backfill: NA

Depth of Seal: NA **ft**

Type of Seal: NA

Depth of Top of Filter Pack: 18 **ft**

Depth of Top of Screen: 20 **ft**

Type of Filter Pack: #1 Sand

ID/Type of Screen: Sch 40

Screen Slot Size: 0.010 inch

Depth of Bottom of Screen: 40 **ft**

Depth of Bottom of Plugged Blank Casing: 40 **ft**

Type/Depth of Backfill/Seal Below Well: NA

Total Depth of Boring: 40 **ft**

APPENDIX C:

Constraints on the Recharge Sources, Flowpaths, and Ages of Groundwater in the Amargosa River Valley Using Stable Isotope, Water Quality, and Noble Gas Data

Report by ML Davisson & Associates, Inc.

June 24, 2014

ML Davisson & Associates, Inc.

PROFESSIONAL GEOLOGIST
M. Lee Davisson
8097
STATE OF CALIFORNIA

INTRODUCTION

There is a need to elucidate further the recharge sources of spring discharge waters within the Amargosa River watershed to help in sustaining or restoring natural flow and anticipating potential upstream impacts. Natural spring flow supports the river flow and habitat regimes, but specific recharge sources and subsurface transport times are still elusive. Although water quality parameters provide some measure of differentiating groundwater, they are often subject to change during subsurface migration. Needed is a measurement tool that potentially provides a conservative tracer that can further differentiate groundwater sources. Dissolved noble gas abundances and helium isotope measurements have demonstrated over the past ~30 years the ability to derive the temperature and elevation of groundwater recharge, provide a qualitative measure of its age, and they are inherently inert and don't react with aquifer rocks (Ozima and Podosek, 2002; Kipfer et al., 2002). Dissolved concentrations of helium, neon, krypton and xenon can be compared to well-known equilibrium solubility curves that vary as a function of temperature and elevation. The relative abundances of the measured noble gases should conform to a specific recharge temperature and elevation in this comparison, which could provide an important boundary condition for recharge areas, particularly when used in conjunction with other available isotope and water quality data. The ^{3}He and ^{4}He isotope ratio is well known in the atmosphere and water in contact with the atmosphere. Any deviation from this known ratio in collected groundwater will indicate either 1) accumulation of excess ^{4}He, which is common for groundwater out of atmospheric contact for thousands of years, or 2) excess ^{3}He, which is commonly observed in groundwater influenced by an active geothermal source in communication with the Earth's mantle. The latter is commonly observed in geothermal processes in active volcanoes (e.g., Welhan et al., 1988).

Note that caveats are always possible with these measurements. Two of which are potential negative outcomes would be: 1) the possibility that any diffuse discharge of spring water compromises the integrity of noble gas abundances dissolved in groundwater, and 2) other dissolved gases in abundance (e.g., hydrogen sulfide, methane) are present in the groundwater and have compromised noble gas abundances due to gas stripping. Unfortunately, the results presented below indicate perhaps both these processes affected dissolved noble gas abundances in groundwater of the Amargosa River Valley. Consequently, in addition to illustrating these results, this report further elucidates recharge sources, potential flowpaths, and groundwater quality using previously reported data. In addition, groundwater ages are discussed in context of the ^{3}He/^{4}He results.

FIELD AND LABORATORY METHODS

Stable Isotopes

Samples for δ^{18}O and δD were collected in 60 milliliter glass bottles equipped with an conical shaped insert inside the cap that when the bottle is closed forms an airtight seal. Samples were shipped to Isotech Laboratories in Champaign, Illinois where the ^{18}O/^{16}O and D/H ratios were measured as a gas using standardized mass spectrometry methods. Results are reported as a normalization to Standard Mean Ocean Water (SMOW), which is an internationally recognized standard in stable isotope analysis. The normalization was converted to standard d (“del”) notation following the convention

$$\delta = \left(\frac{R}{R_{std}} - 1\right)1000$$

where R is the isotope ratio of the sample and R_{std} is the ratio of the standard.

Noble Gas

Noble gas samples were collected in passive diffusion samplers comprising two sections of 1/4” copper tubing attached by a small section of semipermeable silicon tubing (Fig. 1). The terminal ends of the copper tubes were pinched closed with a gas-tight cold seal. This sampler was placed in the water to be sampled for 24 hours. During this equilibration period gases dissolved in the water diffuse through the semipermeable tube and come into an equilibrium concentration inside the copper tube section in proportion to that of the water (Gardner and Solomon, 2009). At the same time, a special meter was used to measure the total dissolved gas in the water. After 24 hours, the sampler is crimped to a cold seal on the semipermeable tube end of the copper to form two separate gas samples enclosed in copper. These two samples were then labeled, the end protected with electrical tape and placed into a plastic bag. Five sample sites in total were collected by this method. All samples were sent to the noble gas laboratory at the University of Utah. There the copper tubes were vacuum fitted to an evacuated container, the copper cold seal was uncrimped to release the gas, followed by cryogenic isolation of noble gases of interest. Noble gas abundances and the $^{3}He/^{4}He$ ratios were measured on a VG-5400 noble gas mass spectrometer. Results are reported as gas volume per milliliter of water.

Figure 1. Passive diffusion sampler used for collection of dissolved noble gases in water samples.

PREVIOUS ISOTOPE STUDIES

A number of previous reports have been published on groundwater geochemistry and isotope abundances in southern Nevada and southeastern California. Notable reports relevant to the Amargosa River area include those of Winograd and Thordarson (1975), Thomas et al. (1996), Davisson et al. (1999), and Larsen et al. (2001). Additional studies that include directly related data can be found in Thomas et al. (2003a and 2003b) and Hurst (2012). Winograd and Thordarson (1975) developed one of the early frameworks for groundwater flow in southern Nevada related to the Nevada Test Site which included extensive discussion of the Ash Meadows springs discharge area. Based on earlier work, they also summarized types of groundwater hydrochemistry. These included calcium-magnesium-bicarbonate ($Ca\text{-}Mg\text{-}HCO_3$) groundwater associated with both the carbonate rock of the Spring Mts. and adjacent Pahrump Valley, sodium-potassium-bicarbonate ($Na\text{-}K\text{-}HCO_3$) groundwater that drains the largely volcanic rock areas south of the Nevada Test Site (e.g., Oasis Valley and Jackass Flats), and Ash Meadows spring discharge which has $Ca\text{-}Mg\text{-}Na\text{-}HCO_3$ water that Winograd and Thordarson (1975) inferred as a mixture of recharge of the two latter water types.

Thomas et al. (1996) also compiled and summarized groundwater chemistry types, as well as isotope abundances in areas that included groundwater throughout southern Nevada and southeastern California with a focus on the regional carbonate aquifers. They concluded from isotope results that the $Ca\text{-}Mg\text{-}Na\text{-}HCO_3$ water discharging from Ash Meadows springs comprised 60 percent Spring Mts. recharge and 40 percent from Pahrangat Valley to the east. They also argue from radiocarbon data that groundwater velocities ranged approximately from 10 to 144 feet per year.

Davisson et al. (1999) showed that radiocarbon was not a reliable method for age dating groundwater in the regional carbonate aquifer due to continual isotope exchange reactions combined with mixing of local recharge sources during long-range transport. They further showed that stable isotopes of oxygen-18 (^{18}O) and deuterium measured in southern Nevada groundwater had been previously evaporated during its original recharge as melted snow in central Nevada (Rose et al., 1999). Applying a methodology that removed the effects of evaporation on oxygen-18 and deuterium they showed a systematic decrease in their abundances with increasing latitude and local elevation throughout southern Nevada, a result inconsistent with previous studies purporting groundwater recharged during the Pleistocene in the last glacial period (Claassen et al., 1986).

Larsen et al. (2001) studied the water quality and stable isotope abundances of groundwater in the Tecopa and Death Valley regions of the Amargosa River Valley and related them to groundwater of southern Nevada to delineate potential recharge sources. They recognized three water types comprising Spring Mts. recharge source, a deep regional groundwater derived from fracture flow of southern Nevada, and groundwater derived from basin-filled groundwater of the Amargosa Desert.

Additional studies providing a greater variety of isotope measurement types have been reported by Thomas et al. (2003a) and Hurst (2012). Thomas et al. (2003a) focused specifically on Oasis Valley and its hydraulic connection to Pahute Mesa, showing that Oasis Valley groundwater is replenished by groundwater flowing through Pahute Mesa that was ultimately derived further north. The Oasis Valley groundwater ultimately replenishes the Amargosa Desert basin fill aquifers.

Hurst (2012) specifically focused on tritium, ^{18}O, deuterium, strontium isotopes, and uranium isotopes in regions along the Amargosa River Valley. He showed that spring samples are largely tritium absent, the ^{18}O and deuterium show only limited evaporation, and that strontium and uranium isotopes show mixing along the entire length of the Amargosa River Valley.

Lastly, one study reported by Thomas et al. (2003b) measured dissolved noble gases in the regional carbonate aquifer of southern Nevada. They showed that noble gas abundances that are typically incorporated in recharging groundwater and reflect the local recharge temperature were systematically being lost during long-range transport from Pahrangat Valley in east-central Nevada towards Ash Meadows at its terminal discharge point. They concluded this loss of dissolved gas was due to fault barriers and cavities in the regional carbonate aquifer that forces groundwater to migrate upward and encounter gas loss in air pockets or vadose zones. This subsequently masked the calculated recharge temperatures derived from the noble gases.

THIS STUDY

This study investigates specifically the relationship between the Tecopa hot springs area and groundwater just to the north and south of these springs. The specific questions address are 1) the hot springs derived from a distinct groundwater perhaps of a more deeper regional source, or 2) are they the same groundwater as that to the north and south but have encountered a local heat source such as a magmatic intrusion. We use both stable isotopes compiled from previous studies along with new data generated on the dissolved noble gases in the water. In addition, we offer additional discussion of groundwater quality results in the context of these new data results.

Below a compilation of stable isotope data from Thomas et al. (1996), Winograd et al. (2003), and Hurst (2012) are used to develop and integrated picture of stable isotope distribution across the Amargosa River corridor to assess potential recharge sources of springs in this area. This assessment will provide a framework to interpret further the noble gas results and water quality results.

RESULTS FROM THIS STUDY

Integrated Assessment of Stable Isotope Data

The stable isotopes of ^{18}O and deuterium in precipitation systematically vary with increasing latitude and elevation (see Appendix Fig. A-1). This results in lower $\delta^{18}O$ and δD isotope values in groundwater from north to south from central Nevada to southeastern California. There is also a regional effect in the American Southwest where summer monsoonal precipitation occurs in areas directly north of the Gulf of California, causing substantial precipitation in some higher elevation areas. This summer monsoonal rain has higher isotope values than winter season equivalents because of warmer temperatures. Local high elevation areas such as Spring Mts., which support annual snow accumulation that promote recharge during the winter, has higher $\delta^{18}O$ and δD values than groundwater found in Oasis Valley on the south side of Pahute Mesa (Fig. 2). Spring Mts. see some portion of their annual precipitation from summer monsoons. The Oasis Valley groundwater ultimately is derived from recharge further north of Pahute Mesa where isotopic values of mean precipitation are even lower and are predominately influenced by winter precipitation (Davisson et al., 1999). This geographic dependency of isotope values provides a means to use these differences to potentially derive recharge sources of groundwater sampled in the Amargosa River corridor. Ash Meadows groundwater isotope values consequently is a mixture between Spring Mts. and Oasis Valley and/or Pahranagat Valley (Winograd and Thordarson, 1975; Thomas et al., 1996). Comparison of measured $\delta^{18}O$ and δD for groundwater and springs is shown in Figure 2 below to illustrate differences among specific geographic groupings. A δD-$\delta^{18}O$ plot is illustrated in highlighted in color for each geographic grouping plotted along with a shaded relief map. Note that Oasis Valley has the lowest isotopic values of all the groupings. In contrast, the Tecopa area springs and wells have the highest. Consequently, their recharge sources are distinctly different, and based on these isotope results we can rule out that Oasis Valley groundwater is a sole source of Tecopa groundwater. Note further, three additional samples were measured for δD-$\delta^{18}O$ during this study. They include ARHS-1 (-91 and -11.0) above Shoshone, Twelve Mile Spring (-99 and -13.6) from the Chicago valley, and Dodge City Spring (-95 and -12.0) from the Tecopa area. All these results are consistent with values measured in the Tecopa area.

Note that the Spring Mts. isotope values are much higher than Oasis Valley groundwater and form a fairly narrow range that conforms to the Global Meteoric Water Line. Comparison among isotope values in Figure 2 for Oasis Valley, Jackass Flats, Springs

Mts. and Ash Meadows indicate that Ash Meadows values overlap all these other groupings and support their recharge sources as a mixture among them. However, the isotope values in the Tecopa grouping only have a moderate overlap with the Ash Meadows data but also overlap with Spring Mts. type isotope values. The one Tecopa area groundwater that overlaps with Ash Meadows is Borax Spring, which suggests Ash Meadows type groundwater as their potential recharge source. The remainder of the Tecopa groundwater is clearly influenced by a more Spring Mts. type recharge isotope value. However, recall that isotope values increase progressively toward the south, which requires that additional recharge source with similar isotope values as Spring Mts. be considered. We also know that the Kingston Range to the south also have higher isotope values. Our only evidence so far is for Crystal Spring that drains from those ranges, which has an evaporated isotope signature and lies to the right of the Global Meteoric Water Line. Nevertheless, its recharge into the groundwater beneath Tecopa can influence the isotope values causing them to be higher than the Ash Meadows grouping. Note also that Sheep Creek Spring also has a higher isotope value and conforms closely with the Global Meteoric Water Line, confirming that local precipitation in this area is much higher than Ash Meadows isotope values. The isotope values for Sheep Creek Spring also illustrate recharge does occur in the areas along local high elevations.

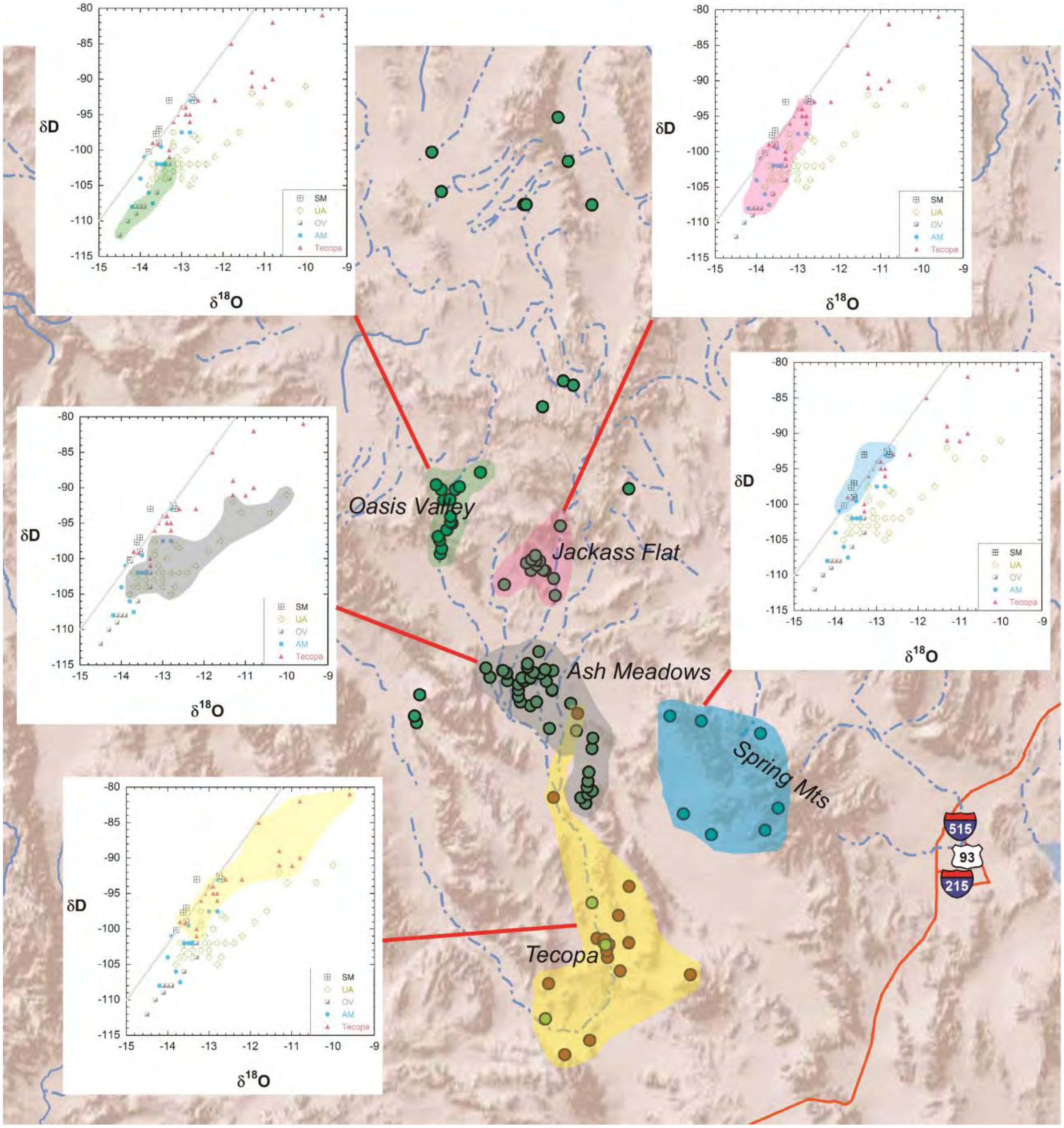


Figure 2. δD-δ^{18}O plots are compared as regional groupings in this map view. Note that the range in δD and δ^{18}O values decreases in general from north to south and that the Tecopa region groundwater overlaps most with Spring Mts. and Ash Meadows. This suggests that either are potential sources for Tecopa groundwater, although for the latter mixing with Spring Mts. or possibly Kingston Range recharge would be required.

Integrated Assessment of Water Quality

Groundwater quality in the Amargosa River Valley tends toward high total dissolved solids contributed by appreciable levels of chloride and sulfate. In order to place this water quality in context with regional groundwater flow, it is best served to compare them to groundwater further north that may or may not contribute to recharge in the Shoshone and Tecopa regions. Figure 3 below is a piper plot that compares water quality of groundwater from the regional carbonate of southern Nevada (in red), groundwater from the Nevada Test Site (in green), and groundwater of the Amargosa River Valley (in blue). Note that the regional carbonate is Ca-Mg-HCO_3 type water and contrasts with the Nevada Test Site water of Na-K-HCO_3 type. Note further that the Ash Meadows water (open red squares) is a mixture of regional carbonate and Nevada Test Site water quality types. The Amargosa River Valley groundwater is also dominated by Na-K-HCO_3 type water quality, but with increasing amounts of chloride and sulfate progressively downgradient. An increase in total dissolved solids also occurs in many of these waters.

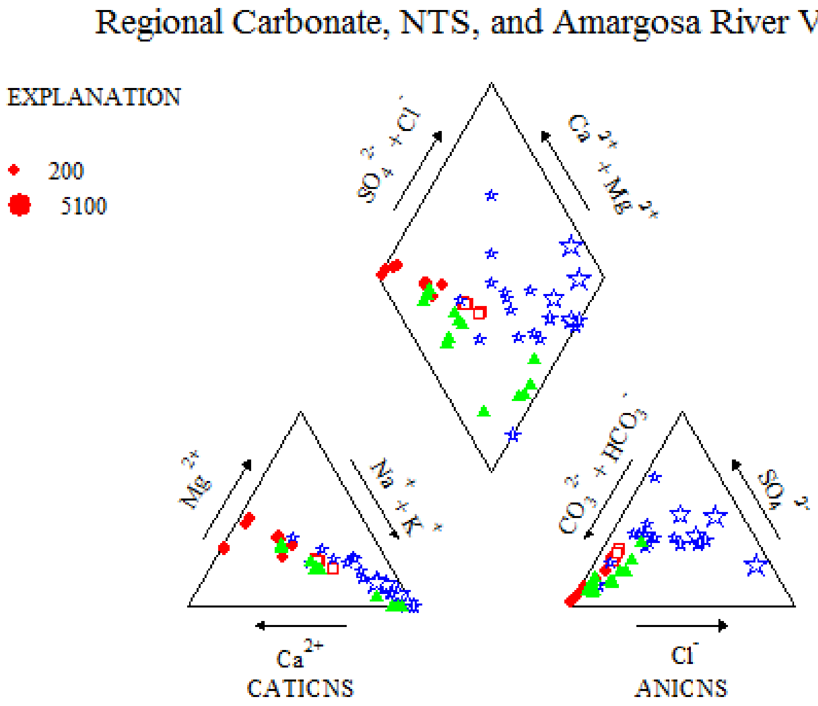


Figure 3. Piper plot comparing cation and anion relative concentrations in groundwater of the regional carbonate aquifer (red circles), Ash Meadows (open red squares), Nevada Test Site (green triangles), and Amargosa River Valley (open blue stars). Note that between the regional carbonate aquifer and the Amargosa River Valley groundwater, water quality changes from Ca-Mg-HCO_3 type toward Na-K-HCO_3-Cl-SO_4 type accompanied by increased salinity.

Two potential processes may influence the water quality in the Amargosa River Valley groundwater. One may be the ubiquitous Tecopa lake bed geologic deposits that uniquely occur in the Tecopa region. These lake beds were accumulated during high stands of glacial ice in the Pleistocene period of Earth's history that caused large amounts of surface runoff that accumulated in closed basin lakes in Nevada and southeastern California. These lakes ultimately went through wet/dry cycles that accumulated precipitated salts (predominately chlorides and sulfates), much like that seen today in desert playas. Modern groundwater encountering the Tecopa lake beds will undoubtedly dissolve salts in the sediment which will contribute to increase salinity of the water.

The additional process that likely contributes to increase salinity in Amargosa River Valley groundwater is the unusual amount of geothermal heat emitted in the Tecopa region. As a matter of fact, high heat flow has been measured throughout this region from the Springs Mts. in the east to the eastern edge of the Sierra Nevada. The heat flow is significantly lower northeast of Ash Meadows, corresponding to the regional carbonate aquifer, but in contrast heat flow is high under the Nevada Test Site. This is best illustrated by groundwater temperatures, which can range up to 45°C in parts of the Nevada Test Site. Groundwater in the Tecopa region also has high temperatures up to 40°C. The regional carbonate aquifer groundwater temperature tends range between 20-30°C. The increase in groundwater temperature can have significant impact on groundwater quality. For instance, dissolved silica increases with increasing temperature, and bicarbonate simultaneously will decrease. This can effect water pH and promote solubility of other elements. A good example is arsenic, which increases solubility with increasing pH (Fig. 4). Arsenic in the Amargosa River Valley may ultimately be associated the lake beds deposits, but as pH increases, their solubility increases to significantly high levels.

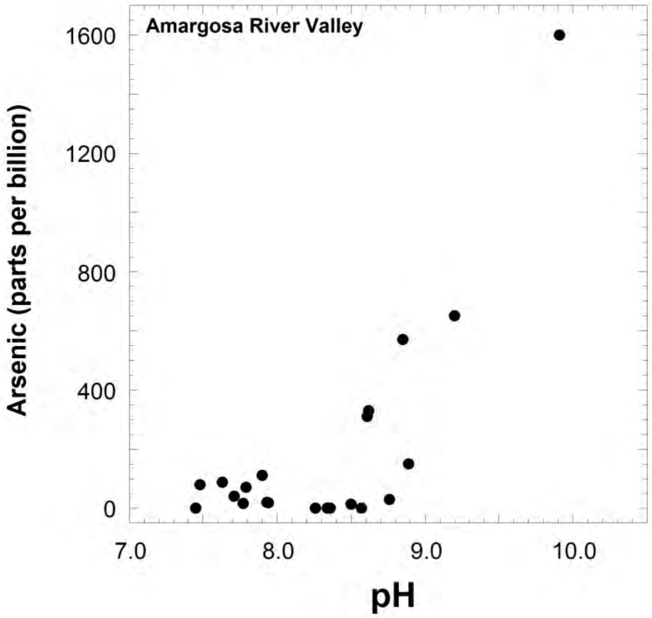
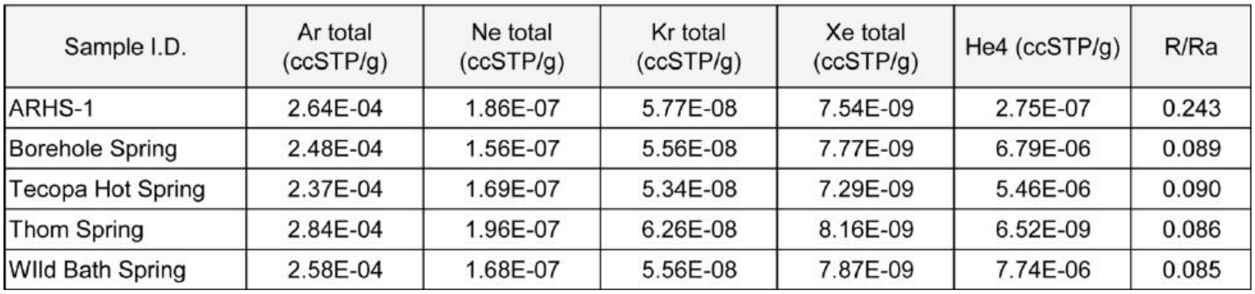


Figure 4. Arsenic solubility increases with increasing pH as illustrated by groundwater in the Amargosa River Valley region. The ultimate source of arsenic is not known but could be associated with the Tecopa lake beds deposits.

Noble Gas Results

The noble gas results are shown below in Table 1. They are presented as volume concentrations (in standard temperature and pressure or STP) per gram of water. The helium concentrations are measured and reported as ^{4}He isotope, which is essentially all of the dissolved helium. The R/R_a is the ^{3}He/^{4}He isotope ratio normalized to the same ratio as measured in air (air ^{3}He/^{4}He ratio = 1.384e^{-6}).

Table 1. University of Utah - Dissolved and Noble Gas Lab



Sample I.D.	Ar total (ccSTP/g)	Ne total (ccSTP/g)	Kr total (ccSTP/g)	Xe total (ccSTP/g)	He4 (ccSTP/g)	R/Ra
ARHS-1	2.64E-04	1.86E-07	5.77E-08	7.54E-09	2.75E-07	0.243
Borehole Spring	2.48E-04	1.56E-07	5.56E-08	7.77E-09	6.79E-06	0.089
Tecopa Hot Spring	2.37E-04	1.69E-07	5.34E-08	7.29E-09	5.46E-06	0.090
Thom Spring	2.84E-04	1.96E-07	6.26E-08	8.16E-09	6.52E-09	0.086
WIld Bath Spring	2.58E-04	1.68E-07	5.56E-08	7.87E-09	7.74E-06	0.085

The approach with analyzing the data in Table 1 is two-fold. Firstly, the relative abundances among the different noble gas concentrations for each sample must be compared to models of equilibrium solubility expected for different temperatures and elevations. Secondly, the R/R_a needs to be evaluated as a potential measure of groundwater age.

Recharge Temperature/Elevation

We start first with determining the best possible recharge temperature and elevation for each sample. But before we can do this, the data need to be evaluated for any potential process that may have compromised their integrity. For example, sampling artifacts are always possible such as loss of gases during sample sealing, any air-water exchange at the sample site affecting representation of the groundwater, or laboratory analysis error. Fortunately, a previous study by Thomas et al. (2003b) for the regional carbonate-Ash Meadows system of southern Nevada provides a comparative framework for the data in Table 1. This comparison is facilitated by Figure 5 below. Here the Ne concentration is compared to Xe of both the Amargosa River Valley samples (solid circles) and those reported by Thomas et al. (2003b) (open squares). The solid line shows recharge temperatures calculated from their model of equilibrium solubility (solid line) and curves for the excess air (dashed lines). Note how Aramgosa River Valley results overlap with their results, particularly with those of the lowest Xe concentrations. The lowest five points plotted from Thomas et al. data are samples measured for Ash Meadows springs and illustrates the striking similarity with the Amargosa River Valley groundwater we measured. They argued that the Ash Meadows spring waters experienced dissolved gas loss during its transport from upgradient in the regional carbonate aquifer. That gas loss they proposed was due to faulted barriers that forced deep groundwater upward and induced depressuring. Adjacent vadose zone or air cavities in karst permeability would exchange with the degassing water and re-equilibrate dissolved gas concentrations and influence calculated recharge temperatures. If this mechanism is valid, then it would suggest that the Amargosa River Valley groundwater undergoes a similar process and results in disagreement in calculated recharge temperatures among the different noble gases.

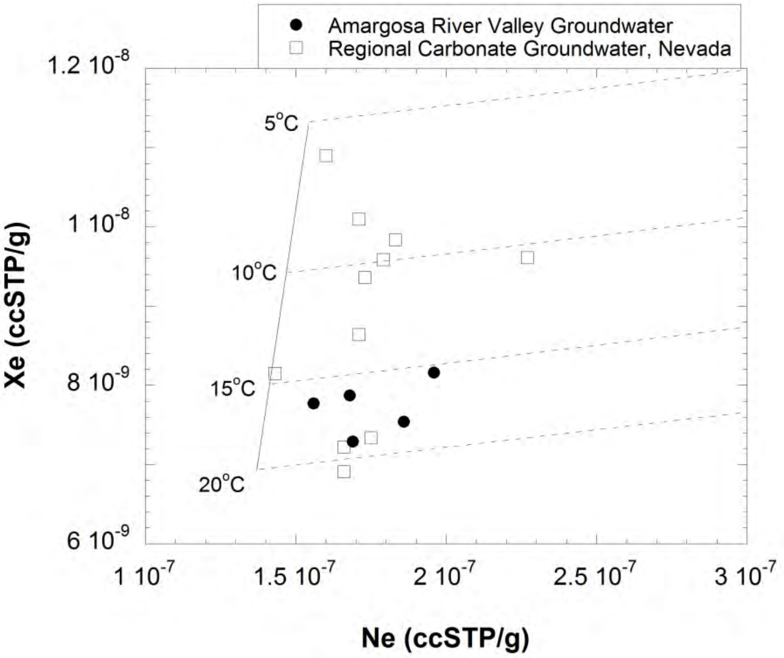


Figure 5. Comparison between Ne and Xe data of the Amargosa River Valley samples (solid circles) and those reported by Thomas et al. (2003b) (open squares). Shown is their recharge temperature model curve (solid line) and excess air curves (dashed lines). Note how Aramgosa River Valley results overlap with their results of Ash Meadows springs (their lowest five points).

We also constructed equilibrium solubility curves for each noble gas over the plausible recharge temperature and elevation in southern Nevada and southeastern California (5-25°C and 500-7000 feet). The Ar, Kr, and Xe results for each sample were analyzed independently for the best fit to a recharge temperature and elevation and compared with each other. The results are shown in Table 2. All of the samples yield an unusually high recharge temperature similar to Thomas et al. (2003b) with possibly the exception of Borehole Spring. Results of each noble gas comparison are indicated and it was common that two of the noble gases would have a common recharge temperature and elevation, but not the third one. Only in Borehole was there good agreement among all the three noble gases. Note that in this case, the noble gases suggest Borehole was recharged at approximately 6400 feet with a recharge temperature of around 19°C. In order to compare this with plausible locations, an atmospheric lapse rate for southern Nevada and southeastern California was calculated for data obtained from the Western Regional Climate Center (http://www.wrcc.dri.edu/CLIMATEDATA.html). This resulted in a *maximum* daily mean air temperature of 17°C at 6400 feet, and a *minimum* of approximately 2°C. The stable isotope values of Borehole Spring ($\delta^{18}O$ = -12.9 and δD = -95) limit recharge to Ash Meadows and/or Spring Mts./Kingston Range. Noble gas recharge temperatures for groundwater sampled on Spring Mts. by Thomas et al. (2003b) ranged between 4 and 10°C, temperatures consistent with *mean* air/soil temperature, but *inconsistent* with Borehole Spring. This suggests that the 19°C recharge temperature is not consistent with temperatures implied by the calculated recharge elevation of 6400 feet. Consequently, it is probable that the dissolved noble gas abundances of Borehole Spring have also been compromised similar to the other groundwater samples in Table 1. It is entirely conceivable that loss of dissolved Ar, Kr, and Xe in Borehole Spring occurred without differential partitioning of each elemental gas and they maintained congruency in recharge temperature/elevation calculations (unlike the remaining samples). This follows then the observation that the lower the noble gas concentrations, the higher the recharge temperature and/or recharge elevation is required, but results in unrealistic determinations.

Table 2. Calculated Noble Gas Recharge ttemperatures and Elevations for Samples Measured in Amargosa River Valley

Sample	Calc Recharge T°C	Calc Elev ft	Comment	
ARHS-1	24	2200	Ar-Kr agreement; Xe too low	
Borehole Spr	19	6400	Ar-Kr agreement	mean max air Temp = 17°C
	19.7	6300	Ar-Xe agreement	
Tecopa Hot Spr	22	6300	Ar-Xe agreement	
	26	3300	Kr-Xe agreement	
Wild Bath Spr	22	4100	Ar-Xe agreement	
	26	1900	Ar-Kr agreement	
Thom Spr	23.5	800	Ar-Kr agreement; Xe too low	

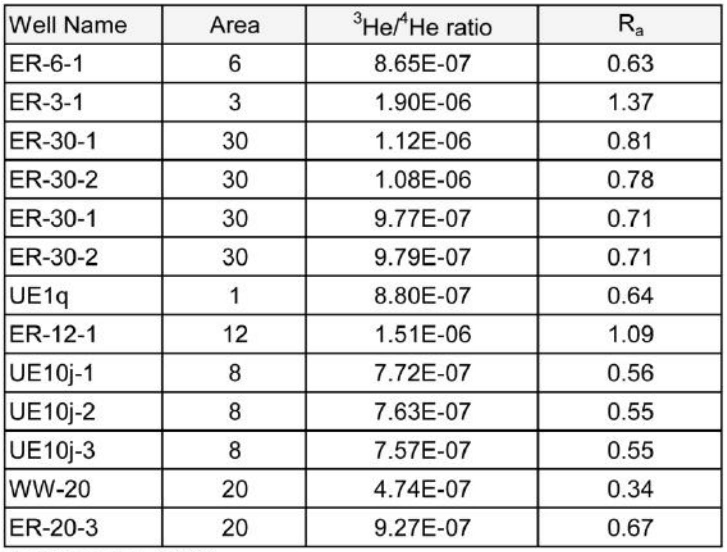
Implications of measured $^{3}He/^{4}He$ ratios

Helium-4 can accumulate in groundwater by two main mechanisms. One is the uranium and thorium naturally in aquifer rock radioactively decays by ejecting an alpha particle, which is simply a charged ^{4}He atom. This is a slow process and commonly averages around $5e^{-11}$ ccSTP/g-yr. After a few thousand years an appreciable dissolved ^{4}He buildup can occur in groundwater resulting in R/R_a between 0.2 and 1. Comparison between radiocarbon ages of groundwater and the R/R_a commonly results in good correlations (Ballentine et al., 2002).

The second mechanism is by more rapid accumulation when groundwater is in more direct contact with the Earth's crust. This occurs because the crust has a much higher abundance of uranium and thorium and hence a higher production of ^{4}He. If a groundwater aquifer is very deep or if it is faulted down to the crust, diffusive transport of ^{4}He from the crust to the overlying groundwater accelerates the accumulation. This can result in very low R/R_a values (<0.2) developing in groundwater in just a few thousand years.

The R/R_a values in Table 1 for the groundwater measured in the Amargosa River Valley show very low values as might be seen for groundwater influenced by a crustal source accumulation. The exception is for ARHS-1, which has a typical value for a groundwater a few thousand years old. As a comparison, Table 3 shows the ^{3}He/^{4}He ratios and R/R_a values for a number of background groundwaters collected from wells on the Nevada Test Site. Note that these R/R_a values are significantly higher than those in Table 1 and more consistent with ARHS-1. The low R/R_a values in the Amargosa River Valley samples suggest that there may be deep faults beneath this area that facilitates more rapid transport of ^{4}He from crustal sources. Otherwise, if the low R/R_a values were due only to ^{4}He accumulation from local aquifer rock, then the implication would be that this groundwater had a subsurface age over 100,000 years old and is essentially fossil water.

Table 3. ^{3}He/^{4}He ratios in groundwater of the Nevada Test Site



Well Name	Area	^{3}He/^{4}He ratio	R_a
ER-6-1	6	8.65E-07	0.63
ER-3-1	3	1.90E-06	1.37
ER-30-1	30	1.12E-06	0.81
ER-30-2	30	1.08E-06	0.78
ER-30-1	30	9.77E-07	0.71
ER-30-2	30	9.79E-07	0.71
UE1q	1	8.80E-07	0.64
ER-12-1	12	1.51E-06	1.09
UE10j-1	8	7.72E-07	0.56
UE10j-2	8	7.63E-07	0.55
UE10j-3	8	7.57E-07	0.55
WW-20	20	4.74E-07	0.34
ER-20-3	20	9.27E-07	0.67

from Rose et al. (1998)

Discussion of Groundwater Recharge and Ages

In desert environments groundwater recharge can be limited to areas of appreciable accumulation of annual precipitation. Recharge can be diffuse and slow where precipitation occurs as rain, but in areas of snow accumulation recharge can be pulsed and rapid. Only in the cases of the Spring Mts. and the Kingston Range does annual precipitation accumulate as snow, but restricted to higher elevation. Additional accumulation can occur in recharge areas supporting Ash Meadows flow. It has been shown with stable isotope results above that groundwater recharge beneath the Amargosa River Valley is limited to either Spring Mts. or a mixture of Ash Meadows, Spring Mts., and the Kingston Range. Consequently, the replenishment of groundwater is limited and sensitive to upgradient changes such as climate change or accelerated groundwater pumping.

The stable isotope results of groundwater in the Amargosa River Valley require at least in part a southern recharge source in order to differentiate it from stable isotope abudances of Ash Meadows and other sources to the north. Stable isotope results discussed earlier support possible flowpaths for groundwater from Pahrump Valley that moves toward Ash Meadows. Ash Meadows groundwater subsequently migrates southward following a path expressed on the surface by the Amargosa River channel. ARHS-1 stable isotope values are consistent with this recharge source. Ash Meadows groundwater ultimately is derived from the regional carbonate to the northeast with potential contributions from the north in the Nevada Test Site area through Oasis Valley and Jackass Flats.

Likewise data supports groundwater moving from Pahrump Valley towards the Chicago Valley beneath the northern end of the Nopah Range and/or toward the south into the California Valley. Groundwater along these paths would subsequently flow into the Tecopa basin and join flow from the north. The stable isotope values of groundwater sampled in the Tecopa area are consistent with this mixed groundwater. However, it should be kept in mind that mixing in groundwater systems is not an efficient process. This is particularly true in porous alluvial type material. In fracture flow system mixing is more efficient and a plausible mechanism for creating mixed stable isotope signatures for the Tecopa groundwater. Fracture flow consequently would need to occur at depths below the Tecopa lake bed deposits. Lastly, previous reports have shown recharge from runoff from the Kingston Range could likewise contribute recharge to the Tecopa groundwater.

Determining the age of groundwater can benefit groundwater management because the time required to naturally replenish a groundwater aquifer provides a direct measure of the rate at which it can be safely used. Groundwater ages are commonly measured by either measuring tritium for groundwater younger than approximately 50 years or with radiocarbon for groundwater ages thousands of years old. Tritium measured in groundwater reported in a previous study of the Amargosa River Valley showed little evidence of young groundwater (Hurst, 2012). However, no radiocarbon has been measured in these groundwaters to date, and any indication of groundwater ages a few thousand to tens of thousands years old is lacking. Radiocarbon has been measured in other studies for groundwater in the regional carbonate aquifer of southern Nevada (Thomas et al., 1996, Davisson et al., 1999) and beneath the Nevada Test Site (Rose et al., 1998). In these cases, radiocarbon was measureable and suggested ages from a few thousand to tens of thousands years old.

The results from the $^3He/^4He$ measurements for the Amargosa River Valley groundwater suggest that groundwater is likely tens of thousands of years old. This is best illustrated for the R/R_a value for sample ARHS-1 (0.243), which is somewhat lower, but similar to those measured for groundwater beneath the Nevada Test Site. Since radiocarbon was measureable for these latter groundwaters, it stands to reason that ARHS-1 groundwater would have measureable radiocarbon.

In the case of the remaining groundwater samples measured in the Amargosa River Valley, the unusually low R/R_a values suggest that ^4He may accumulate rapidly in this area due to presence of deep faults. In the absence of this mechanism, the implication of low R/R_a values would be that groundwater in the Tecopa area is isolated from ARHS-1 groundwater and replenishes at an extremely low rate. Using a in-situ ^4He accumulation rate of $5e^{-11}$ ccSTP/g-yr would imply groundwater ages greater than 100,000 years and possibly up to 1,000,000 years. These old ages are rare in groundwater system, particularly those with active spring discharge as seen in this area.

CONCLUSIONS AND RECOMMENDATIONS

- Although argument has been made that most Amargosa River Valley groundwater could be recharged from the Spring Mts., it is more consistent with available data that Amargosa River Valley groundwater is a mixture of Ash Meadows and Spring Mts./Kingston Range sources. Fracture flow would likely be required to induce mixing among these sources since alluvial type deposits would not be an efficient mechanism. Borax Spring is an exception and is likely the same recharge source as Ash Meadows.
- Groundwater in the Tecopa hot springs area is derived from the same groundwater source as that for Shoshone Spring to the north and Thom Spring to the south. The elevated temperature of the Tecopa spring water is not unusual since similar temperatures are seen at depth under the Nevada Test Site. However, the warm groundwater has been driven to the surface in Tecopa area probably by some geologic structural control.
- Water quality in the Amargosa River Valley groundwater likely evolves from a mixture of regional carbonate and Tertiary volcanic rock influences, but acquires increased chloride and sulfate possibly from the Tecopa lake bed deposits. Additionally, increases in regional subsurface heat flow increases groundwater temperature and contributes to increased dissolved silica, decreased bicarbonate, and possibly increased pH, with the latter resulting in the high arsenic concentrations.
- Noble gas concentrations of Amargosa River Valley groundwater have striking similarity to those measured in the regional carbonate-Ash Meadows of southern

Nevada groundwater by Thomas et al. (2003b). Their conclusions were that dissolved gas loss occurred during subsurface transport across faulted boundaries and compromised recharge temperature/elevation calculations.

- The noble gas recharge temperatures/elevation calculations for Amargosa River Valley groundwater mostly support the conclusions of Thomas et al. (2003b). The best model fit resulted for Borehole Spring with a recharge temperature of 19°C and elevation of 6400 feet derived from the Ar, Kr, and Xe concentrations. The noble gas concentrations of remainder of the samples could not converge on a single recharge temperature and elevation due to gas losses from subsurface processes. However, a 19°C recharge temperature at 6400 feet is *inconsistent* with plausible recharge areas and suggests dissolved noble gas in Borehole Spring likewise been compromised.
- The ^{3}He/^{4}He ratios for all measured springs in Amargosa River Valley are unusually low, indicating old groundwater ages. The Amargosa River Valley ratios are around 5-10 times lower than measured for groundwater under the Nevada Test Site.
- The low ^{3}He/^{4}He ratios in the Amargosa River Valley groundwater could be due to high ^{4}He flux from the earth's crust caused by deep faults. Otherwise, if the low ratio is due to steady-state accumulation from local deposits, then groundwater ages greater than 100,000 years would be required.
- Groundwater management in the Amargosa River Valley requires better understanding of recharge sources, recharge rates, and flow paths. To further this understanding it is recommended as follow-up work to pursue the following water quality and isotope measurements:
- Investigate the solubility of salts in the Tecopa lake bed deposits. This would provide comparative datt to the high TDS spring water in the area to determine if this is a viable mechanism to explain the spring water quality compositions.
- Measure additional samples for δD-δ^{18}O to better resolve zones of recharge and direction of groundwater flow. In particular, samples from the Chicago and Pahrump Valleys, as well as additional samples from the Kingston Range area would facilitate this effort.
- Measure the radiocarbon abundance of spring water in the Amargosa River Valley with the lowest ^{3}He/^{4}He ratios. If radiocarbon is present, then this would indicate that the low ratios are due to high ^{4}He flux along faults from the deep crust.
- Measure additional ^{3}He/^{4}He ratios in groundwater collected between Ash Meadows and Tecopa area. This would provide a continuum of ^{3}He/^{4}He ratios with downgradient distance and would facilitate the development of a groundwater age model.

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Appendix 1. Use of Isotope Measurements in Groundwater

A.1 Stable Isotopes

The stable isotope measurements of oxygen-18/oxygen-16 ($^{18}O/^{16}O$) and deuterium/hydrogen (D/H; deuterium is hydrogen-2) ratios in water are used to delineate different water populations in recharged groundwater. Their value lies in the fact that these isotope abundances significantly vary with changes in temperature, inland distance, and elevation. For example, the average ^{18}O abundance in precipitation is shown for North America in Figure A.1. Note that these abundances are highest along coastal regions and rapidly decrease where mountain belts occur as well as with increasing latitude. These differences are typically reflected at the local and regional scale relevant at scales for groundwater basin studies (see further discussion below).

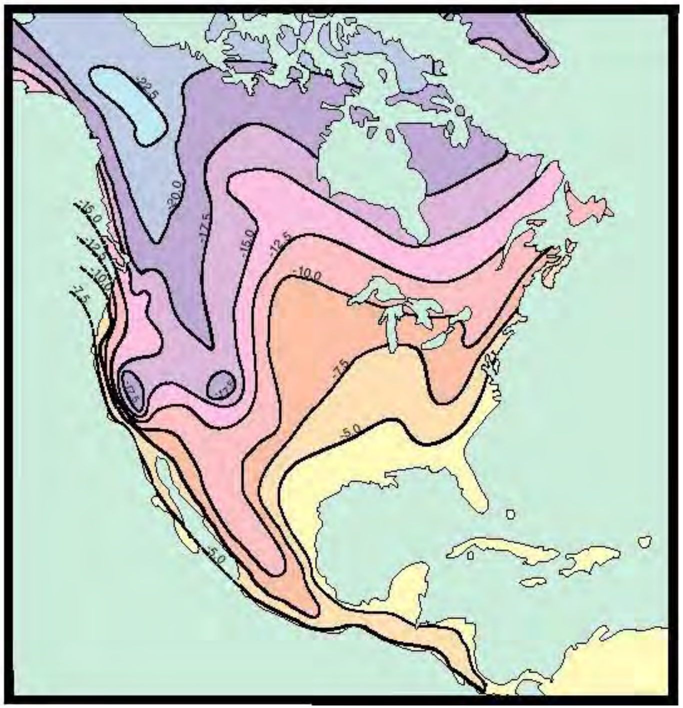

Figure A.1. Average $\delta^{18}O$ abundances of precipitation across North America show highest values along coastal regions and decrease rapidly with elevation in mountain belts and with increasing latitude.

The measured $^{18}O/^{16}O$ and D/H ratios are normalized to a recognized standard and the converted results are reported in δ notation (pronounced "del"), where

$$\delta D = \left(\frac{D/H}{D/H_{std}} - 1 \right) 1000$$

$$\delta^{18}O = \left(\frac{^{18}O/^{16}O}{^{18}O/^{16}O_{std}} - 1 \right) 1000$$

The $^{18}O/^{16}O_{std}$ and D/H_{std} are the isotopic ratios of "Standard Mean Ocean Water" (SMOW). A δ value is a per mil (or parts per thousand) deviation from the standard.

The atomic masses differences of these different isotopes in water molecules underlie differences in measured ratios. These differences arise from phase transitions in water (i.e., vapor, water, ice) which favors higher atomic masses in lower energy states of matter. For example, the measured difference in the $\delta^{18}O$ value measured between a water vapor and its condensed liquid form at 25°C is approximately 9.3 per mil. This difference is large compared to the typical measurement precision of 0.1 per mil.

The isotopic ratios of ocean water are remarkably uniform worldwide, owing to global circulation patterns. However, since all continental precipitation originates from the ocean, isotopic partitioning occurs between water phases, and because continental storm fronts are isolated from the ocean and behave as closed systems, the isotopic ratios of measured precipitation varies systematically. This variation is almost exclusively driven by elevation difference and distance inland from the ocean. An example of $\delta^{18}O$ variations in precipitation across British Columbia are illustrated below in Figure A.2a. Figure A.2b shows how shallow groundwater collected on the western slope of the Sierra Nevada record this systematic $\delta^{18}O$ variation in its recharge.

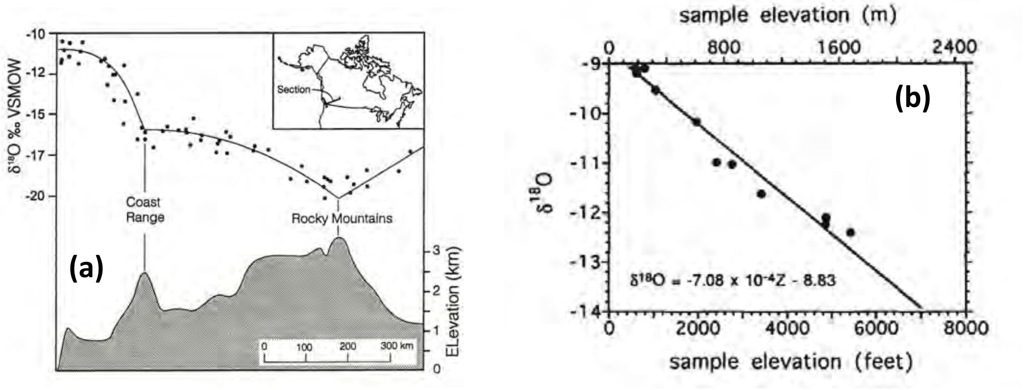

Figure A.2a,b. Figure A-2a shows systematic variation of $\delta^{18}O$ values in precipitation across British Columbia (from Yonge et al., 1989). Figure A.2b shows how shallow groundwater records this systematic variation on the western slope of the Sierra Nevada (from Rose et al., 1996).

The method for comparing the isotopic character of different waters lies in the use of a δD- $\delta^{18}O$ plot of the isotope ratios. A plot of δD vs. $\delta^{18}O$ values provides a graphical means to distinguish various populations of data relating to different water masses of different origins (Fig. A-3).

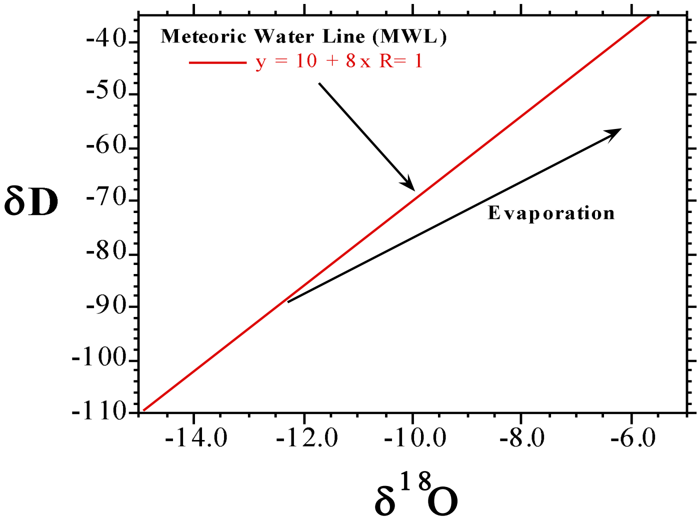

Figure A-3. General δD-δ^{18}O plot showing the Meteoric Water Line (MWL) and the effects of evaporation on natural waters. The slope of the evaporation line can vary between 2 and 6 and depends on the ambient temperature and humidity. The MWL has a constant slope of 8 for global precipitation.

Also on this plot lies what is referred to as the Global Meteoric Water Line (MWL), a linear regression through the values of various unevaporated precipitation collected world-wide, which results in an empirical equation of $\delta D = 8\ \delta^{18}O + 10$. The slope of this line originates from the fact that isotopic partitioning of deuterium between water vapor and liquid is approximately 8 times greater than for ^{18}O. Since global precipitation forms a slope of 8 indicates that cloud water establishes isotopic equilibrium between vapor and liquid.

However, when liquid water evaporates from the surface of water body, a non-equilibrium partitioning develops between the relative deuterium and ^{18}O abundances, causing isotopic enrichment of the remaining liquid water. On a δD- δ^{18}O plot, progressive evaporation causes a shift of the remaining liquid to the right of the MWL along a straight line (see Fig. A-3). The slope of this evaporation line depends on temperature and humidity of the surrounding air. The proximity of an evaporated isotopic value relative to the MWL is proportional to the extent of evaporation or isotopic enrichment.

A.2 Tritium-Helium-3 Age Dating

Attempts have been made in the past to date groundwater with the radioactive (unstable) hydrogen-3 isotope tritium (^{3}H; see Mazor, 1991 and references therein). Because of its radioactive half-life of 12.43 years, it is ideally a good chronometer for young (≤40 years) groundwater flow. Unfortunately from a dating standpoint, ^{3}H concentrations in precipitation have varied considerably over the past 50 years due to ^{3}H production from surface testing of thermonuclear weapons (Fig. A-4).

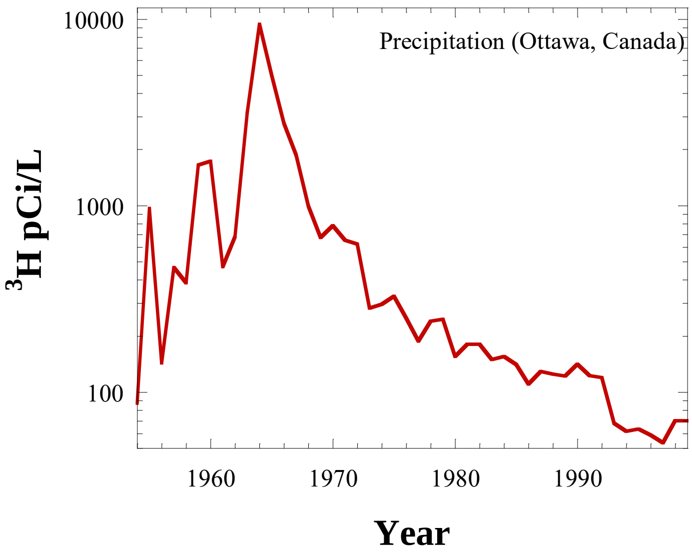

Figure A-4. Changes in the ^{3}H concentration in precipitation have varied over an order of magnitude due to fallout of thermonuclear-produced tritium from surface testing. IAEA/WMO (2001). Global Network of Isotopes in Precipitation. The GNIP Database. Accessible at: http://isohis.iaea.org

Tritium measurements in groundwater 30-40 years ago were useful from the standpoint of tracing the "bomb-pulse" ^{3}H that had recharged into groundwater in the early 1960s and calculating the groundwater travel time based on the observed depth of the "bomb pulse". Today, however, much of the "bomb-pulse" is not well defined in groundwater due to ^{3}H decay and groundwater dispersion. Tritium measurements alone cannot be used for dating groundwater reliably because of the uncertainty in what the original ^{3}H concentration was at the time of recharge, but it does serve the purpose of defining relatively young groundwater when it is observed.

In more recent years with the development of high-precision noble gas mass spectrometry, the radioactive decay product of ^{3}H, helium-3 (^{3}He), can be measured. The advantage to this lies in the dating equation, where

$$-17.9 \ x \ ln\left(\frac{^3H}{^3H_0}\right) = age \ ,$$

^3H is the concentration of the tritium at any given time, and ^3H_o is the original tritium concentration at the time of recharge. Since the ^3H_o has a large uncertainty due to the spatially and temporally variable "bomb pulse" tritium, the resulting age calculation will have large uncertainties. By simultaneously measuring the ^{3}He produced by tritium decay (known as the tritiogenic ^{3}He or $^3He_{trit}$) we can reconstruct the ^3H_o by adding together the measured tritiogenic $^3He_{trit}$ and the ^3H which leads to

$$-17.9xln\left(\frac{{}^{3}H}{{}^{3}H+{}^{3}H_{trit}}\right)=age,$$

Dissolved ^{3}He measured in a groundwater is actually derived from several sources that include:

$${}^{3}He_{meas} = {}^{3}He_{trit} + {}^{3}He_{equil} + {}^{3}He_{excess} + {}^{3}He_{rad}\ ,$$

where ${}^{3}He_{meas}$ is the total ^{3}He analytically measured, ${}^{3}He_{equil}$ is the amount of ^{3}He dissolved in a non-turbulent surface water in equilibrium with the atmosphere and is temperature dependent, ${}^{3}He_{excess}$ is the amount of ^{3}He dissolved in water exceeding the equilibrium amount (a common phenomenon in groundwater due to excess dissolved air), and ${}^{3}He_{rad}$ is the amount of ^{3}He produced from radioactive decay of isotopes other than tritium. The latter species is very minor and totals only about 0.2% of the total ^{3}He. Separating these different components of the ^{3}He requires additional measurements of the ^{4}He abundance which comprise:

$${}^{4}He_{meas} = {}^{4}He_{equil} + {}^{4}He_{excess} + {}^{4}He_{rad,}$$

where the subscripts are the same as those for ^{3}He. In the case of ${}^{4}He_{rad}$, a product of uranium-thorium decay, the abundance can be significant where older waters are involved (e.g. >1000 years old) and has been used numerous times as an independent groundwater age measurement due to its steady state accumulation.

The ${}^{3}He_{equil}$, ${}^{4}He_{equil}$, and ${}^{4}He_{rad}$ terms are either assumed or determined by other noble gas abundance measurements (see below), while the ${}^{3}He_{rad}$ term is assumed. The two unknowns left are the excess air terms and the tritiogenic ^{3}He, of which we can formulate two equations to solve for them.

The ${}^{4}\mathrm{He}_{\mathrm{meas}}/{}^{4}\mathrm{He}_{\mathrm{equil}}$ ratios provide a method for determining the excess air contribution to the sample, since a ratio >1.0 is created by incorporation of more dissolved helium than in equilibrium with the atmosphere, assuming an appreciable amount of ^{4}He has not accumulated from radioactive decay (see below). This assumption can be validated with additional noble gas measurements. If radiogenic ^{4}He is a concern, though, the ^{3}He/^{4}He ratios can be calculated and compared to ratios expected in water at equilibrium concentrations. This comparison is important since if there is any appreciable radiogenic ^{4}He, then the ^{3}He/^{4}He ratio relative to equilibrium will be <1.0. This is due to the accumulation of ^{4}He from uranium-thorium decay. Where there are indications of radiogenic ^{4}He we can correct for it in the age calculations.

A.3 Noble Gas Abundance

The noble gases of helium, neon, argon, krypton, and xenon naturally occur at trace abundance in the atmosphere. They also dissolve in groundwater during recharge. Their concentration in groundwater is controlled by 1) equilibrium solubility and 2) incorporation of excess air. The solubility of the noble gases in non-turbulent, free-standing water is temperature dependent, with increasing solubility with decreasing temperature. This temperature dependency is most pronounced in the argon, krypton, and xenon concentration (Fig. A-5).

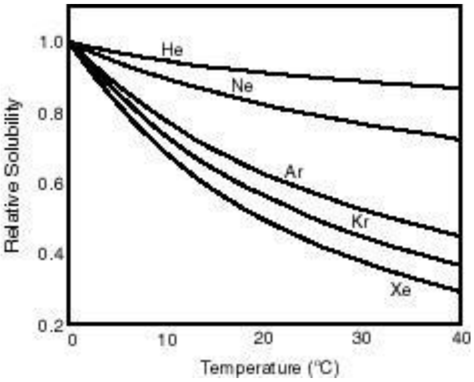

Figure A-5. Solubility of noble gases in water at various temperatures can be used to calculate groundwater recharge temperatures. See Mazor (1991) for examples and further discussion.

The curves in figure A-5 provide a means to calibrate measured dissolved noble gas abundances in groundwater against its recharge temperature. During most groundwater recharge, the mean soil temperature dictates the equilibrium noble gas concentrations dissolved in recharging water, which in most regions is around 2°C greater than the mean annual air temperature.

Dissolved noble gas abundances in groundwater other than helium that exceed an equilibrium amount are due to dissolution of excess air. Incorporation of excess air into recharged groundwater is thought to occur when air in the vadose zone is trapped by a plug of recharge water and is transported to deep enough depths that it is dissolved. Groundwater recharged through a vadose zone likely has excess dissolved air. In almost all cases the composition of the excess air is the same as the atmosphere (Heaton et al., 1981). Therefore, the amount of noble gases dissolved in groundwater above the equilibrium amount is a simple arithmetic addition of each noble gas from the atmosphere. Consequently, the amount of each dissolved noble gas relative to each other within a single sample should reflect a single equilibrium solubility temperature at the time of groundwater recharge. The amount of excess air dissolved in a groundwater can also provide qualitative information about the type of groundwater recharge. For instance, high excess air content may suggest recharge by a periodic "piston" flow under vadose zone conditions. Little excess air may suggest recharge with a limited vadose zone such as in river or lake infiltration.

The remaining noble gas effect that requires some consideration is the build-up of radiogenic ^{4}He. There is a constant flux toward the ground surface of ^{4}He derived from radioactive decay of uranium and thorium in the Earth's crust that, given enough time, can accumulate in groundwater. Typically groundwater that is thousands of years old will have an appreciable amount of radiogenic ^{4}He, while young groundwater (<100 years old) has little or none except in special conditions such as close proximity to large-scale active faults.

To test for the presence of radiogenic ^{4}He, the other noble gas abundances must be measured and calibrated to a recharge temperature. With this recharge temperature, the ^{4}He content can be predicted based on equilibrium solubility. Any ^{4}He that is above this predicted amount can be attributed to radiogenic ^{4}He, and subsequently subtracted. This will provide a revised ^{3}He/^{4}He ratio that can be used for calculating the groundwater age.

A.5 Radiocarbon and Carbon-13

Radiocarbon, or carbon-14 (^{14}C) is a radioactive isotope of carbon with a half-life of 5730 years. For decades ^{14}C has been used for age-dating of carbon-bearing materials (e.g. archeological artifacts) in the range of 100 to 50,000 years. Groundwater has also been dated, and most commonly by the ^{14}C abundance in dissolved inorganic carbon (DIC). Although many successful studies have been conducted using DIC ^{14}C measurements, much debate still continues about how and to what the extent carbonate minerals in aquifer systems dilute ^{14}C in recharging groundwater. As a result, absolute age determinations of groundwater using ^{14}C are limited to special cases where the absence of carbonate can be demonstrated or ^{14}C correction models can be validated. For the most part, absolute ages ≤1000 years old are usually highly uncertain.

The stable isotope of carbon, carbon-13 (^{13}C), is often measured in DIC and can provide either a source indicator or a relative measure of carbonate mineral reaction. Groundwater acquires DIC during recharge through plant root zones. The partial pressure of CO_2 in the soil root zone is usually higher (i.e. factor of 2 to 1000) than the atmosphere. Recharging groundwater will dissolve this soil zone CO_2, which is chemically neutralized by dissolution of minerals. Soil carbonate is the most common mineral interaction, but in its absence, aluminosilicates can also serve as a reactive substrate. Atmospheric CO_2 has a δ^{13}C value of approximately –7.5 per mil (the del system is the same as used for ^{18}O and deuterium, but carbon isotope ratios are compared to a reference carbonate material instead). Higher plants growing on the surface use this CO_2 for photosynthesis and in the process preferentially use ^{12}C over ^{13}C. As a result, plant δ^{13}C values tend to either be around –28 per mil, or for many grasses around –13 per mil. These same δ^{13}C values will occur in the soil zone CO_2 which originates from plant roots. Consequently, the δ^{13}C of DIC in recharging groundwater will be a mixture of the root zone CO_2 and any carbonate mineral it reacts with. To complicate matters further, for root zones where the partial pressure of CO_2 can be 10 times greater than the atmosphere, and recharging groundwater is relatively slow, isotopic exchange can occur between the DIC and the atmospheric CO_2, causing an enrichment in the δ^{13}C DIC value (partitioning between DIC and CO_2 is approximately 8-10 per mil, depending on temperature). This latter complication is common to desert environments. With all these variables in the recharging groundwater, predicting the final DIC ^{14}C and δ^{13}C values of groundwater reaching the saturated zone creates many uncertainties. As a result, it is more common to take an empirical approach and compare populations of δ^{13}C values of groundwater DIC collected in the same general vicinity, and estimate the amount of carbonate interaction and the recharge dynamics.

References

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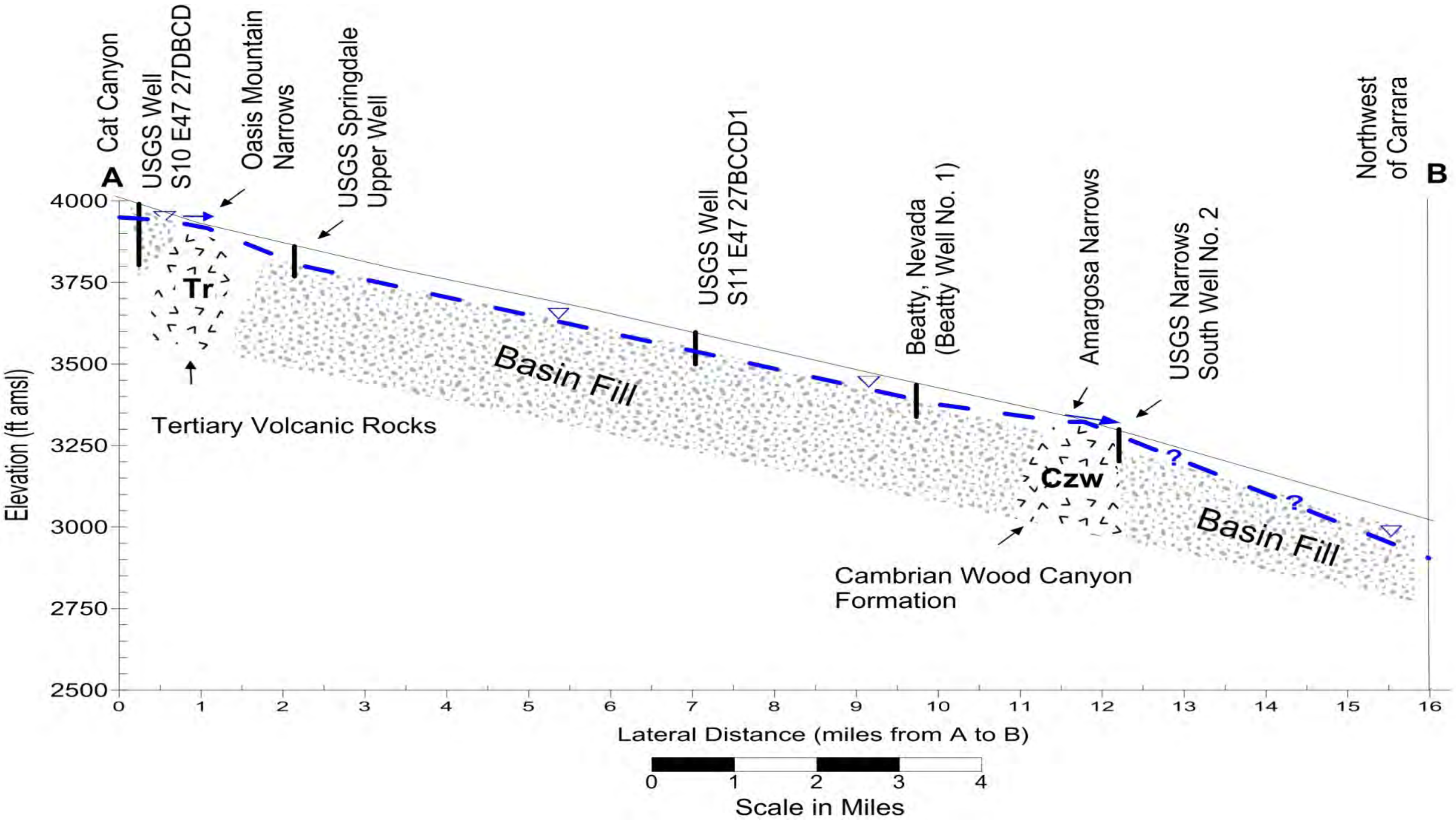
Heaton T.H.E. and Vogel J.C., 1981, "Excess air" in groundwater. *J. Hydrol.*, 50, 210-216.

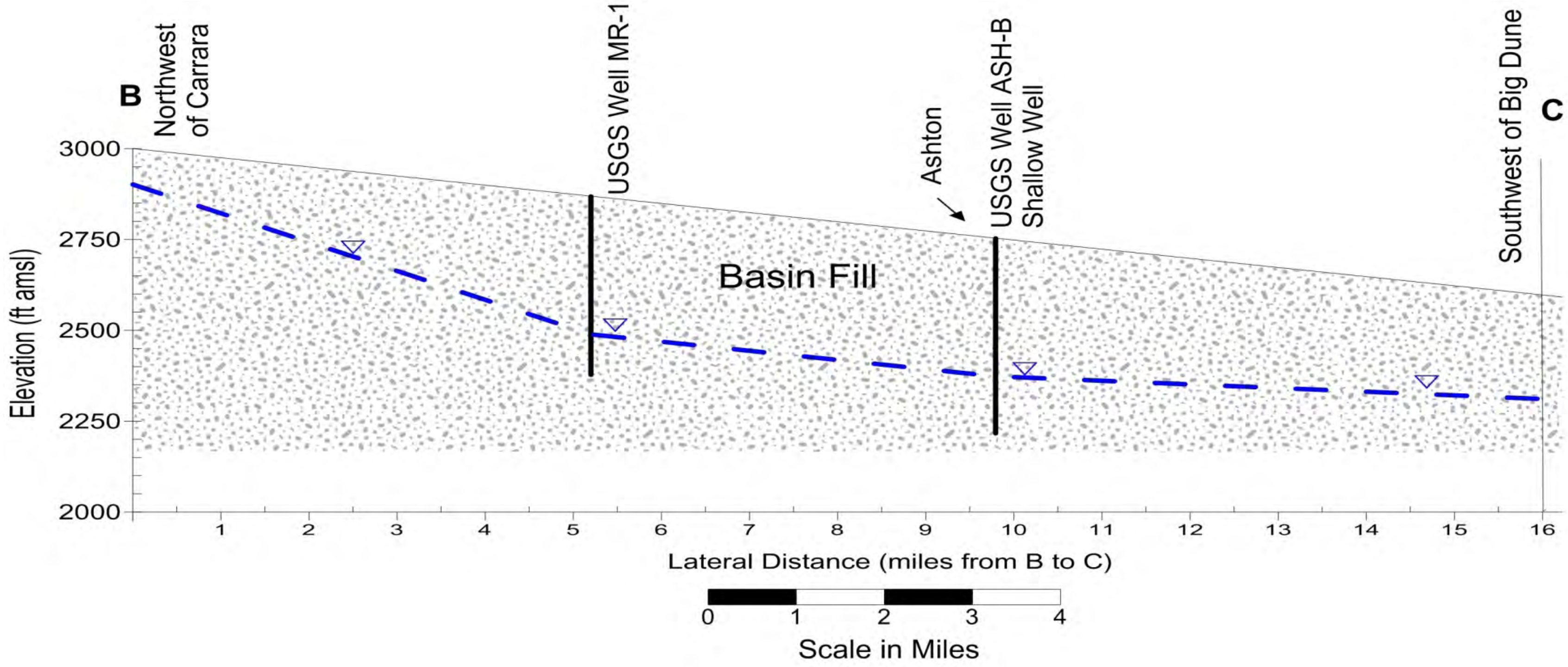
Mazor, E., 1991, Applied Chemical and Isotopic Groundwater Hydrology. Halsted Press: New York, 274 pgs.

APPENDIX D:



Conceptual Cross Section A-B: Amargosa River Course

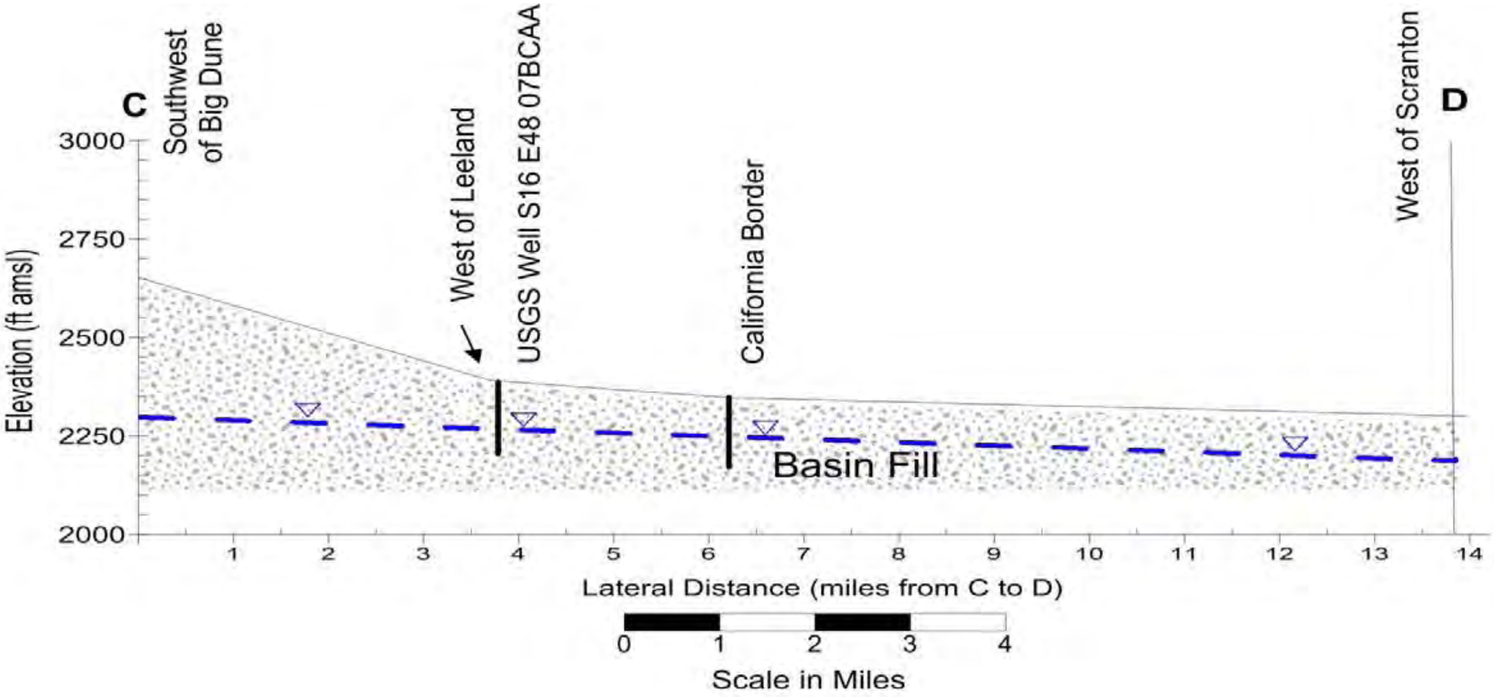
Southwest of Oasis Mountain to Northwest of Carrera, NV



Conceptual Cross Section B-C: Amargosa River Course

Northwest of Carrera to Southwest of Big Dune, NV

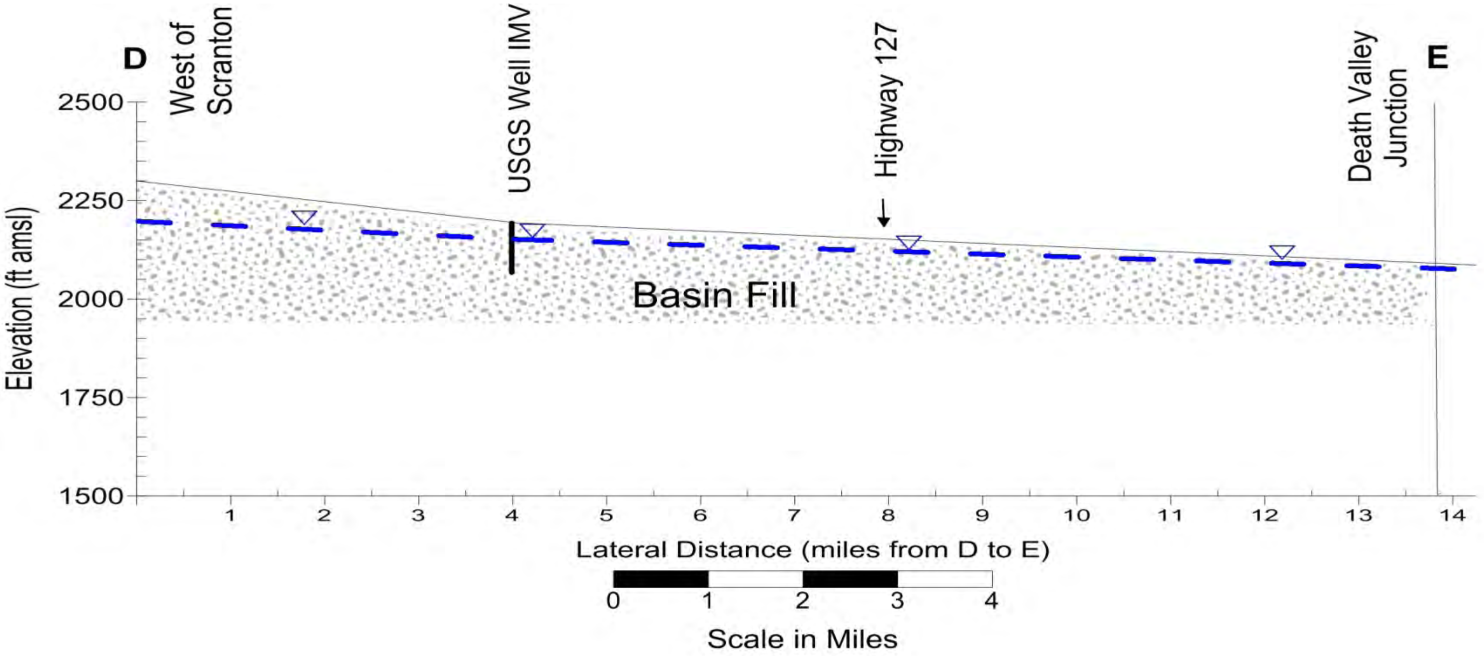
ANDY ZDON &
ASSOCIATES, INC.



Conceptual Cross Section C-D: Amargosa River Course

Southwest of Big Dune, NV to West of Scranton, CA

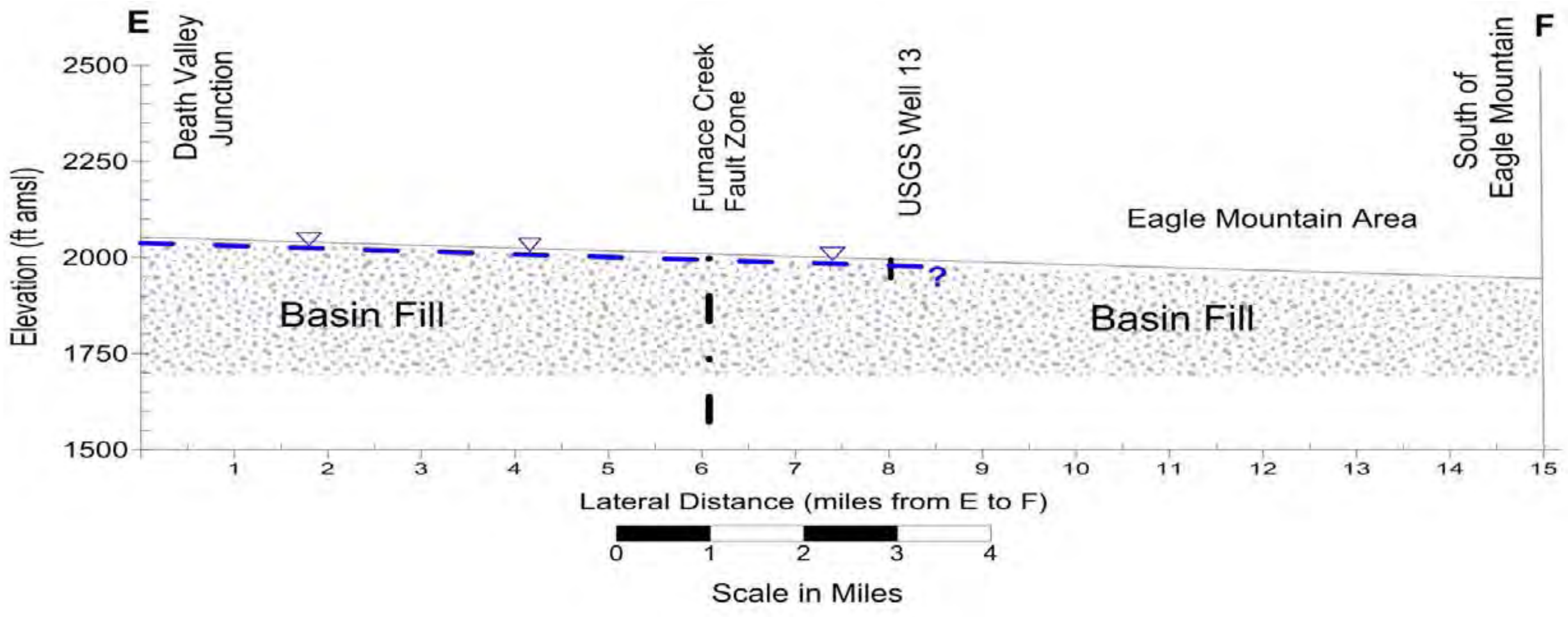
ANDY ZDON &
ASSOCIATES, INC.



Conceptual Cross Section D-E: Amargosa River Course

West of Scranton to Death Valley Junction, CA

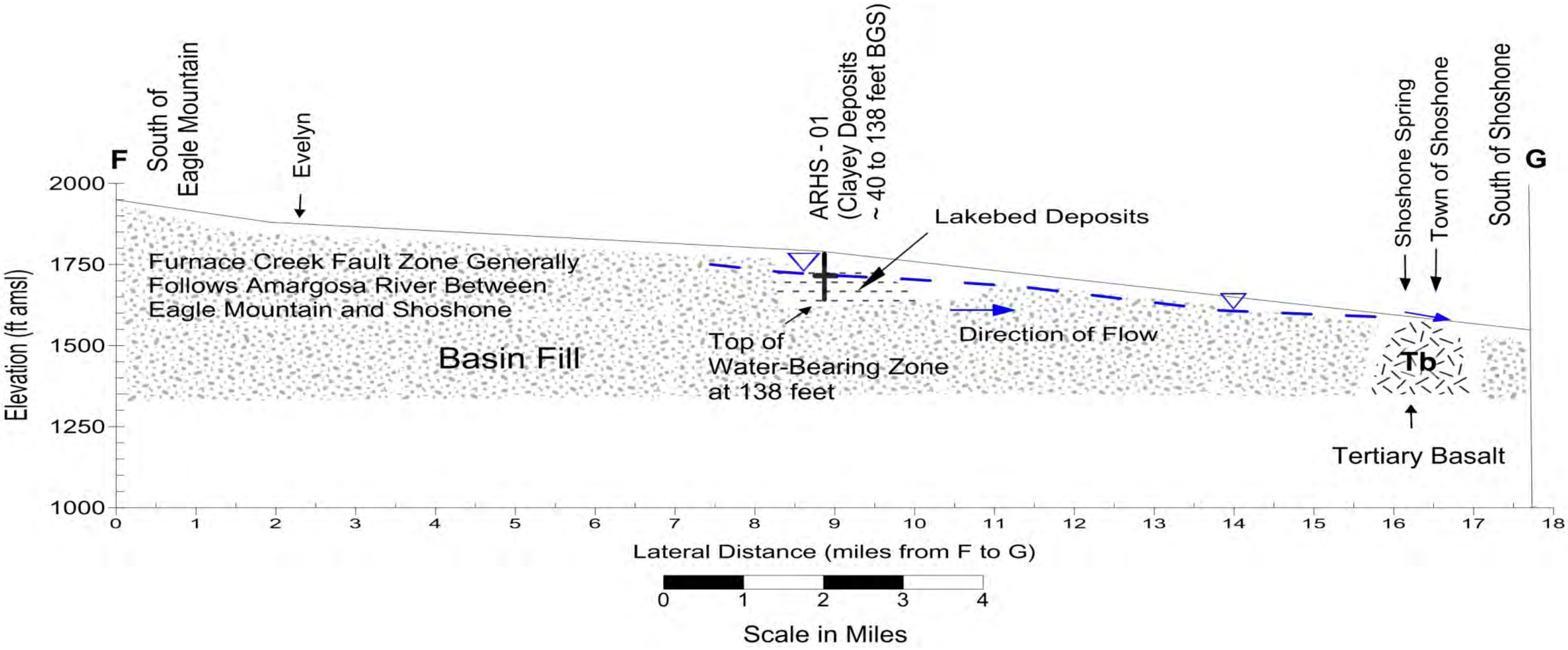
ANDY ZDON &
ASSOCIATES, INC.

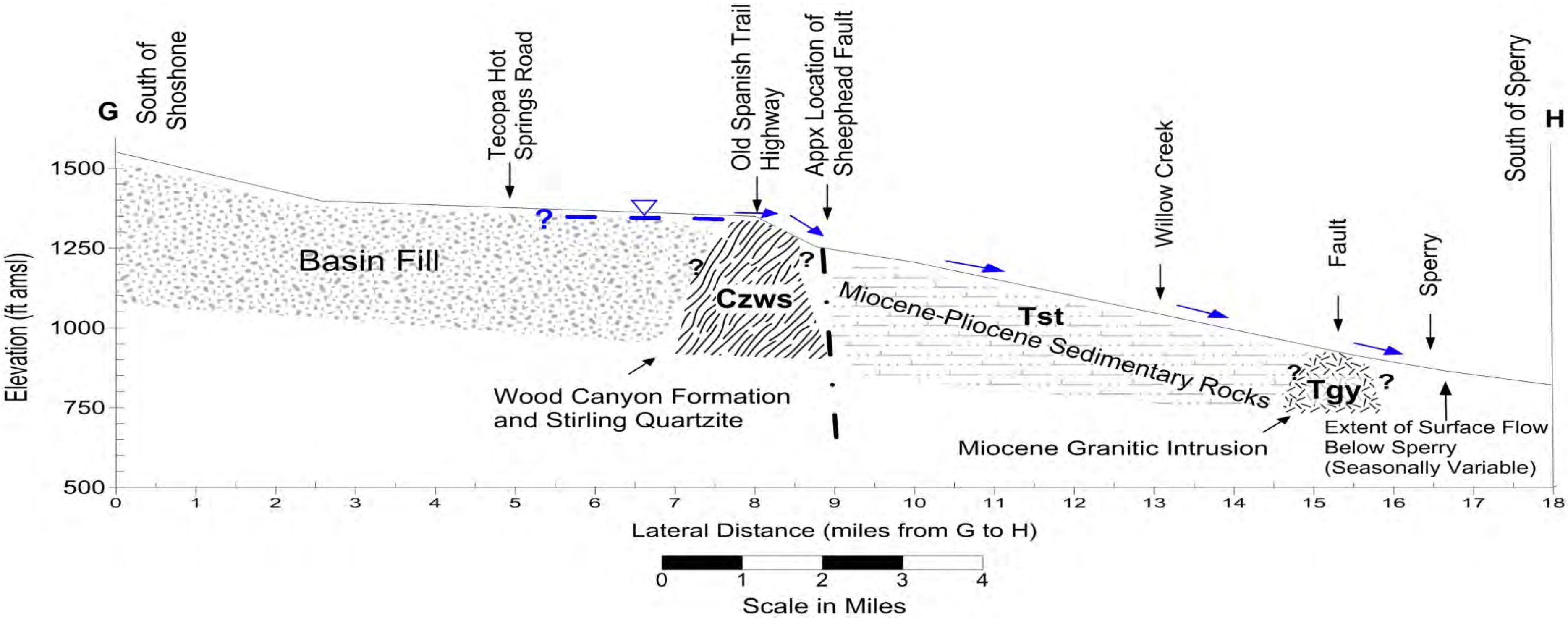


Conceptual Cross Section E-F: Amargosa River Course

Death Valley Junction to South of Eagle Mountain, CA

ANDY ZDON &
ASSOCIATES, INC.


F
South of Eagle Mountain
Evelyn
ARHS - 01 (Clayey Deposits ~ 40 to 138 feet BGS)
Lakebed Deposits
Shoshone Spring
Town of Shoshone
South of Shoshone
G
Furnace Creek Fault Zone Generally Follows Amargosa River Between Eagle Mountain and Shoshone
Basin Fill
Top of Water-Bearing Zone at 138 feet
Direction of Flow
Tb
Tertiary Basalt
Elevation (ft amsl)
2000
1750
1500
1250
1000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Lateral Distance (miles from F to G)
0
1
2
3
4
Scale in Miles


G
South of Shoshone
Tecopa Hot Springs Road
Old Spanish Trail Highway
Appx Location of Sheephead Fault
Willow Creek
Fault
Sperry
South of Sperry
H
Elevation (ft amsl)
1500
1250
1000
750
500
Basin Fill
?
Czws
Tst
Miocene-Pliocene Sedimentary Rocks
Tgy
Wood Canyon Formation and Stirling Quartzite
Miocene Granitic Intrusion
Extent of Surface Flow Below Sperry (Seasonally Variable)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Lateral Distance (miles from G to H)
0
1
2
3
4
Scale in Miles

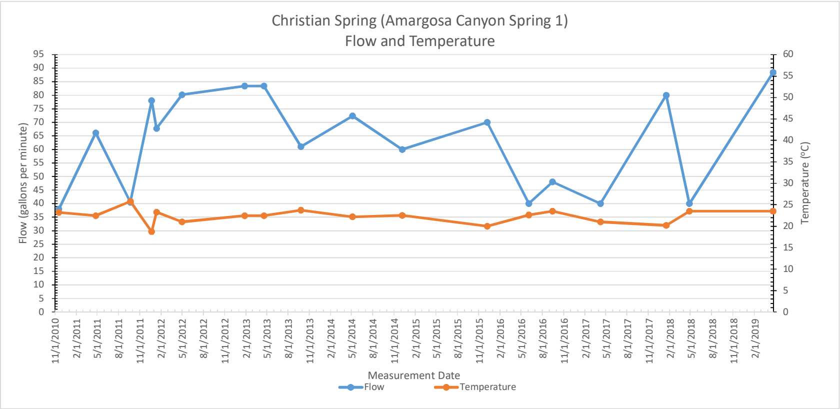
APPENDIX E: (see thumbdrive)

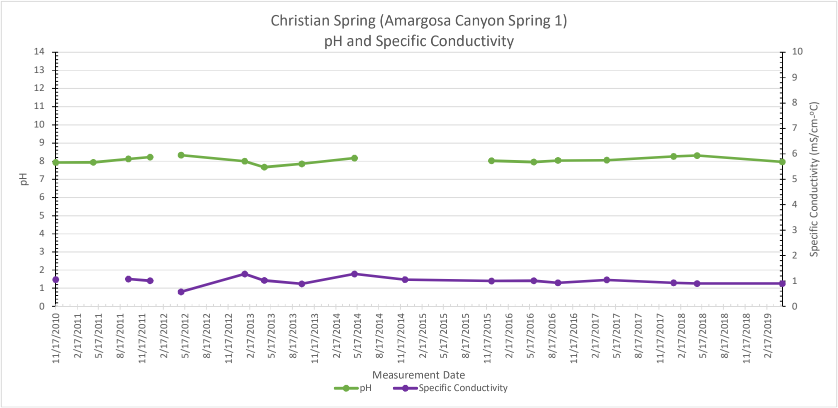
APPENDIX F:

SPRING DATA AND TRENDS
SPRINGS ALONG AWSR

Christian Spg (AM CYN1)

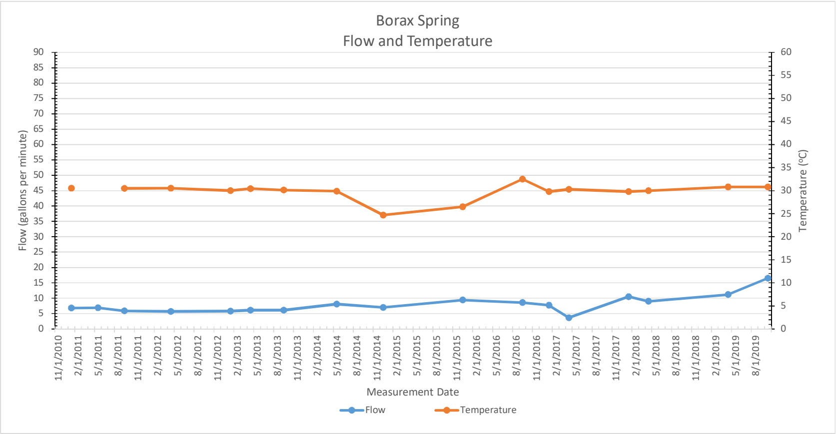
Date	Flow	Date	Temperature	pH	Specific Conductivity
11/17/2010	38	11/17/2010	23.22	7.93	1.053
5/11/2011	66.1	4/25/2011	22.46	7.94	
9/21/2011	40.5	9/21/2011	25.79	8.12	1.076
12/22/2011	78	12/22/2011	18.73	8.22	1.009
1/12/2012	67.7	1/12/2012	23.27		
5/1/2012	80.2	5/1/2012	21	8.33	0.573
1/26/2013	83.4	1/26/2013	22.44	8	1.274
4/19/2013	83.4	4/19/2013	22.44	7.67	1.02
9/25/2013	61	9/25/2013	23.74	7.85	0.886
5/6/2014	72.4	5/6/2014	22.2	8.17	1.278
12/6/2014	60	12/6/2014	22.5		1.054
12/8/2015	70	12/8/2015	20.0	8.02	1.001
6/4/2016	40	6/4/2016	22.6	7.95	1.012
9/14/2016	48	9/14/2016	23.5	8.04	0.925
4/9/2017	40	4/9/2017	21.0	8.05	1.046
1/17/2018	80	1/17/2018	20.2	8.26	0.927
4/27/2018	40	4/27/2018	23.5	8.31	0.9
4/23/2019	88.4	4/23/2019	23.5	7.96	0.9

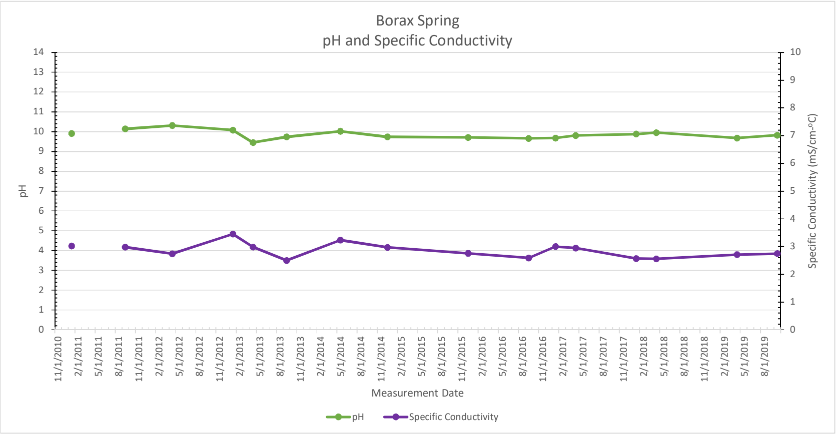




Borax Spring

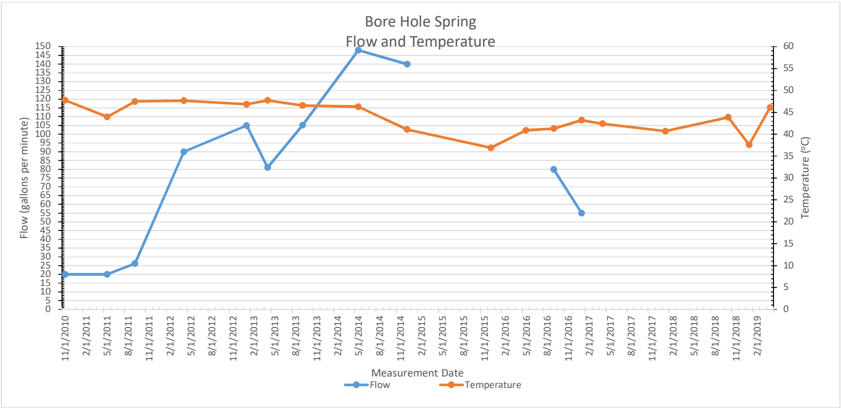
Date	Flow	Date	Temperature	pH	Specific Conductivity
1/12/2011	6.8	1/12/2011	30.53	9.91	3.019
5/5/2011	6.9	5/5/2011			
9/21/2011	5.9	9/21/2011	30.51	10.14	2.981
4/30/2012	5.7	4/30/2012	30.52	10.31	2.740
1/28/2013	5.8	1/28/2013	30.02	10.08	3.451
4/18/2013	6.1	4/18/2013	30.44	9.45	2.985
9/23/2013	6.1	9/23/2013	30.14	9.74	2.498
5/12/2014	8.1	5/12/2014	29.88	10.02	3.234
12/5/2014	7	12/5/2014	24.7	9.74	2.969
12/8/2015	9.4	12/8/2015	26.5	9.71	2.756
9/15/2016	8.6	9/15/2016	32.5	9.66	2.590
1/10/2017	7.7	1/10/2017	29.8	9.68	3.001
4/10/2017	3.63	4/10/2017	30.3	9.81	2.949
1/17/2018	10.5	1/17/2018	29.8	9.88	2.568
4/27/2018	9	4/27/2018	30	9.95	2.56
4/23/2019	11.2	4/23/2019	30.8	9.68	2.713
10/1/2019	16.5	10/1/2019	30.8	9.82	2.745

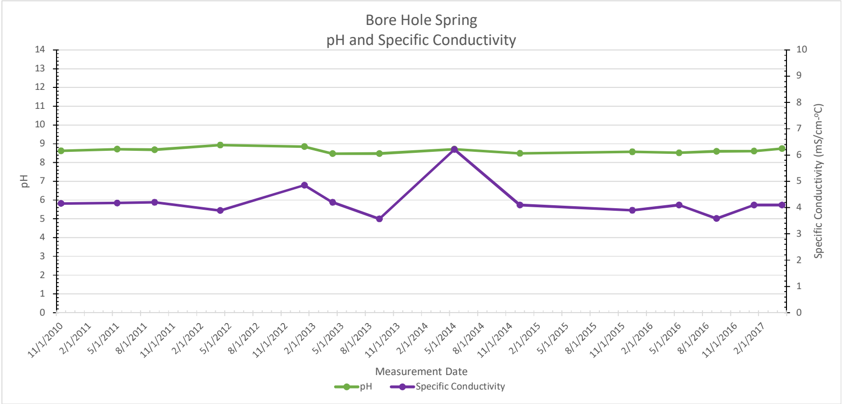




Bore Hole Spring

Date	Flow	Date	Temperature	pH	Specific Conductivity
11/11/2010	20	11/11/2010	47.77	8.62	4.156
5/2/2011	20	5/2/2011	43.98	8.71	4.176
9/21/2011	26.2	9/21/2011	47.48	8.68	4.202
4/30/2012	90	4/30/2012	47.68	8.93	3.890
1/25/2013	105	1/25/2013	46.83	8.85	4.852
4/18/2013	81	4/18/2013	47.75	8.47	4.202
9/24/2013	105.2	9/24/2013	46.59	8.48	3.571
5/10/2014	148	5/10/2014	46.3	8.71	6.215
12/3/2014	140	12/3/2014	41.1	8.49	4.1
12/6/2015		12/6/2015	36.9	8.57	3.893
5/31/2016		5/31/2016	40.9	8.52	4.1
9/15/2016	80	9/15/2016	41.3	8.60	3.582
1/8/2017	55	1/8/2017	43.2	8.61	4.1
4/10/2017		4/10/2017	42.4	8.74	4.1
1/16/2018		1/16/2018	40.7	8.59	3337
10/22/2018		10/22/2018	43.9	8.65	4000
1/18/2019		1/18/2019	37.6	8.76	3815
4/23/2019		4/23/2019	46.1	8.41	3903

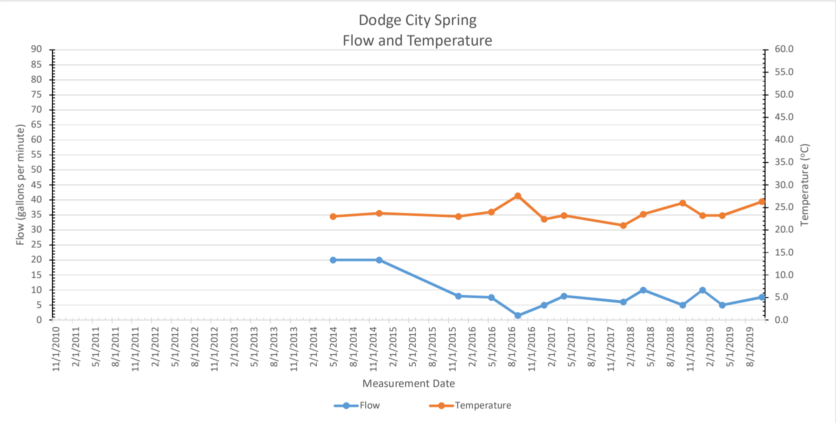


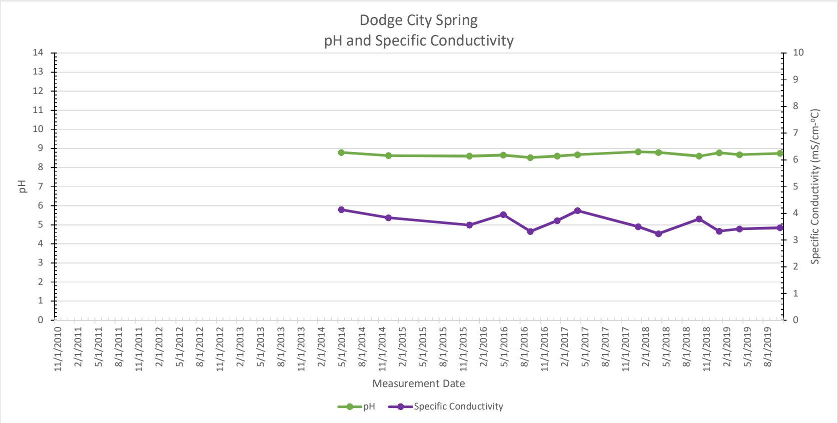


SPRING DATA AND TRENDS
SPRINGS ALONG AWSR

Dodge City Spring

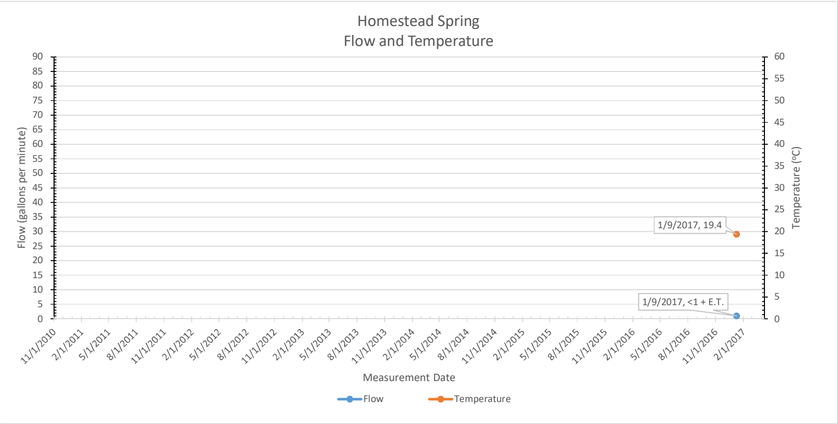
Date	Flow	Date	Temperature	pH	Specific Conductivity
5/4/2014	20	5/4/2014	23.0	8.79	4.141
12/3/2014	20	12/3/2014	23.7	8.63	3.832
12/6/2015	8	12/6/2015	23.0	8.60	3.564
5/31/2016	7.5	5/31/2016	24.0	8.65	3.955
9/15/2016	1.5	9/15/2016	27.6	8.52	3.324
1/8/2017	5	1/8/2017	22.4	8.60	3.725
4/10/2017	8	4/10/2017	23.2	8.67	4.1
1/6/2018	6	1/6/2018	21	8.83	3.499
4/27/2018	10	4/27/2018	23.5	8.79	3.234
10/22/2018	5	10/22/2018	26	8.6	3.793
1/8/2019	10	1/8/2019	23.2	8.78	3.333
4/23/2019	5	4/23/2019	23.2	8.67	3.418
10/1/2019	7.6	10/1/2019	26.3	8.75	3.459

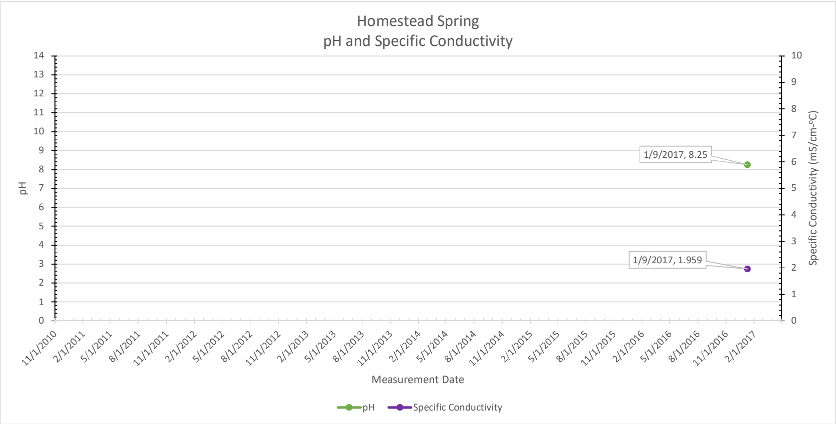




Homestead Spring

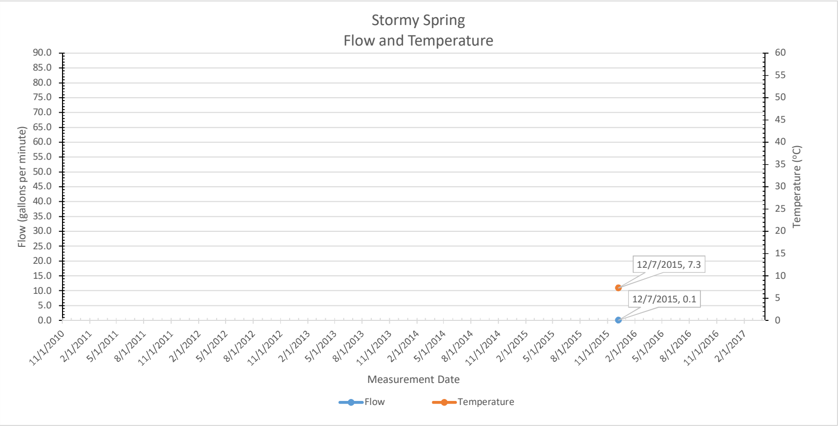
Date	Flow	Date	Temperature	pH	Specific Conductivity
1/9/2017	1	1/9/2017	19.4	8.25	1.959

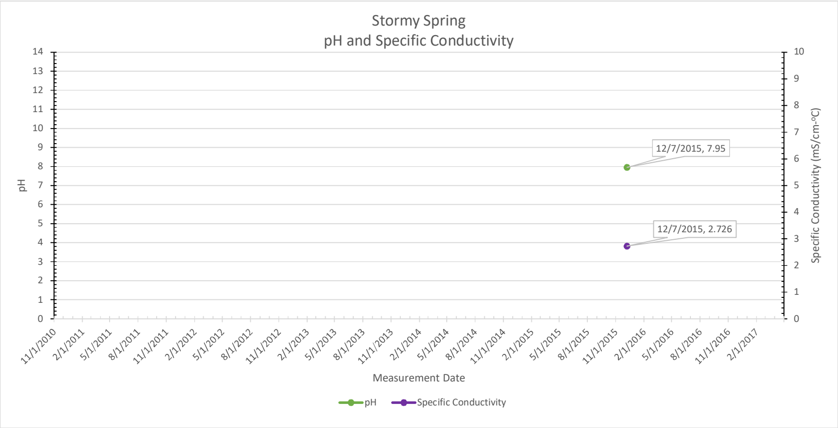




Stormy Spring

Date	Flow	Date	Temperature	pH	Specific Conductivity
12/7/2015	0.1	12/7/2015	7.3	7.95	2.726

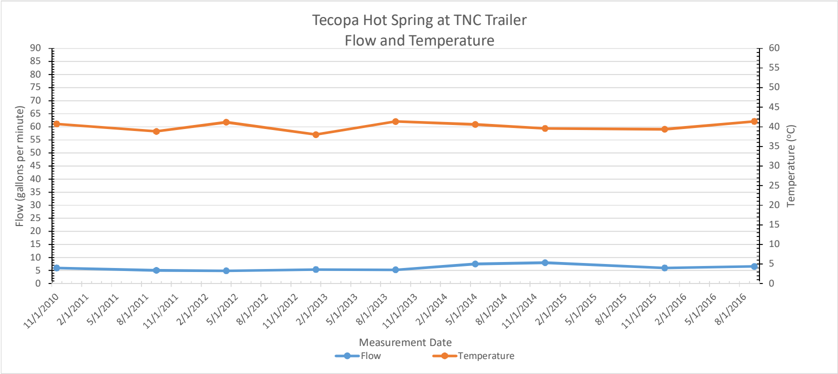


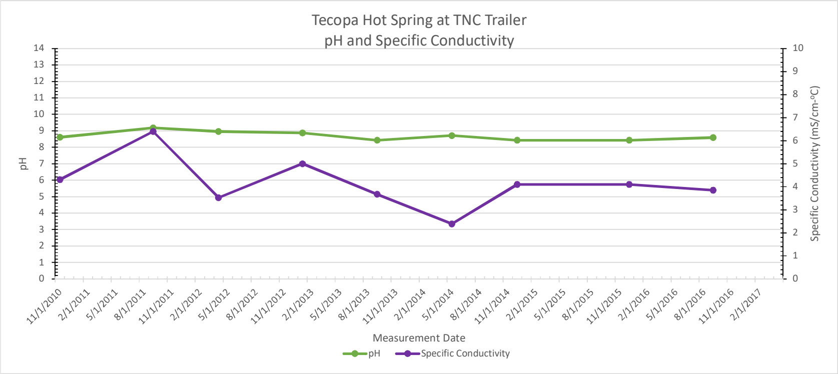


SPRING DATA AND TRENDS
SPRINGS ALONG AWSR

Tecopa Hot Spring at TNC Trailer

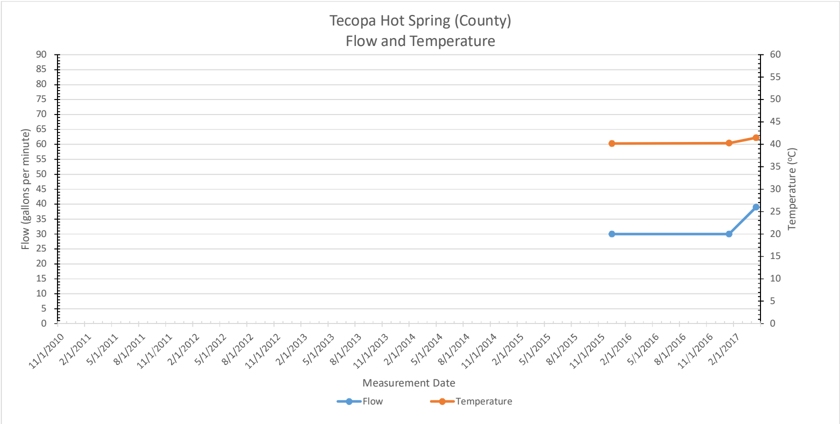
Date	Flow	Date	Temperature	pH	Specific Conductivity
11/11/2010	6	11/11/2010	40.76	8.61	4.306
9/21/2011	5.1	9/21/2011	38.85	9.18	6.400
4/30/2012	4.9	4/30/2012	41.2	8.96	3.525
1/29/2013	5.4	1/29/2013	38.02	8.87	5.000
9/23/2013	5.3	9/23/2013	41.38	8.43	3.675
5/10/2014	7.5	5/10/2014	40.6	8.71	2.390
12/5/2014	8	12/5/2014	39.6	8.43	4.1
12/7/2015	6	12/7/2015	39.4	8.43	4.1
9/14/2016	6.6	9/14/2016	41.4	8.59	3.850

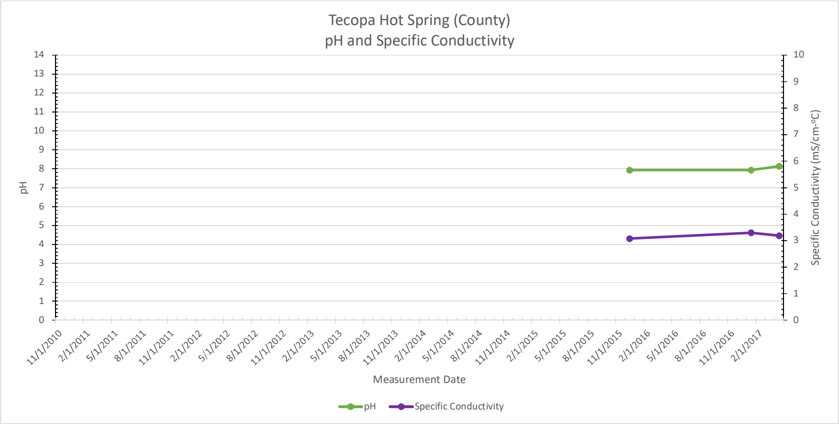




Tecopa Hot Spring (County)

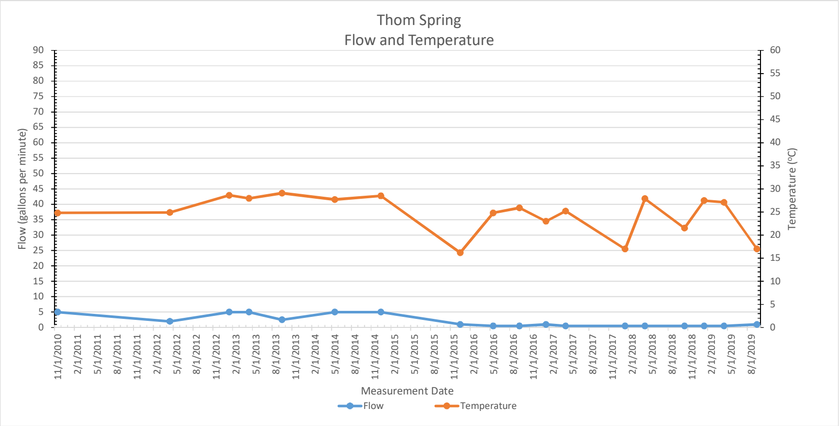
Date	Flow	Date	Temperature	pH	Specific Conductivity
12/7/2015	30	12/7/2015	40.2	7.93	3.076
1/9/2017	30	1/9/2017	40.3	7.93	3.295
4/10/2017	39	4/10/2017	41.5	8.13	3.187

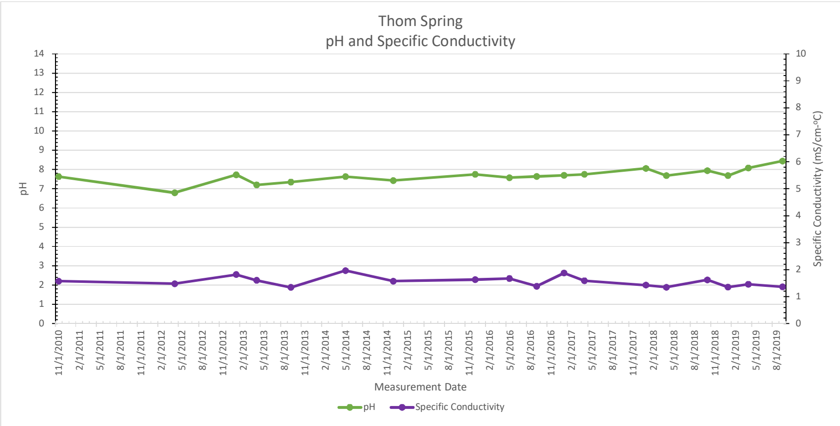




Thom Spring

Date	Flow	Date	Temperature	pH	Specific Conductivity
11/11/2010	5	11/11/2010	24.81	7.63	1.571
4/30/2012	2	4/30/2012	24.9	6.79	1.478
1/28/2013	5	1/28/2013	28.63	7.73	1.819
4/30/2013	5	4/30/2013	27.96	7.2	1.601
9/25/2013	2.5	9/25/2013	29.09	7.35	1.34
5/5/2014	5	5/5/2014	27.7	7.63	1.965
12/3/2014	5	12/3/2014	28.5	7.43	1.572
12/7/2015	1	12/7/2015	16.2	7.75	1.630
5/31/2016	0.5	5/31/2016	24.8	7.57	1.672
9/15/2016	0.5	9/15/2016	25.9	7.64	1.382
1/9/2017	1	1/9/2017	23.0	7.70	1.876
4/10/2017	0.5	4/10/2017	25.2	7.75	1.588
1/16/2018	0.5	1/16/2018	17	8.06	1.425
4/27/2018	0.5	4/27/2018	27.9	7.68	1.347
10/22/2018	0.5	10/22/2018	21.5	7.94	1.617
1/8/2019	0.5	1/8/2019	27.5	7.68	1.351
4/22/2019	0.5	4/22/2019	27.1	8.08	1.458
9/30/2019	1	9/30/2019	17	8.44	1.362

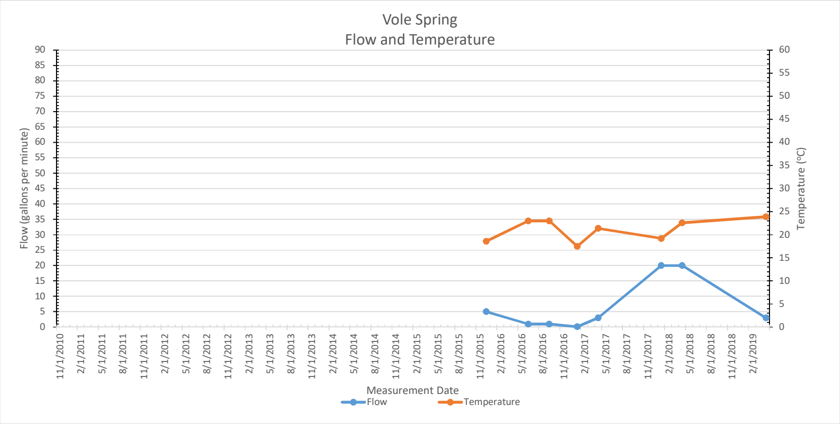


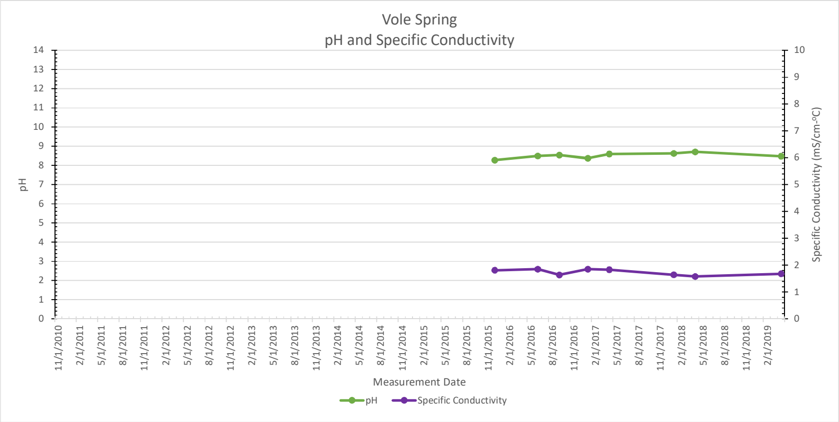


Vole Spring

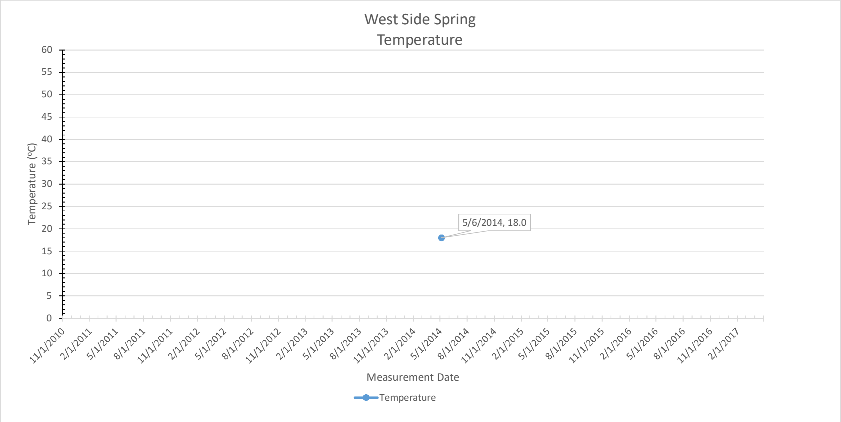
SPRING DATA AND TRENDS
SPRINGS ALONG AWSR

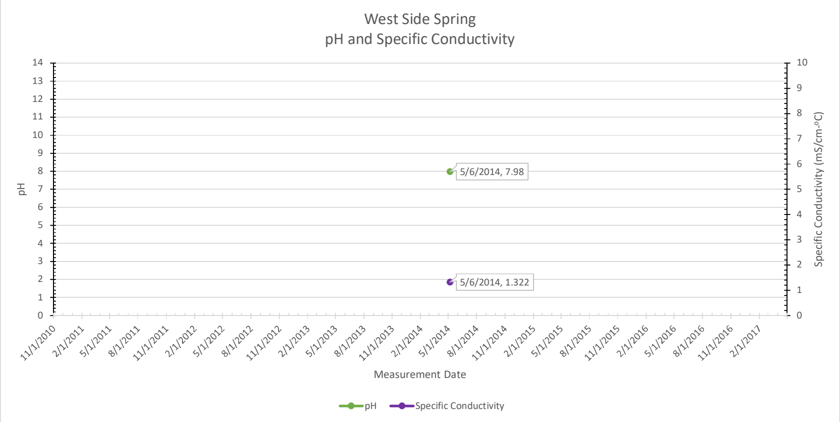
Date	Flow	Date	Temperature	pH	Specific Conductivity
12/7/2015	5	12/7/2015	18.6	8.28	1.809
6/3/2016	1	6/3/2016	23.0	8.50	1.853
9/15/2016	1	9/15/2016	23.0	8.54	1.640
1/9/2017	0.1	1/9/2017	17.5	8.37	1.853
4/10/2017	3	4/10/2017	21.4	8.60	1.831
1/16/2018	20	1/16/2018	19.2	8.63	1.642
4/27/2018	20	4/27/2018	22.6	8.71	1.583
4/23/2019	3	4/23/2019	23.9	8.48	1.68



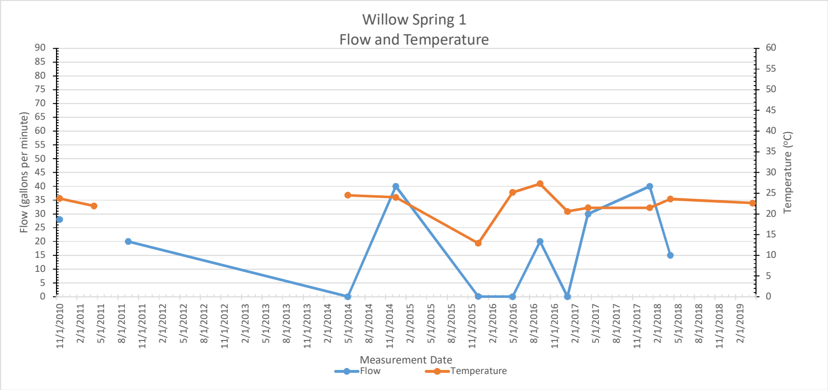


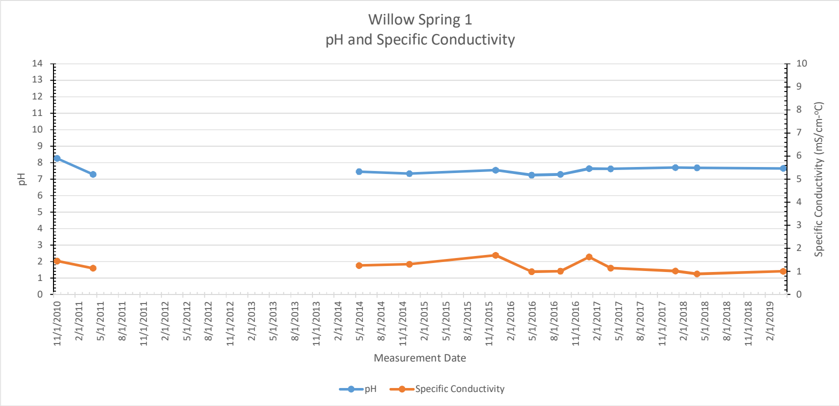
West-side Spring					
Date	Flow	Date	Temperature	pH	Specific Conductivity
5/6/2014	N/A	5/6/2014	18.0	7.98	1.322

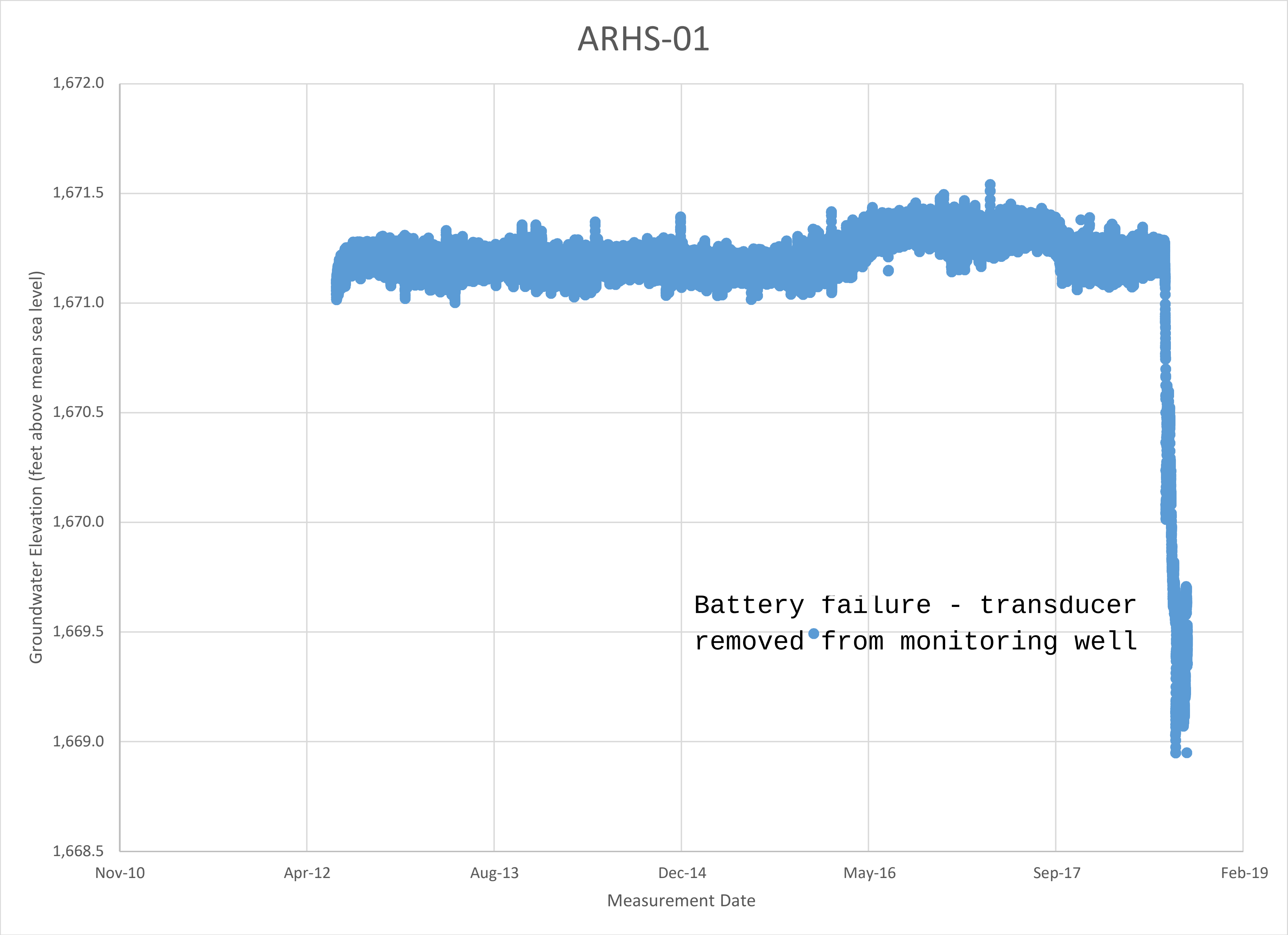


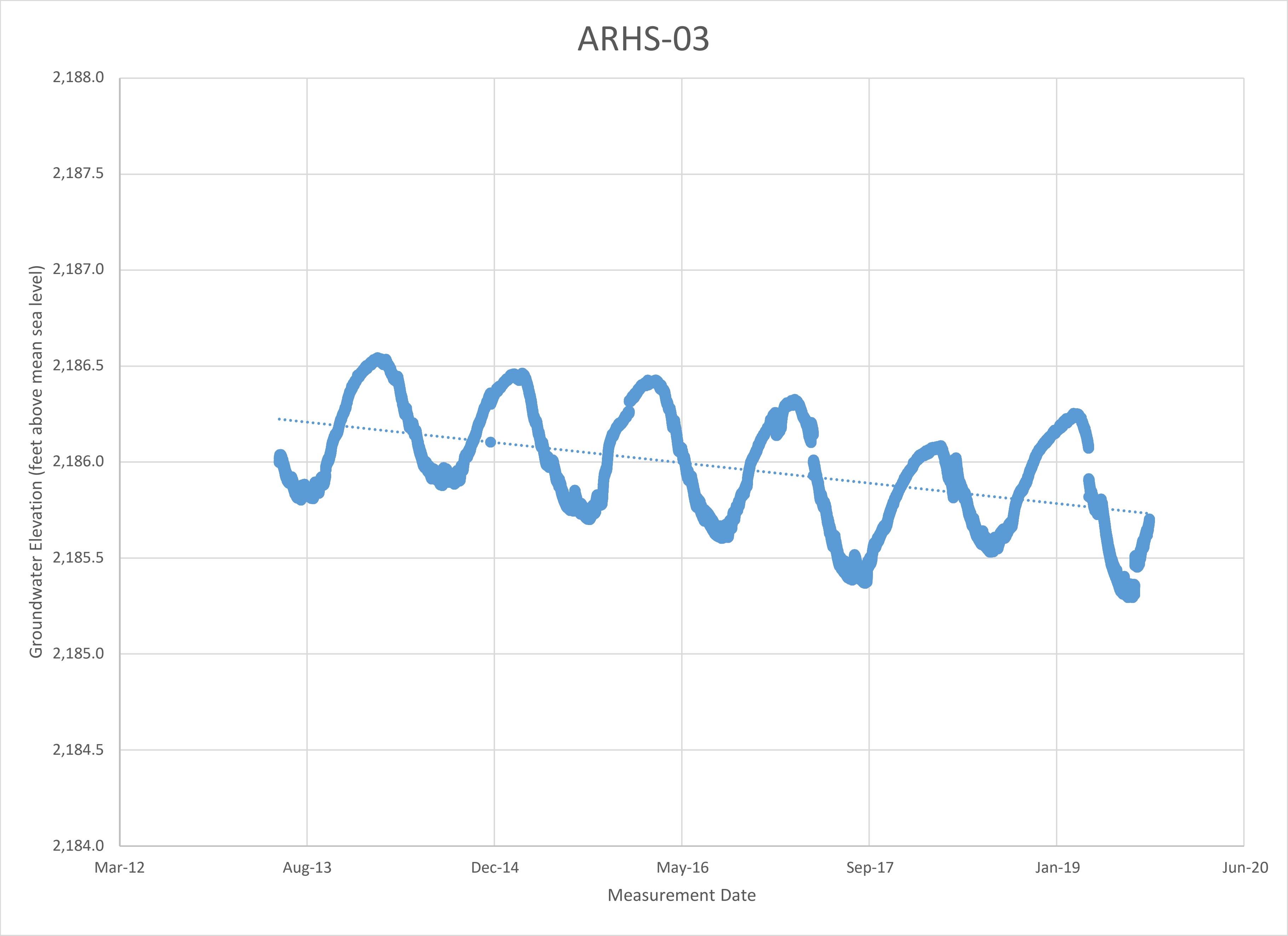


Willow Spring 1					
Date	Flow	Date	Temperature	pH	Specific Conductivity
11/3/2010	28	11/3/2010	23.73	8.26	1.453
4/26/2011		4/26/2011	21.92	7.29	1.141
9/23/2011	20	9/23/2011			
5/9/2014	N/A	5/9/2014	24.5	7.46	1.256
12/6/2014	40	12/6/2014	24.0	7.34	1.312
12/5/2015	0.1	12/5/2015	12.9	7.55	1.703
5/31/2016	2.5	5/31/2016	25.2	7.25	0.986
9/17/2016	20	9/17/2016	27.3	7.29	1.011
1/9/2017	2.5	1/9/2017	20.6	7.64	1.631
4/11/2017	30	4/11/2017	21.5	7.63	1.147
1/16/2018	40	1/16/2018	21.5	7.71	1.02
4/29/2018	15	4/29/2018	23.6	7.69	0.893
4/25/2019		4/25/2019	22.6	7.66	1.008






ARHS-01
Groundwater Elevation (feet above mean sea level)
1,672.0
1,671.5
1,671.0
1,670.5
1,670.0
1,669.5
1,669.0
1,668.5
Nov-10
Apr-12
Aug-13
Dec-14
May-16
Sep-17
Feb-19
Measurement Date
Battery failure - transducer removed from monitoring well


ARHS-03
Groundwater Elevation (feet above mean sea level)
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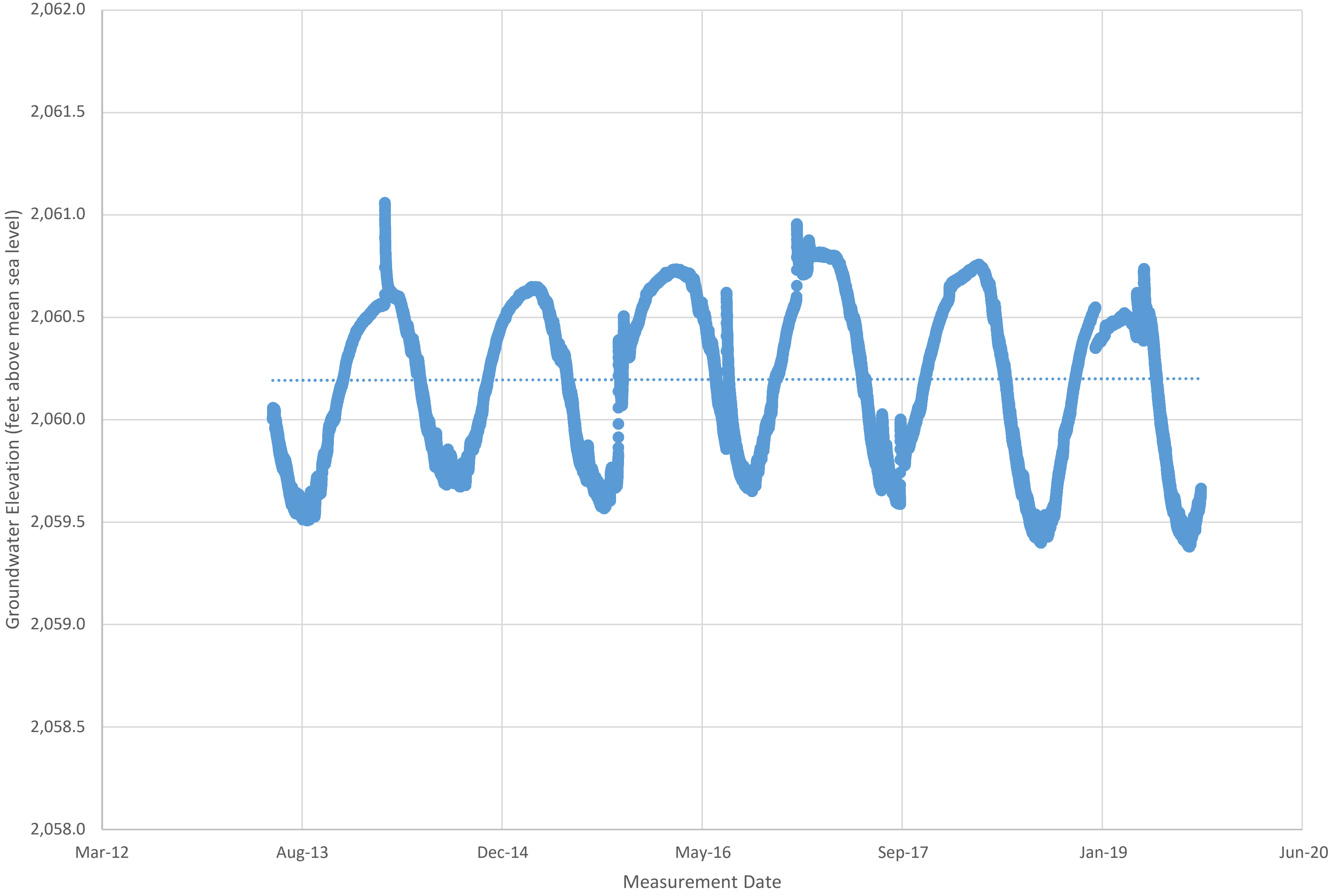
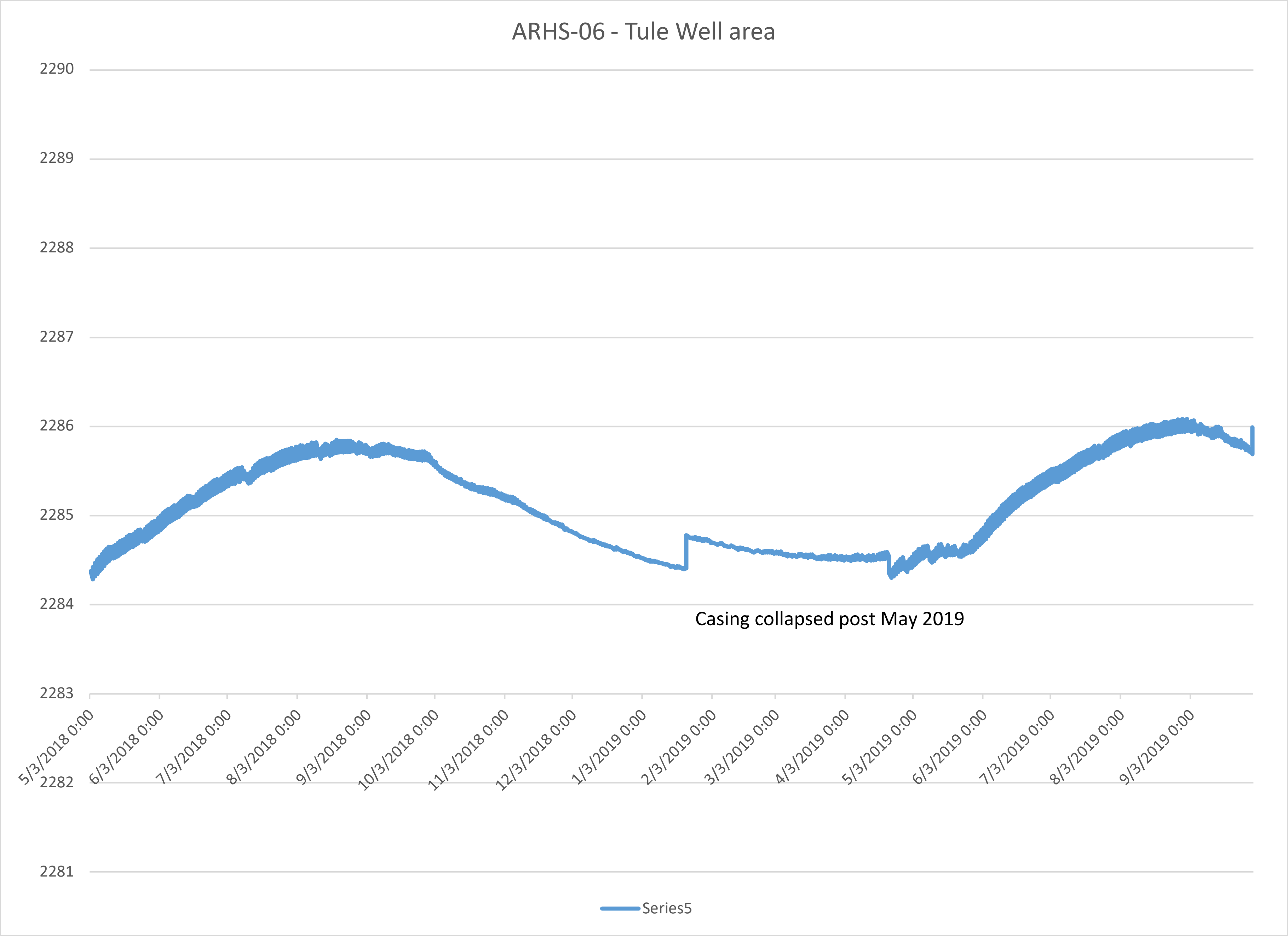
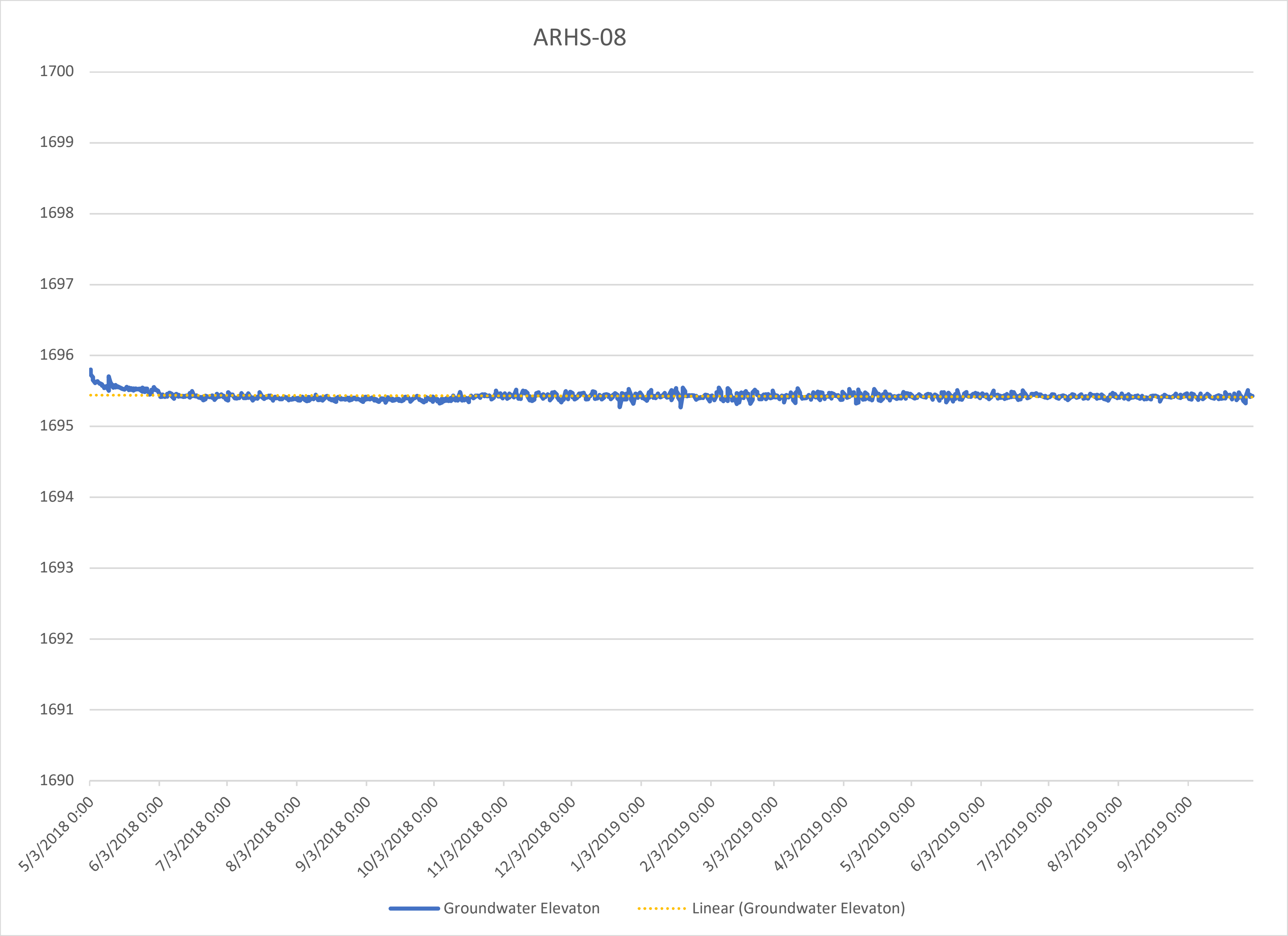
2,187.5
2,187.0
2,186.5
2,186.0
2,185.5
2,185.0
2,184.5
2,184.0
Mar-12
Aug-13
Dec-14
May-16
Sep-17
Jan-19
Jun-20
Measurement Date

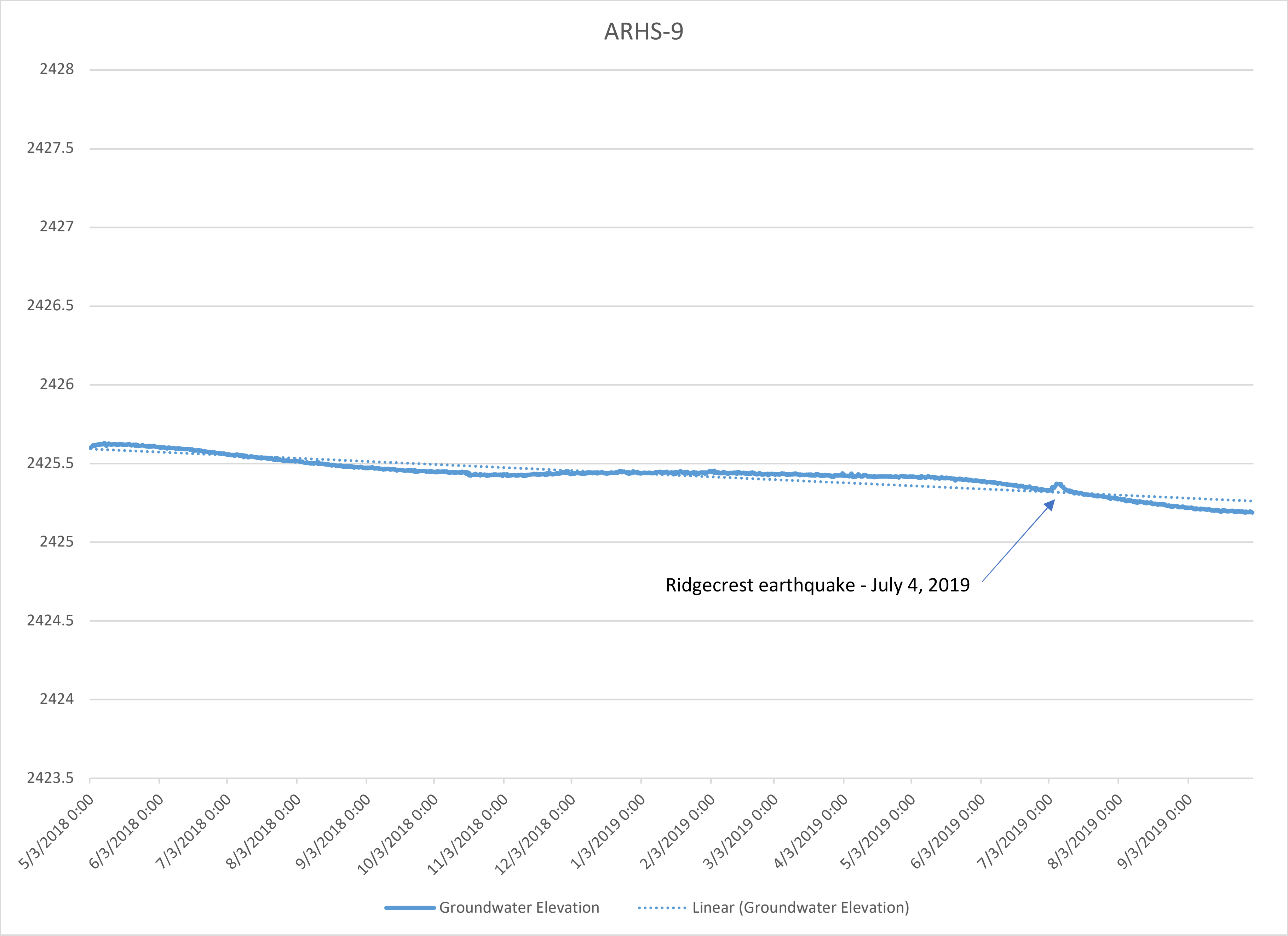
ARHS-04

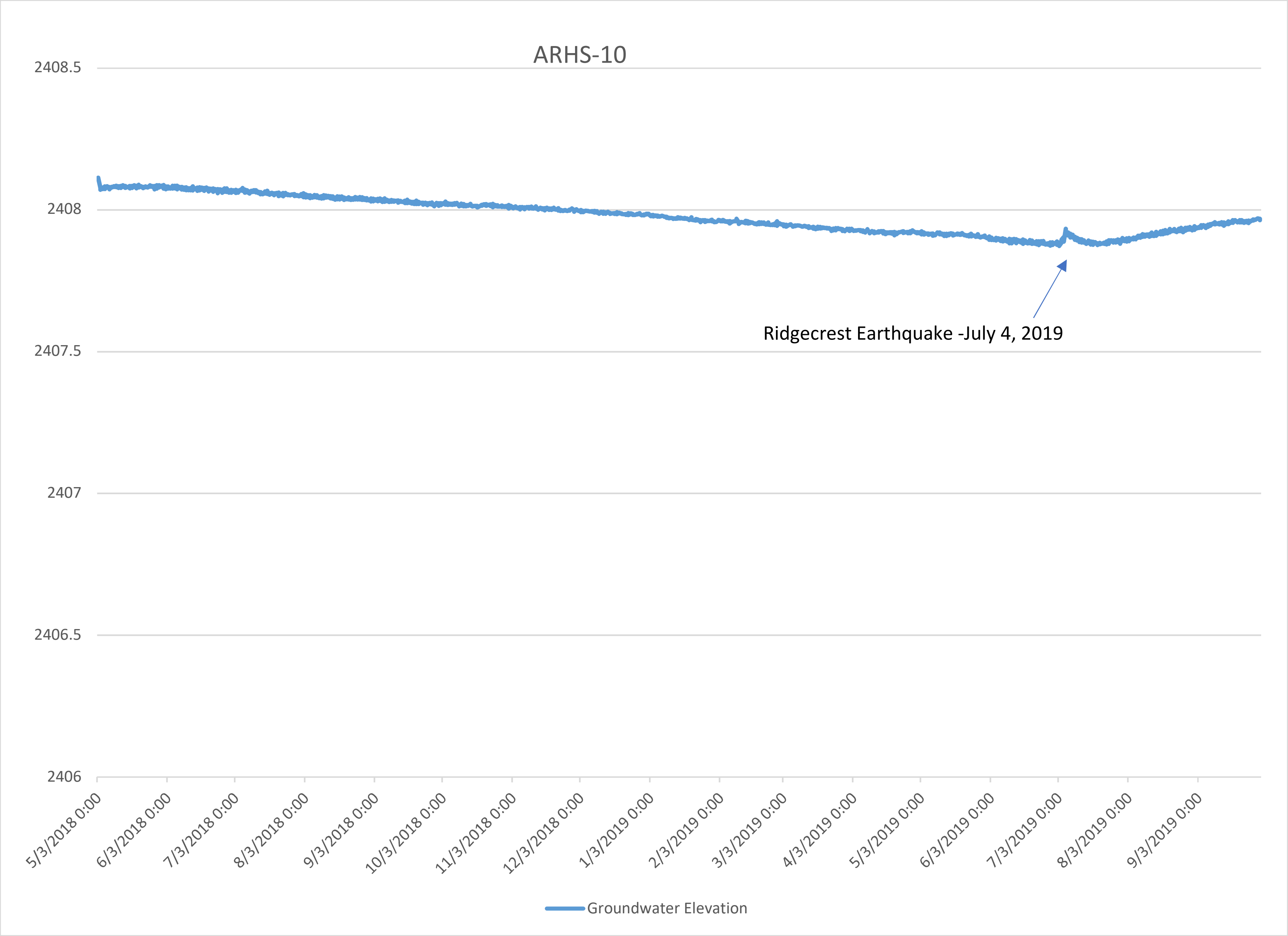


2,062.0
2,061.5
2,061.0
2,060.5
2,060.0
2,059.5
2,059.0
2,058.5
2,058.0
Groundwater Elevation (feet above mean sea level)
Mar-12
Aug-13
Dec-14
May-16
Sep-17
Jan-19
Jun-20
Measurement Date


ARHS-06 - Tule Well area
2290
2289
2288
2287
2286
2285
2284
2283
2282
2281
5/3/2018 0:00
6/3/2018 0:00
7/3/2018 0:00
8/3/2018 0:00
9/3/2018 0:00
10/3/2018 0:00
11/3/2018 0:00
12/3/2018 0:00
1/3/2019 0:00
2/3/2019 0:00
3/3/2019 0:00
4/3/2019 0:00
5/3/2019 0:00
6/3/2019 0:00
7/3/2019 0:00
8/3/2019 0:00
9/3/2019 0:00
Casing collapsed post May 2019
Series5


ARHS-08
1700
1699
1698
1697
1696
1695
1694
1693
1692
1691
1690
5/3/2018 0:00
6/3/2018 0:00
7/3/2018 0:00
8/3/2018 0:00
9/3/2018 0:00
10/3/2018 0:00
11/3/2018 0:00
12/3/2018 0:00
1/3/2019 0:00
2/3/2019 0:00
3/3/2019 0:00
4/3/2019 0:00
5/3/2019 0:00
6/3/2019 0:00
7/3/2019 0:00
8/3/2019 0:00
9/3/2019 0:00
Groundwater Elevaton
Linear (Groundwater Elevaton)


ARHS-9
2428
2427.5
2427
2426.5
2426
2425.5
2425
2424.5
2424
2423.5
5/3/2018 0:00
6/3/2018 0:00
7/3/2018 0:00
8/3/2018 0:00
9/3/2018 0:00
10/3/2018 0:00
11/3/2018 0:00
12/3/2018 0:00
1/3/2019 0:00
2/3/2019 0:00
3/3/2019 0:00
4/3/2019 0:00
5/3/2019 0:00
6/3/2019 0:00
7/3/2019 0:00
8/3/2019 0:00
9/3/2019 0:00
Groundwater Elevation
Linear (Groundwater Elevation)
Ridgecrest earthquake - July 4, 2019


ARHS-10
2408.5
2408
2407.5
2407
2406.5
2406
5/3/2018 0:00
6/3/2018 0:00
7/3/2018 0:00
8/3/2018 0:00
9/3/2018 0:00
10/3/2018 0:00
11/3/2018 0:00
12/3/2018 0:00
1/3/2019 0:00
2/3/2019 0:00
3/3/2019 0:00
4/3/2019 0:00
5/3/2019 0:00
6/3/2019 0:00
7/3/2019 0:00
8/3/2019 0:00
9/3/2019 0:00
Ridgecrest Earthquake -July 4, 2019
Groundwater Elevation