Subsurface Hydrogeologic Investigation of the Superstition Vistas Planning Area, Maricopa and Pinal Counties, Arizona

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Subsurface Hydrogeologic Investigation of the Superstition Vistas Planning Area, Maricopa and Pinal Counties, Arizona

Drilling operations at Exploratory Boring A2. View to north with Superstition Mountains in background.

July, 2017

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A USB flash drive accompanies the physical copy of the report and includes digital PDF files of the report, tables, figures, plates, appendices and GIS data. GIS data includes layer, raster and shapefiles for the alluvial unit boundaries.

EXECUTIVE SUMMARY

This hydrogeologic report describes a Phase-II study to investigate and characterize groundwater resources in the southeastern East Salt River Valley (ESRV) area, referred to as the Superstition Vistas Planning Area (SVPA), located primarily in the Phoenix Active Management Area (AMA) and a small portion of the Pinal AMA in northern Pinal County. This study follows a Phase-I reconnaissance study conducted by SRP during 2013 and 2014, which initially set out to estimate groundwater storage and determine geologic and hydrogeologic characteristics in SVPA.

The main objectives of this study were to define hydrogeologic unit and boundary conditions, determine aquifer characteristics, and establish baseline water quality for sustainable groundwater supply and recharge potential. New subsurface data were collected through drilling, seismic analysis and aquifer testing in SVPA. Tasks to analyze and interpret drilling and seismic data were performed by Arizona Geological Survey (AZGS), in partnership with Salt River Project (SRP). AZGS subcontracted with University of Arizona (UA) Reflection Seismology Research Group to complete processing, calibration and analysis of vintage seismic data. This investigation was funded by SRP, Arizona Department of Water Resources (ADWR), and Resolution Copper (RC) with in-kind contributions from the Arizona State Land Department (ASLD) and Arizona Water Company (AWC) and with technical support from regional stakeholders, participating agencies and water planners collectively referred to as the Technical Working Group. The Technical Working Group consisted of SRP, ASLD, ADWR, AZGS, AWC, U.S. Bureau of Reclamation (USBR), and RC.

A total of six exploratory borings were drilled in SVPA during 2016. One of the borings was developed into a 12-inch diameter well used to conduct aquifer testing in a previously untested area. Each exploratory boring was logged using a variety of geophysical survey tools to characterize lithology, mineralogy, particle-size distribution and geophysical character. Designation of alluvial unit boundaries were also made following these analyses. These new borings represent the most thorough analysis of the subsurface geology in SVPA to date. All data were used to compile depth-to-unit boundaries and isopach maps for the Upper Alluvial Unit (UAU), Middle Alluvial Unit (MAU), and Lower Alluvial Unit (LAU). The UA seismic reflection group processed six (6) new vintage seismic reflection lines that crisscross SVPA, calibrated from four of the borings. Application of seismic reflection imagery in this study was especially useful and improved the structure and geometry of bedrock in many, but not all areas of SVPA. Aquifer testing and zonal water quality sampling was conducted at Test Well B2a in a previously untested area. Aquifer testing was also performed at one ASLD well and two AWC wells.

The following is a summary of conclusions resulting from a combination of previous studies, new drilling, new analysis of vintage seismic-reflection lines, and new aquifer testing in SVPA:

- Depth to bedrock, and saturated thickness, were significantly increased throughout SVPA, especially along bedrock piedmonts adjacent to the Superstition Mountains and Mineral Mountains. At each of the five new borings and one test well (where bedrock was encountered) the depth to bedrock increased 400 to 1,800 ft below land surface (ft-bls) beyond previous estimates. Discrepancies between these findings and previous depth-to-bedrock determinations are believed to be due to the lack of well data-calibration and under-estimation of the areal extent of a thick and partially consolidated basalt-basin-fill sequence associated with the LAU.
- The thickness and extent of the LAU was significantly increased throughout SVPA as a result of drilling and interpretation of seismic data. The presence of multiple faults related to the Elephant Butte fault, which offset and tilt LAU deposits and bedrock, were

confirmed in the Far West area thus complicating the basin structure in the eastern portion of SVPA. The base of the LAU (bedrock) was significantly revised based on these new findings. Interpretation of a significantly deeper alluvial basin in southern portion of SVPA and potential extension/connection of the LAU aquifer south of the Gila River into the northern Picacho Basin in the Pinal Active Management Area (AMA) is suggested.

- The piedmont between Hawk Rock and Florence Junction, the Superstition Mountains piedmont, represents a relatively uniform erosional piedmont averaging 400 to 1,000 feet thick, with localized subsurface paleo-topography, consistent with similar conclusions made by Warren (2009) along the Santan Mountains piedmont.
- The UAU and MAU could not be successfully defined from seismic reflection imagery. However, detailed lithologic, mineralogic and geophysical logging provided a basis for determining hydrogeologic boundaries for these units. Depth-to-unit maps and isopach maps were updated throughout SVPA. Depth to water estimated from sonic logs and measured at the new Test Well B2a show the UAU to be mostly dry and the MAU partially saturated.
- Mineralogic analyses from each boring significantly aided in characterizing at least three distinct sedimentary and mineralogical facies in SVPA, and significantly improved understanding of basin evolution with regard to Queen Creek and its tributaries.
- Aquifer testing at Test Well B2a was successfully completed, resulting in an average transmissivity of 9,832 gallons per day per foot (gpd/ft) and specific capacity of 4.2 gallons per minute per foot (gpm/ft). This specific capacity correlates well with the final reported specific capacity of 3.83 gpm/ft for Apache Junction Well No. 6, located approximately 6 miles north-northwest of Test Well B2a. The similarity in specific capacity values suggests the presence of similar, relatively homogenous aquifer characteristics between Test Well B2a and the Apache Junction Well. Zonal water quality sampling in Test Well B2a revealed good water quality overall.
- Transmissivity was found to be greatest in the center of the SPVA near Queen Creek Wash, decreasing to the north and south of the wash. Transmissivities in the area south of Queen Creek Wash tend to be higher than to the north of the wash.
- Newly interpreted LAU in the Far West area is likely “hydrogeologic bedrock” based on aquifer test results for wells in this area.
- Water sampling results suggest that groundwater in the study area is subject to a number of different recharge sources and flow paths for the northern and southern parts of the study area; overall, the groundwater quality from the wells sampled within the SPVA appears to be good.

Results from this study greatly improved the understanding of the geology and hydrogeology in SVPA. Many areas of investigation remain untested or lack sufficient data to permit a more robust characterization of hydrogeology at depth and in data-deficient areas. In order to provide additional characterization, potential areas of future investigation have been proposed.

Acknowledgements

This study was made possible through the support of the members of the Technical Working Group, including SRP, Arizona Department of Water Resources (ADWR), Arizona State Land Department (ASLD), Bureau of Reclamation (BOR), Arizona Water Company (AWC), and Resolution Copper (RC). This group collectively provided direction on key aspects of this Phase II investigation, namely the siting of exploratory borings and test wells and the proposed drilling program. Special thanks to Bob Harding (ASLD), who was instrumental in obtaining site access to drill the exploratory borings and test wells on State Trust land; special thanks to Jersy DePonty for field oversight of the exploratory boring and test well drilling and testing operations; SRP Groundwater Resources staff for providing project coordination and oversight; Jim Kudlinski (SRP Environmental Services) and Rick Anduze (SRP Biological and Cultural Resources) for assistance with the necessary AZPDES permits and archaeological clearances, respectively; Desert Archaeology, working under the direction of SRP, for their Archaeology survey report. This study was financially supported by SRP, a grant from the ADWR Water Management Assistance Program, and by Resolution Copper.

The following individuals or groups are recognized for their contributions to the findings and improved understanding of the geology and aquifer characteristics of the study area: AWC (Richard Hacker and Fred Schneider) for providing aquifer test data on two AWC wells in the eastern portion of the study area to fill data gaps in that region and Clear Creek Associates for data analysis and reporting. SRP Groundwater Resources staff (Walker Milici and Shuyun Liu) for collecting aquifer test data on one ASLD well and for data analysis and reporting. Steve Skotnicki (Independent Consultant) and the ASU/SRP Joint Research Program Group: Jersy DePonty (SRP), Bob Pane (SRP), Ron Dorn (ASU), Matthijs C. van Soest (ASU), and Yeong Seong (Korea University) for an independent mineralogical analysis of the exploratory borings and test well and for valuable insights on the evolution of the Queen Creek drainage. Heather Gluski (Resolution Copper) for her expertise and sharing of data and information on RC well drilling and testing in the Far West area. The AZGS team (Brian Gootee, Joe Cook, Jeri Young, Charles Ferguson, Randi Bellassai, and Phil Pearthree) and Professor Roy Johnson and graduate students (Saba Keynejad and Dominik A. Kardell) of the University of Arizona for countless hours analyzing borehole data and reprocessing and calibrating vintage seismic lines to improve our understanding of the geologic framework within the Superstition Vistas area. Arizona Department of Transportation Construction and Materials Group provided professional, timely and courteous support and sieving analysis following completion of each boring.

In preparing this report, thanks to SRP Groundwater Resources staff for the write-up of Section 5.0 and to SRP Cartographics (Brian Skerven) for preparing some of the maps used in this report; Bob Harding and SRP Groundwater Resources staff for critical review and comments on the initial draft; and the entire Technical Working Group for their review of the final draft report.

1.0 Introduction

This hydrogeologic report represents an ongoing effort by Salt River Project (SRP), Arizona State Land Department (ASLD), Arizona Department of Water Resources (ADWR), Bureau of Reclamation (BOR), Arizona Water Company (AWC), and Resolution Copper (RC) to investigate and characterize the groundwater system in East Salt River Valley (ESRV), Superstition Vistas Planning Area (SVPA) in northern Pinal County (Figure 1 and Plate 1). The SVPA area of interest is largely undeveloped land owned by ASLD, and is also situated within the SRP Power Service Area. Due to the lack of development and proximity to the Phoenix metropolitan area, the SVPA has been identified as an area of future growth. This investigation represents a Phase-II exploratory effort to characterize the geologic and hydrogeologic framework in the SVPA, estimate depth to bedrock, define aquifer units, delineate aquifer properties, and establish baseline groundwater quality for sustainable groundwater supply and recharge potential, thus to assess groundwater adequacy and availability for the future management of existing groundwater resources. This investigation was funded by SRP, with a grant from the ADWR Water Management Assistance Program, financial support from Resolution Copper, in-kind contributions of ASLD and AWC, and technical support from all TWG members.

This Phase-II study and report follows a Phase-I reconnaissance study conducted by SRP in collaboration with TWG members ASLD, ADWR, AWC, and BOR during 2013 and 2014 (SRP, 2014), initially set out to estimate groundwater storage and determine the geologic and hydrogeologic characteristics in SVPA.

The purpose of this Phase-II investigation was to collect additional subsurface data through drilling, seismic analysis and aquifer testing in SVPA. Four tasks were proposed in Phase II and they are listed below:

Task 1 – Aquifer Testing at Existing ASLD and AWC Wells

Task 2 – Exploratory Borehole and Test Well Siting Evaluation

Task 3 – Exploratory Borehole Drilling and Test Well Installation

Task 4 – Geophysical Data Interpretation

Aquifer testing at the ASLD well (i.e., Queen Creek Pit Well) was performed by SRP in collaboration with ASLD. Aquifer testing at the two AWC wells was conducted by Clear Creek Associates on behalf of AWC. Results of Task 1 aquifer testing are summarized in Section 5 of this report, and the individual aquifer test reports can be found in Appendices F & G with this report.

The majority of this report documents the collection and analysis of subsurface data through drilling, seismic analysis, and geologic data interpretation proposed in Tasks 2 through 4 (Sections 2-4 of this report). SRP coordinated and provided oversight of the exploratory borehole and test well drilling activities performed by Yellow Jacket Drilling (YJD), contractor by SRP. A well completion report for Test Well B2a is included as Appendix H. The Arizona Geological Survey (AZGS) was contracted by SRP to collect and analyze subsurface data, define hydrogeologic unit and boundary conditions, estimate depth to bedrock, and improve our understanding of the alluvial basin structure of the SVPA area. AZGS' work included three main steps:

1. Collect, identify and analyze borehole data from six exploratory borings in SVPA.
2. Process and analyze vintage seismic-reflection surveys, calibrated to new exploratory borings drilled during this study, for the purpose of developing image

basin-fill stratigraphy, bedrock and structure, under an AZGS sub-contract with the University of Arizona.

3. Integrate new borehole data and post-processed vintage seismic data with existing datasets, cross-sections, and models to identify thickness, extent and boundary of hydrogeologic units and depth-to-bedrock (DTB) in SVPA.

Steps 1 and 3 were performed by AZGS, in partnership with SRP. AZGS subcontracted with University of Arizona Reflection Seismology Research Group to complete Step 2. List of wells and borings is summarized in Appendix A. Geophysical logs and other borehole data are provided in Appendix B. Cross-sections and photographs are given in Appendices E and I, respectively.

2.0 Borehole Data and Analysis

2.1 Site Evaluation and Selection

A total of four exploratory borings and two test well sites were evaluated in SVPA to refine or explore depth to bedrock and aquifer characteristics (Figure 1 and Figure 2). Areas of interest within SVPA were defined by SRP and the Technical Working Group based on data gaps, distribution and quality of other subsurface data (aquifer tests, gravity, and seismic). Areas and sites chosen for further investigation are shown in Figure 3. A large factor in the site selection process was proximity to the location, availability and quality of vintage seismic survey lines. AZGS and UA conducted localized seismic data and analyzed basin-wide vintage seismic data in 2007-08 (AZGS, 2008) with limited success, largely due to the lack of available well data and borehole geophysical data necessary for calibrating seismic velocity-depth.

One of the major aims of this project was to combine new well drilling and borehole geophysics with vintage seismic lines. Roy Johnson, project leader with UA seismic group, originally evaluated the location and quality of seismic data to determine which lines would benefit most from utilizing new borehole data. Based on information from each area, specific target sites within each area were categorized and ranked by priority. SRP and ASLD reviewed each site for access, logistics and permit constraints, including contingency sites. The final exploration borehole and test well sites were determined by SRP and the Technical Working Group (Table 1).

2.2 Sample Collection and Analytical Methods

Sample collection from the exploratory borings was an integral component of this project. Samples were used for lithologic identification, mineral identification, and sieve analysis. Borehole samples were collected during drilling at 10 foot intervals throughout the borehole as part of a direct-flow drilling method, below the hopper-sand cone assembly, a well-tested method of sample collection.

Drilling and sample collection was performed by Yellow Jacket Drilling (YJD) and supervised by a SRP geohydrologist. Samples were then collected by SRP and AZGS. Two sets of chip trays were collected, one each by SRP and AZGS. Additional samples were collected for isotopic analysis by ASU as part of a separate grant study to determine age and provenance of sediments (Skotnicki et al., 2016). Overall, the sampling methodology was found to yield returns considered representative of the formations encountered. Out of the six boreholes drilled during the investigation, samples from only a few 10-ft intervals were not collected or damaged in the sampling process. These intervals are noted in the borehole logs.

Samples collected from the exploratory boreholes are stored at various locations. The majority of samples are stored with AZGS. SRP retained one set of chip trays from each borehole. The type of samples and storage location are listed in Table 2.

2.2.1 Lithology Analysis

Lithology for each boring was recorded by AZGS. Samples for both chip trays and sample bags (Hubcos) were collected from cutting piles. Cutting piles were taken from below the hopper-sand cones and laid on tarp mats by YJD. Although the majority of particle sizes were represented using this method, a minor portion of the silt- and fine-sand sized particles were recirculated back into the mud system. The chip tray samples were primarily used to describe lithology, supplemented by additional cuttings from the tailing piles and Hubco bags. The United Soil Classification System (USCS) was used to classify the size and percent

lithology. A Munsell soil color chart was used to describe sample color when wetted with a mister. Ten percent diluted hydrochloric acid was used to test for reactivity as an indication of carbonate content.

2.2.2 Mineral Analysis

Drill cutting samples of rocks and minerals large enough to be identified were estimated qualitatively or counted quantitatively. This process is referred to as mineral analysis and was done for samples from each borehole as an additional tool for comparison and possible correlation to rock types and known geologic units mapped at the surface. It is a time consuming process and requires significant experience. This method is a valuable tool for understanding the history of erosion and deposition at the drilling site, near adjacent wells, watershed to the site, and a better understanding of basin evolution.

A qualitative relative percent analysis of the cuttings was conducted by Brian Gootee (AZGS) during and following completion of drilling. A quantitative weight percent analysis was conducted by Dr. Steven Skotnicki after completion of the borehole. Steve Skotnicki's analysis was done independently because he has been using his analytical methods in the ESRV for many years prior to this study, in addition to having personally mapped much of the bedrock that borders SVPA.

Coarse sand (larger than 1mm) and gravel samples were used to identify minerals and lithic rock types. The smaller the particle the more difficult and challenging it is to identify the original rock or mineral type. Samples for this analysis were collected from directly below the Hopper during drilling or alternatively from the cutting piles. A second set of Hubco bags were set aside for Steve Skotnicki's mineral analysis. Each sample was sieved through a 1/16-inch strainer. The coarse (retained) fractions were then allowed to air dry and bagged in Ziploc bags labeled with Well ID, Sample type and Sample depth. Mineral and rock identification evaluations were performed with either a hand lens or microscope. The semi-quantitative method done by Brian Gootee estimated the relative percent of the different minerals and rock types encountered in the borehole (e.g. granite, quartz, quartzite, felsic volcanics, etc.). Degree of rounding, size, rare grains, or any other aspects of the sample were also noted. The results were then tabulated in spreadsheet form and plotted. Results and interpretations from both methods are summarized in a later section of the report, and for each borehole in Appendix B.

2.2.3 Sieve Analysis

Samples were also collected for particle size (sieve) analysis. Arizona Department of Transportation (ADOT) performed the sieve analyses using ASTM Method 204. Sieve intervals were determined by SRP and AZGS based on the samples and initial electric log, typically in the field during geophysical logging. Sieve samples typically consisted of composited samples covering a texturally homogenous interval in the borehole, however, depending on other characteristics such as drilling penetration rate and mineralogical difference, sieve intervals were also designed to represent these breaks. Sieve intervals were not collected in intervals considered to be bedrock. All sieve data are listed in Appendix B.

2.3 Borehole Geophysics

Borehole or wireline geophysical logs were collected for each exploratory boring by Southwest Exploration Services. Each borehole was logged with a different suite of geophysical tools depending on borehole diameter and the material encountered. A complete list of geophysical logs performed at each borehole are listed in Appendix A. All geophysical logs are

displayed for each borehole in Plates 3 through 8. Selected geophysical logs were also included in the borehole log sheets (Appendix B).

2.4 Designation of Hydrogeologic Units

Interpretation of designated alluvial units, their thickness, boundaries, extent and physical and chemical characteristics was a major objective in this study. Hydrogeologic units in the ESRV area have been studied since the mid 1970's. The currently accepted nomenclature for hydrogeologic basin-fill units is from Corkhill et al. (ADWR, 1993). Since then additional investigations have been performed in the study area, including the activities described herein. For the purposes of this investigation the ADWR unit-nomenclature has been used, however, much about the spatial and temporal (age) constraints that bound each unit remain poorly or inadequately understood in terms of a finite basin model. A summary of previous studies and nomenclature, including descriptions for each hydrogeologic unit are presented in Table 3.

Thicknesses and extent of alluvial units varies throughout the alluvial basin, and criteria for determining alluvial unit boundaries were generally based on grain size distribution, degree of compaction, and degree of cementation. In the case of the Lower Alluvial Unit, the presence of basalt flows interbedded with sediment is considered diagnostic of this unit in many parts of the SVPA. Distribution of grain mineralogy has not generally been used to determine alluvial units although such an analysis was found to be helpful in determining history and evolution of basin-fill and valley-fill sedimentation. Geophysical logs coupled with lithology and mineral logs were especially useful in defining stratigraphy. Application of seismic line data across areas near boreholes were used primarily to define depth, structure and shape of basin-fill strata and bedrock. All available data were relied upon to determine hydrogeologic unit boundaries and relationships with each other and with bedrock. Characteristics, age and nomenclature of alluvial and bedrock units are summarized in Table 3.

2.5 Summary of Borehole Analyses

During this investigation, five exploratory borings and one test well were successfully completed within the SVPA, shown in Figure 2 and Plate 1. A summary of well characteristics are listed in Table 1. A summary of findings, data, analyses, problems encountered, interpretations, conclusions and implications for future investigations are discussed for each borehole in the following sections and are intended to accompany and expand upon the borehole log data compiled in Appendix B. An abbreviated summary of contacts and boundaries determined for each borehole, including revised boundaries and recommendations for further investigation are listed in Table 4.

2.5.1 Exploration Borehole A1

Boring A1 was chosen to resolve discrepancies in depth to bedrock between modeled gravity (ADWR, 2013) and bedrock possibly encountered in nearby existing wells. The area evaluated was a northwest-southeast trending 'gravity low' located between US Hwy 60 and the base of the Superstition Mountains. Several vintage seismic lines also cross the area of A1, therefore, this location anticipated strong calibration for analyzing seismic data.

Boring A1 was successfully drilled through sediments into bedrock (schist) at a depth of 946 ft below land surface (bls), approximately 646 ft lower than estimated depth to bedrock (DTB) (ADWR, 2013) (see DTB in Figure 3). Sediments encountered in A1 generally consisted of sand and silty sand with minor gravel and clay (Appendix B, borehole log and sieve data).

Mineralogy in this borehole consisted of primarily schist, granite and felsic volcanic clasts (Appendix B). Percentages of schist decreased up-section while felsic volcanic and granite constituents tended to increase. Percent quartzite appeared to remain the relatively constant. Grain size versus mineral content may be a factor in preservation of minerals (i.e. granite may be too small or too disaggregated to identify in silt-rich sands). Quartzite and schist clasts were noticeably more well-rounded than other types. Due to the relative homogeneity of mineralogy in A1, the base of the basin-fill sequence from 880 to 940 ft-bls overlying bedrock was targeted for further analysis (as part of a separate study, Skotnicki et al., in progress) to determine the age of deposition.

Geophysical logging successfully measured physical properties of sediment and bedrock in A1. Density and 4x sonic-receiver data were successfully calibrated to seismic lines, discussed later. The Acoustic Televiewer Log (ATV) was able to identify oriented fractures in bedrock which aided in determining the bedrock contact. Depth to water was estimated from sonic logging to be 540 ft-bls.

Each alluvial unit was identified in boring A1 based on criteria typically used to determine properties and boundaries between alluvial units across the ESRV. In A1 the lithology and mineralogy did not change significantly, however, density, sonic and electric logs did reveal breaks in the basin-fill sequence correlated to represent hydrogeologic boundaries. At A1 the UAU is estimated to be approximately 270 ft thick consisting of sand and silty sand with minor gravel. The MAU is estimated to be approximately 310 ft thick, ranging from 270 to 580 ft-bls, consisting of primarily silty sand with minor clay. The LAU makes up the remainder of sediment in A1 between 580 and 946 ft-bls, comprised mainly of silty sand. Fractured Pinal Schist was encountered for the remainder of the borehole down to total depth (TD) at 1045 ft-bls.

2.5.2 Exploration Borehole A2

Similar to A1, boring A2 was also located in the gravity low to resolve discrepancies in DTB (Figure 3). Two seismic lines intersect at site A2 and provide potential stratigraphic-control to site A1.

Boring A2 penetrated bedrock interpreted as Tertiary conglomerate at 588 ft-bls and schist basement was encountered at 704 ft-bls, and continued to TD at 824 ft-bls. Potential tilting of Tertiary conglomerate was not observed. DTB was previously estimated to be approximately 200 ft-bls (ADWR, 2013) and thus DTB was increased approximately 400 additional feet. Borehole log data for A2 is listed in Appendix B. Sediments in boring A2 generally consisted of medium to coarse sand and gravelly sand with minor silt and clay (Appendix B, borehole log and sieve data).

Mineralogy of cuttings in A2 were significantly different from A1, consisting of three to four distinct assemblages (Appendix B, mineral analyses). The upper 360-370 ft of A1 consisted of predominantly felsic volcanics and granitic clasts assemblages. Between 380 and 588 ft-bls clasts consisted primarily of schist and quartzite. A third assemblage between 588 and 660 ft-bls exhibited a mix of mineral assemblages different from the upper two assemblages. Mineral analysis by Steve Skotnicki evaluated cuttings from 660 ft-bls and concluded they were almost entirely Pinal schist type. Mineral analysis by AZGS observed more variety in the cuttings at this interval. Based on the other logs, especially gamma, density and resistivity, it was determined that the conglomerate/schist contact could possibly be at 620 ft-bls. Regardless, the favored interpretation for bedrock remains at 588 ft-bls in Tertiary conglomerate, which may be equivalent to the “Red Unit”. Below 700 ft-bls Pinal schist was encountered to TD. As part of a separate study (Skotnicki et al., in progress), the interval from 530 to 580 ft-bls was sampled for geochronologic dating. The basin-fill sequence above 588 ft-bls is believed to represent two

different watersheds, possibly related to stream capture from Coffee Flats in the Superstition Mountains to the A2 site. Red clay between 588 and 630 ft-bls is interpreted to represent weathered bedrock based on a lower degree of consolidation and density, thus constituting an unconformity. The contact between the Tertiary conglomerate and schist is less certain and may represent either an unconformity or be fault related.

Geophysical logging correlated fairly well with lithology and mineralogy. Density logging identified breaks around the mineralogy break identified at 380 to 400 ft-bls. This may represent an unconformity between two types of sediment. Most logs identified the bedrock contact at around 590 ft-bls. Depth to water was estimated from sonic logging to be 320 ft-bls.

Based on density and lithology, the base of the UAU was initially determined to be 270 to 280 ft-bls, which upon subsequent development of the UAU contour map, was raised to be between 220 to 240 ft-bls. The base of the MAU is estimated to be around 400 ft-bls, where drilling rate and density increased, and resistivity decreased. It is unclear whether this MAU/LAU boundary pick is associated with the mineralogical change observed near 380 ft. The bedrock, base of LAU, was identified at 588 ft-bls.

2.5.3 Exploration Borehole C1

Boring C1 was chosen to investigate discrepancies in depth to bedrock derived from gravity (ADWR, 2013), and similar uncertainty in bedrock depth based on driller's logs from two AWC wells approximately 2 mi northeast of C1, and also to determine the thickness of deposits associated with the Queen Creek watershed in the northern SVPA. Two vintage seismic lines terminate near site C1 thus making this site a valuable control point and calibration for these lines.

Boring C1 was successfully drilled through basin-fill sediments into bedrock (rhyolite flow) at a depth of 1,455 ft-bls, 705 ft lower than the 750-ft-bls modeled DTB (ADWR, 2013) (see DTB in Figure 3). Characterization of the basin-fill sequence in C1 was especially challenging and difficult for several reasons discussed in this section.

Sediments encountered in C1 overall consisted of sand and gravel with relatively minor clay and silt (Appendix B, borehole log and sieve data). The upper 380 ft-bls in C1 was notably coarser and overlaid finer-grained clayey sand and sand. From 380 to approximately 1,100 ft-bls the lithology consisted of a relatively homogenous, sand with minor silt and clay. Drilling times progressively increased (drilling rate slowed) (Appendix B, penetration rate graph for C1). From 1,100 to 1,455 ft-bls drilling times increased even more, as if bedrock conglomerate was being drilled; however, mineralogy and lithology stayed relatively uniform. This interval was interpreted to represent a basin-fill sequence, and based on the compaction and degree of cementation, has been interpreted to represent a moderately-well cemented LAU. A very hard rhyolite flow was encountered at 1455 to 1,540 ft-bls.

Mineralogy in C1 was remarkably uniform, verified independently by AZGS and Steve Skotnicki (Appendix B, mineral analyses). Mineral assemblages throughout C1 from 0 to 1,455 ft-bls consisted of nearly equal portions, of Pinal schist, quartzite, quartz and felsic volcanics, confirming the presence of a thick facies assemblage believed to be sourced from a watershed similar to the modern Queen Creek. Similar to the quartzite and schist observed in A1 and A2, these lithologies were notably more rounded than other lithologies. Felsic volcanics represented the largest size fraction, although this may have been skewed by the sampling methodology. The base of the coarse fraction in C1, 0-380 ft-bls, is interpreted to represent relatively recent deposits from Queen Creek across a bedrock ridge between Queen Valley and C1. Samples were collected from the base of this coarse-grained interval from 320 to 380 ft-bls for geochronologic analysis (Skotnicki et. al., in progress).

GIS analysis of the Queen Creek watershed upstream from C1 was performed in order to evaluate the rock types and distribution of map units at the surface (Appendix B, watershed map, distribution pie chart). Using the ArcMap Extract tool, geologic map units in the Queen Creek watershed were extracted from the watershed area to quantify the percentage of geologic units exposed at the surface. Map data were obtained from a recent compilation by Pearthree et al. (2015). This was successful in showing a general correlation of abundance of mineral assemblages in C1 with units exposed in the watershed. Older Tertiary sedimentary rocks are also exposed upstream and may have contributed to secondary “contamination” of clasts in these deposits. A point count of clasts in the Queen Creek channel located immediately west of C1 revealed a similar distribution of rock types and minerals observed in C1 and in the Queen Creek watershed (Appendix B, “clast count in modern Queen Creek”, from unpublished work related to Pearthree et al., 2015).

A robust suite of geophysical logs were performed in C1. Although the electric logging tool successfully reflected changes in resistivity, for reasons still unclear, the magnitude of the readings were unusually low throughout the borehole, despite confirmation that the resistivity tool was properly calibrated. Even the rhyolite flow below 1,455 ft-bls registered below 100 ohms per meter (ohm-m), when a typical response would be several hundred ohm-m. Depth to water was determined from sonic log to be at 660 ft-bls. Density in C1 was subtly uniform (Appendix B, borehole log). The lowest density was recorded in the upper 300 ft-bls, and the highest below 1,455 ft-bls. Density in the basin-fill sequence below approximately 300 ft-bls ranged from 2.1 to 2.15 gram per cubic centimeter (g/cm^3) compensated density. Although that is a narrow range, density readings were reevaluated to plot a 10-ft moving average, and based on this plot at least three subtle yet distinct intervals could be identified, 300 to 600 ft-bls, 600 to 1,100 ft-bls, and 1,100 to 1,455 ft-bls (Appendix B, density log only). Somewhat counterintuitively, the lowest of these three density plots was from 1,100 to 1,455 ft-bls, the interval with the slowest penetration rates, possibly due to a higher degree of cementation. An acoustic televiewer log was run between 1,185 ft-bls and 1,540 ft-bls to capture structural aspects of the borehole such as fractures, texture, bedding planes and joints. Southwest Geophysical Services performed statistical analysis on these features (presented in Plate 5). For the interval between 1,186 ft-bls and 1,350 ft-bls these deposits are interpreted to be clastic, gravel-dominated deposits with bedding planes dipping between approximately 20 and 55 degrees. The average dip direction was about N90E. Few fractures were observed in this interval. For the interval between 1,350 and 1,455 ft-bls bedding planes were similarly scattered with low to moderate dip amounts of 15 to 50 degree, and orientation averaging N25E. Fractures were also notably infrequent in this interval. Below 1,455 ft-bls there were abundant moderate to high-angle (50-60 degrees) open- and closed-fractures with a predominant N45E dip direction. The preferred interpretation of the observed fracture orientations are that they represent dense antithetic fractures opposing a SW-dipping fault. Other geophysical logs exhibited typical records for the material encountered.

Given the significant thickness of basin-fill material interpreted to have been derived from the same watershed, and in close proximity to exposed bedrock, determining alluvial unit boundaries was especially difficult and relatively subjective when compared to unit boundaries present in boreholes closer to the basin center. The base of the UAU was chosen at 280 ft-bls, but may be as much as 380 ft-bls. The base of the MAU was estimated to be approximately 500 to 620 ft-bls. The LAU was not divided into upper or lower units and is interpreted to unconformably overlie (rhyolite) bedrock at 1,455 ft-bls.

2.5.4 Exploration Borehole C3a1

Site C3a1 was chosen to determine DTB in a largely devoid and data-deficient area of ESRV (Figure 3). Seismic line PW2 connects site C3a1 with site C1 and this further supported the location of borehole C3a1 for purposes of calibration and potential correlation. DTB was estimated from gravity data to be between 800 and 1,600 ft-bls (ADWR, 2013).

Boring C3a1 penetrated basin-fill sediments from 0 to 620 ft-bls and encountered interbedded basalt and cinder between 620 to 941 ft-bls (total depth (TD)). The upper 620 ft-bls of sediment consisted of sandy silt, silty gravelly sand with some beds of clayey sand. Notable breaks in lithology and density were observed to occur around 120 ft-bls, 290 ft-bls, and 620 ft-bls. Drilling through basalt flows was very slow (9 to 50 min/ft), while drilling through cinder-rich beds comparatively was fast (3 to 10 min/ft).

Mineralogy in C3a1 is exemplified by Steve Skotnicki's findings of three distinct assemblages. The upper assemblage is dominated by Pinal schist and quartz, although the base of this assemblage is not well constrained. Based on lithology this break may lie around 120 ft-bls. The second assemblage consisted of uniform percentages of felsic volcanics, quartzite, granite and quartz, and notably only a very low percentage of basalt. AZGS qualitative mineral analysis supported a similar conclusion if feldspar and granite were lumped together. The mineralogy below 620 ft-bls consisted largely of basalt and cinder. The interval below 620 ft-bls to the TD of the borehole was carefully scrutinized for the presence of sediment interbedded with basalt/cinder, criteria used to characterize the LAU (see Table 3). The small fraction of other lithologies present in the samples was confirmed to be due to contamination from overlying units after the ATV confirmed the presence of solid basalt flows and washout zones around 80 ft-bls, 130 to 380 ft-bls, 640 ft-bls, and 690 ft-bls. These washout zones were a major concern and source of fluid loss during drilling.

Despite the significant loss of fluid during drilling in site C3a1, geophysical logging was very successful. Caliper, density and sonic logs showed significant washout zones. Temperature was relatively uniform to 585 ft-bls and then increased notably from approximately 26^0C to 30^0C (78^0F to 86^0F) in basalt and cinder beds. Resistivity and 4x-sonic logs corresponded well with basalt flows (high resistivity) and cinders (low resistivity). Depth to water was derived from the sonic log to be 523 ft-bls. Gamma log results varied from basalt flow to basalt flow. The ATV log showed some bedding dips and directionality in the basin-fill sequence, but were mostly low-angle with no identifiable pattern. Basalt flows were moderately fractured with moderate dips at various angles, yet no discernable orientation was evident.

Based on lithology, the base of the UAU was interpreted to be at between 290 and 300 ft-bls. The differences in mineralogy observed from near the surface to approximately 120 ft-bls may represent a change in watershed and source area for the alluvial material underlying site C3a1 via stream capture away from ESRV to the Gila River. This capture most likely happened after deposition of the LAU. In C3a1, the interval between 120 ft-bls and 620 ft-bls is thought to be derived from transport of source material from this pediment. To test this interpretation two alternative watershed maps were created to "restore" the un-captured watershed to the depositional environment at C3a1 (Appendix B, modern and extended watershed maps). The percent exposure of map units reveals that an extended watershed map to the south and east captures granitic source areas, which is seen in the formation samples at C3a1 below 120 ft-bls, but not above. Thus, the extended watershed map area is the favored explanation for the material found at C3a1 between 120 ft-bls and620 ft-bls. The base of the MAU is interpreted to be unconformable with the basalt and cinder layers in C3a1 below 620 ft-bls. The basalt is interpreted from logging to be weathered between 620 and 628 ft-bls. Because basalts in this area are relatively young, Pliocene in age, and to some degree morphologically preserved, the

basalt and cinder at C3a1 has been interpreted to represent the LAU sequence. Based on the four basalt flows and interbedded cinder identified in C3a1, this sequence has been interpreted as indicative of a cinder cone or flank of one, at least 320 ft thick. Gravity and seismic data both indicate a greater depth to bedrock in this area, thus depth to the base of the LAU and bedrock was not interpreted to have been encountered at C3a1. Based on seismic and gravity data the revised depth to bedrock at C3a1 is estimated to be around 3200 ft-bls.

2.5.5 Exploration Borehole A3a

Site A3a was chosen to evaluate a data-deficient area along Queen Creek near the center of SVPA, develop a test well and conduct aquifer testing. Site A3a would also assess the character of basin-fill sediments as they relate to a shallow bedrock margin to the east-northeast (Figure 3). Site A3a would provide useful information between seismic lines PW7 and PW3 even though it was not anticipated that bedrock would be encountered. The large diameter (14.75-inch) exploratory boring A3a was intended to be reamed to a larger diameter (20-inch) and converted to a test well as planned, however, due to plumbness and alignment problems the test well was not completed.

Boring A3a penetrated basin-fill sediments to the total depth of the well, 1,500 ft-bls. Overall basin-fill consisted of sand, silty sand and gravelly sand with minor clay. In general, A3a was found to be unusually coarse-grained throughout its depth and despite its location near the center of the basin. Mineralogy in A3a was relatively uniform, confirmed independently by AZGS and Steve Skotnicki (Appendix B, mineral analyses). Thus mineralogy supports the presence of a thick Queen Creek facies similar to observations in borings C1 and B2a. The AZGS mineral analysis did observe one interval rich in basaltic cuttings around 590 ft-bls. This correlated with a strong change in color between 590 ft-bls and 530 ft-bls. Mineralogy at 500 and the 600 ft-bls intervals did not show appreciable differences, so the most likely interpretation is that there was a brief change in the source area and watershed for the formation material underlying A3a. This may translate to a change in the position of Queen Creek before and after the deposits at 590 ft-bls, and may possibly correlate with an interval in boring C1 at a similar elevation not detectable from the log data. Another slight difference between the two mineral analyses is the presence of basalt cuttings identified by AZGS below 590 ft-bls to the TD of the borehole. Given this difference, the presence of basalt may indicate a difference in stratigraphy, but the source area for minerals comprising the formations underlying A3a are largely unchanged. If the apparent difference in mineralogy between 590 and 890 ft-bls is real, there are two potential source areas where basalt is known to exist in the subsurface. These source areas are the Mineral Mountain/Far West area and in the two AWC wells immediately northeast of Hwy 60. Because C1 lacked an obvious signature of basalt in its mineralogy, the favored interpretation for basalt in A3a below 590 ft-bls is a source area that includes, at least in part, a facies associated with the Mineral Mountain piedmont. Due to the absence of basalt flows in A3a, and low percentage of formation samples containing basalt, the interval at 590 ft-bls, down to possibly as low as 890 ft-bls, is believed to post-date volcanism associated with the LAU further southeast and possibly east, correlating to the late LAU or MAU in age.

Geophysical logging in A3a was successfully accomplished, despite the larger diameter exploratory borehole (14.75-in). Depth to water was determined from the sonic log to be at 488 ft-bls. Resistivity logs showed fairly consistent pattern of coarsening-upwards sequences, punctuated by finer-grained intervals. Gamma log response increased below 590 to about 850 ft-bls, which correlated with overall darker colored lithology (gray-brown), and an increase in percent basalt in formation samples (AZGS mineral analysis). Density log results were noticeably lower above 590 ft-bls (1.9 to 2.1 g/cm^3), yet uniform between 590 and 1,500 ft-bls

(2.1 to 2.2 g/cm^3). There was no indication that cementation or density showed significant change below 590 ft-bls.

Based on lithology, the base of the UAU in A3a was estimated to be 350 ft-bls, but the contact could be interpreted to be as shallow 290 ft-bls. The base of the MAU was estimated at approximately 750 ft-bls, but may be as shallow as 530-550 ft-bls based on density log data. Although not encountered during drilling of the exploratory borehole, the depth to bedrock was estimated to be between 3,500 and 4,000 ft-bls (ADWR, 2013).

2.5.6 Test Well B2a

Test Well B2a was chosen to determine aquifer characteristics in a data-deficient area near the basin-fill margin. Following an incomplete test well at site A3a, site B2a was selected as the sixth exploratory boring to be completed as a test well (Figure 3). Site B2a was also chosen based on proximity to seismic lines PW9 and CX19, and boring A1 and well SG10.

B2a penetrated basin-fill sediments to the total depth of 1,500 ft-bls. Overall, this sequence was found to consist of uniformly fine-grained sand, silt and clay, averaging 45% fines, 48% sand and 7% gravel (Appendix B, sieve data). Similar to A3a and C1, mineralogy in B2a is relatively homogenous. Mineralogy in B2a consisted of nearly equal portions of Pinal schist, quartzite, quartz and felsic volcanics (Appendix C, B2a). B2a differed from A3a and C1 in that there was a higher percentage of felsic volcanic clasts and lower percentage of Pinal schist. This occurrence is what would be expected if the source area was largely derived from the Superstition Mountains, hence mineralogy in portions of B2a is thought to represent this facies. However, Steve Skotnicki found that the coarser intervals more closely resembled lithology representative from C1, a Queen Creek facies (Appendix C). Given the significant difference in grain size and distance from exposed bedrock, A2 cannot be reasonably correlated to B2a facies. A1 however, can be, if sand-size clasts of granite are not discernable in B2a as would be expected given how fine-grained B2a was. The AZGS mineral analysis of B2a was able to discriminate granite from other minerals, thus the favored interpretation between B2a and A1 could be reasonably correlated and therefore possibly representative, at least overall, of a facies derived from the Superstition Mountains. Given the mineral facies in B2a appears to reflect both aspects of mineralogy seen in C1 (Queen Creek facies) and A2/A1 (Superstition Mountains facies), mineral facies at site B2a may represent a portion of the basin, such as a playa, which received sediment from both source areas where streams and distributary channels overlapped. The minor percent of basalt below approximately 600 ft observed by both mineral analyses was not conclusive towards identifying a source area, although these observations may suggest the basin-fill deposits are more closely related to a younger LAU sequence, or part of the MAU sequence eroding deposits which contained some basalt

The results of the geophysical logging suite of B2a was relatively unremarkable with no significant breaks observed. Due to the larger borehole diameter (16 inches) a density log could not be performed. Subtle changes between 600 and 850 ft-bls in electric, gamma and sonic logs may suggest a gradual formation change. These changes may have something to do with mineralogy, but this remains uncertain.

Based on lithology and logging, the base of the UAU was determined to be in the interval 350-400 ft-bls. The base of the MAU was interpreted to be at 890 ft-bls based on changes observed in mineralogy and sonic logs. Although below the TD of the borehole, the depth to the base of the LAU, or bedrock, was estimated to be between 2,700 and 3,000 ft-bls (ADWR, 2013). A depth to water of 448 ft-bls was measured in the new Test Well B2a on November 13, 2016. A Test Well B2a Completion Report is provided in Appendix H. Discussion of the aquifer testing results can be found below in Section 5.0 (Aquifer Test Analysis).

3.0 Vintage Seismic Reflection Data and Analysis

The application of existing vintage seismic survey data as outlined in Step 2, was a major contributor to improving the understanding of the structure and stratigraphy of SVPA. In the following sections we present a summary of the UA Reflection Seismology group's work based on their reporting and in-person meetings during 2015, and during and following drilling operations in 2016. The processing methods, stacking of datasets, and calibration to borehole data are reported by the UA group in Appendix D. These data are proprietary and confidential under contract between the UA Seismology group and Conoco-Phillips. Results and interpretations presented in this report may be reproduced, although original raw digital data remain confidential. Vintage seismic data used as part of an AZGS-ASLD study (AZGS, 2008) were also revisited in this study following incorporation of new borehole data.

As part of Step 2, selected vintage seismic-reflection survey data, and the results of exploratory drilling and geophysical logging were used to help calibrate seismic data, for the purpose of imaging and identifying basin-fill stratigraphy and structure to the extent feasible.

3.1 Site Evaluation and Selection

As part of Step 2 a total of six vintage seismic lines were chosen and processed from available seismic lines in the basin. To accomplish this the Technical Working Group identified areas of interest and priorities in SVPA (Figure 3). AZGS initially chose several possible borehole locations based on the availability and proximity of vintage seismic data, with the caveat that available seismic data may or may not be useful for siting wells. Seismic data and vintage survey lines used during the AZGS 2007 study (AZGS, 2008) were also used here to help evaluate which areas and additional vintage lines to consider in this project. In addition, exploratory drilling conducted by RC was also considered when evaluating sites for new boreholes and seismic lines.

At a preliminary meeting to discuss site selection of wells and seismic lines, AZGS presented an initial proposal to the Technical Working Group of proposed sites to consider for locating exploratory boreholes and test wells. Each area and site was ranked based on the proximity to previously analyzed data, additional available vintage seismic data and existing well data provided by AWC and RC. Once areas and individual sites were chosen, UA seismic group focused on availability and quality of existing vintage seismic data shown in Figure 4.

3.2 Analysis

Once areas of interest were identified in SVPA, UA project leader Roy Johnson and graduate students Dominique Gomez and Saba Keynejad evaluated the quality of seismic lines that intersected these areas. Original seismic data was collected during the 1970's and 1980's by petroleum exploration companies. Raw data from each seismic line were reprocessed to evaluate quality. The reprocessed lines provided an indication of the data quality and what might be expected with further processing following further calibration with data obtained from the drilling program. Seismic data were brute-stacked with time in milliseconds (ms) only for the entire dataset and corrected with velocity techniques to aid in determining the quality of reflectors. Based on these methods six seismic lines were chosen, shown in Figure 4. Supplemental data such as gravity and borehole log data from RC wells in the Far West area were subsequently supplied to UA at their request.

As drilling operations during 2016 progressed, geophysical log data were provided to the UA group. The primary type of geophysical data used for this purpose were the 4x-sonic receiver and density logs. These data were used to calibrate velocity-depth in the adjacent

seismic line(s). Seismic lines were re-stacked based on the new input and used to re-interpret reflectors along each line. The quality of reflectors varied along each line, but overall borehole log and seismic lines were able to be coupled and calibrated successfully. As expected, the main limitation with the raw seismic data was the lack of reflection data at relatively shallow depths, depths ranging 500 to 1,500 ft. This is due to the spacing of geophones used during the original acquisition of seismic data. Some more recent methods and techniques were used to post-process the data, in an attempt to improve the quality at shallower depths, with mixed success. Although determining seismic facies at shallower depths was for the most part not possible from these lines, the overall shape, depth to reflector and structures could be identified. Seismic lines 1 and 2 from AZGS (2008) study were not used in this study due to the lack of new data in the far northwest corner of SVPA, and the poor quality of return from those two lines.

3.3 Findings and Interpretations

Overall new borehole data were able to provide a successful calibration for seismic velocities across SVPA, especially where bedrock was encountered in sites A1, A2, and C1. Borehole lithology and depth to bedrock contacts were also calibrated to the nearest seismic line(s). The final processed seismic lines were stacked with velocity, in milliseconds, and depth, in meters, shown in Appendix D. Each line was then evaluated in conjunction with all other available borehole, well and gravity data. Observations and interpretations for each line are compiled in Table 5. This information was incorporated into the geologic cross-sections discussed in Section 4. All information was subsequently reviewed with the seismic group in Tucson, including AZGS geologist Charles Ferguson who originally mapped much of the geology surrounding SVPA with Steve Skotnicki in the late 1990's.

4.0 Subsurface Hydrogeologic Analysis

In order to further enhance the understanding of the subsurface hydrogeology in SVPA, and improve the Site Conceptual Model developed during the Phase-I study by SRP (2014), a wide variety of methods were employed by combining existing and new data. Geologic cross-sections were used to reconstruct basin geometry and hydrogeologic units. Data from the individual boreholes were used to supplement cross-sections and re-evaluate criteria used to define hydrogeologic unit boundaries. Seismic data were used to evaluate basin shape, structure, depth and stratigraphy. Subsidence data were used to define horizons susceptible to compaction. Geologic mapping was necessary for identifying relationships between surface and subsurface units. Numerous discussions with individuals in meetings and field trips were especially useful in understanding of basin structure and evolution in SVPA. Collectively these methods were used to update the conceptual model for SVPA. In this section we utilize the findings and conclusions from the previous two sections that summarized borehole log and seismic data in conceptual maps and cross-sections.

4.1 Approach and Methods

A thorough assessment of all new and existing boreholes and seismic data in and surrounding SVPA was performed by AZGS as part of Step 3 outlined in Section 1. Previous data sets and reports were a large part of the evaluation effort for the hydrogeology in SVPA (Laney and Hahn, 1986; AZGS, 2008; Gootee, 2013; SRP, 2014). Concurrent subsurface data in SVPA were provided by SRP (well data), UA (seismic data), ASLD (well data), ADWR (well, gravity and subsidence), AWC (well data) and RC (gravity and well data).

Geologic cross-sections were constructed initially as a matter of preference for development of a revised conceptual hydrogeologic model based on all data. Cross-sections adjacent to seismic lines were developed first. Spatial data were plotted and processed within ESRI ArcMap v.10.2 (e.g. rasters and isopach maps). Geologic surficial maps were derived from Pearthree et al., 2015 and used in ArcMap to build cross-section surfaces. Arc Hydro Groundwater v. 3.3.1 by Aquaveo was used to build layered well data into cross-sections and raster surfaces. Well data were incorporated from datasets built by AZGS (2008) and Gootee (2013). SRP and the Technical Working Group thoroughly evaluated groundwater data in SVPA (SRP, 2014) and provided updated groundwater elevation contours (updated 2015/2016) which were added to the cross-sections. The depth-to-groundwater contour map generated in 2014 (SRP, 2014) is shown in Figure 5.

In this study, wells were categorized by lithology rather than by hydrogeologic unit selections made by AZGS (2008) and Laney and Hahn (1986). The purpose of utilizing lithology was to reevaluate basin-fill deposits and facies based on new borehole and seismic data. Data from each new borehole and seismic line were analyzed independently, then integrated with adjacent data sets to assist in reconstructing basin sedimentology, stratigraphy, facies distribution and geologic structures. Based on this approach the existing basin-fill sequence and time-based stratigraphic nomenclature developed from Corkhill et al. (1993) was determined to be adequate and applicable as hydrogeologic units in ESRV (Table 3). However, the lack of stratigraphic markers, age control and well-defined structures throughout the basin-fill sequence creates challenges when correlating units, facies changes and unit boundaries. For example, although the LAU can be further subdivided into upper and lower LAU (AZGS, 2008), based on the structural complexity revealed in the eastern part of SVPA during this study, stratigraphy within the LAU was unable to be subdivided consistently throughout the study area.

Once all cross-sections were updated with lithology and hydrogeologic unit boundaries, depths to the base of hydrogeologic units were contoured in map form. Then raster surfaces

were interpolated between cross-sections and slightly beyond the SVPA boundary. Both methods were then reconciled and updated to reflect all boundary conditions. However, since the cross-sections preserve more detail and complexity along bedrock margins, slight differences exist between the model-oriented contour maps and hand-drawn cross-sections in these areas.

Developing criteria to define the UAU and MAU in SVPA were challenging. This was especially true along basin margins where hydrogeologic unit boundary conditions are not present, not clearly defined, or not well understood. These constraints are discussed in more detail in the following sections.

Mineralogical analysis of new boreholes, and recent analysis of aggregate and mineral resources in the region (Pearthree et al., 2015) were a significant contribution to understanding source area, relative timing, and deposition at the drilling sites. Such analysis was useful for developing facies distribution in SVPA. Although this is a new application in SVPA we find its application useful for potentially correlating basin-fill units with facies properties such as grain size, mineralogy, isotope analysis, or water chemistry.

4.2 Hydrogeologic Cross-Sections

A large part of the hydrogeologic conceptual model in SVPA was developed through the construction of hydrogeologic cross-sections. A total of eight cross-sections were located across specific areas to coincide with boreholes, seismic lines, or previous cross-sections (Figure 6). All cross-sections are contained in Appendix E. Cross-section LL' was chosen as a fairly representative cross-section across SVPA and is thought to represent most major components of hydrogeology in SVPA (Figure 7). Basin structure, depth-to-bedrock, basin-fill stratigraphy, facies, groundwater elevations, and hydrogeologic units are discussed in the following sections, with references made to specific cross-sections and maps.

4.3 Geologic Setting and Structure

SVPA lies within the northwest-southeast trending Higley basin, or eastern ESRV, in the south-central portion of the Basin and Range tectonic province. SVPA is bound by the Superstition Mountains to the north and northeast, Mineral Mountains to the east, and Santan Mountains to the south and southwest. Sedimentary deposits that overlie bedrock in SVPA are referred to as the basin-fill sequence. The basin-fill sequence in SVPA is estimated to be less than 15 to 17 million years old (My) (Laney and Hahn, 1986; Reynolds et al., 1986) and to unconformably overlie a mid-Tertiary volcanic sequence in some areas and Proterozoic crystalline units (commonly referred to as "basement" rocks), collectively bedrock. The history and structure of the underlying Proterozoic crystalline rocks are not discussed due to their complexity and are not pertinent to this study. Mid-Tertiary volcanic history and structure is discussed briefly as it relates to the development, history and structure of the ESRV basin-fill deposits in SVPA. Historically the "Red Unit" has been described at various locations in the Salt River Valley (see Table 3), and in the western part of the ESRV (Laney and Hahn, 1986). This unit is considered part of the mid-Tertiary volcanic and sedimentary sequence (bedrock), and consists of well-cemented sediment derived from granitic and volcanic detritus, which may have been encountered in Boring A2. A geologic map compilation and location of known or inferred faults in SVPA is shown in Figure 8.

4.3.1 Mid-Tertiary sequence

The mid-Tertiary volcanic sequence is a result of an early Miocene episode of volcanism closely associated with the Superstition Mountains volcanic sequence and is exposed at the

surface around the eastern half of SVPA. South of SVPA, the Santan Mountains are comprised of an up-thrown fault block that bounds the southern margin of Higley Basin. These mountains consist mostly of Cretaceous-Tertiary granitic rocks and Proterozoic metamorphic rocks overlain by late Tertiary sedimentary and volcanic rocks (Ferguson and Skotnicki, 1996). Early Proterozoic Pinal Schist and granodiorite outcrop at the surface and are cross-cut by Middle Proterozoic diabase intrusions. Southwest-tilted remnants of the mid-Tertiary volcanic sequence are exposed along the southwestern margin of the range (Ferguson and Skotnicki, 1996). A low-angle fault referred to as the Higley Fault contours around the northern margin of the mountain range and has been imaged from seismic reflection in the subsurface approximately 5 km from the mountain front, dipping northeasterly into Higley basin and SVPA (Warren, 2009). The Higley fault is interpreted to be the main basin-bounding fault in Higley Basin as basin-fill deposits were deposited in the hanging wall side of the fault, labeled in Figure 8. Eastern SVPA is structurally more complex and oriented differently from the southern and western portion. The Higley fault south of SVPA is summarized further by Warren (2009) and Gootee (2013).

The northeastern, eastern and possibly southeastern boundary of SVPA is bound by a major normal fault referred to as the Elephant Butte fault (Ferguson and Skotnicki, 1995). The Elephant Butte fault appears to have been active during deposition of the mid-Tertiary volcanic and sedimentary sequence, and is estimated to have down-to-the west displacement of approximately 3,300 ft (1,000 m), and may exhibit up to approximately 3,300 ft (1,000 m) dextral (west-to-the-north) offset. Recent drilling by Resolution Copper in the Far West area (FW wells; Figure 2) penetrated basin-fill and mid-Tertiary volcanic sequences in what is interpreted as one or more hanging-walls of the Elephant Butte fault and other synthetic (minor associated) faults (see faults in SVPA, Figure 8). This fault system trends north-south parallel to the Mineral Mountain piedmont and clearly post-dates deposition of mid-Tertiary volcanic rocks, notably the Apache Leap tuff (approximately 18 Ma). Many north-south trending fault structures immediately north of Florence Junction not mapped at the surface are likely present, concealed by talus and colluvium (Ferguson, 2016, personal communication). The Apache Leap tuff was encountered in multiple wells in close proximity to surface exposures (AWC wells 55-583450 and 55-588620, and some FW wells; Appendix E, cross-sections CC2, KK', and LL'). The data quality and spacing of these wells, combined with geologic mapping of basin-fill and basalt flows in the Queen Valley area (Ferguson and Skotnicki, 1995) and seismic imaging processed in this study, confirmed the presence of faults in these areas associated with down-to-west structures. Given the magnitude of offset, general strike of these faults, and similar relationships observed in the Florence area in southern SVPA, it is likely that these structures and similar offsets of the mid-Tertiary sequence and overlying basin-fill sequence may continue into the northern Picacho basin (Gootee, 2015).

4.3.2 Basin-fill sequence

Basin structure largely controls the lithology, thickness and physical properties of the basin-fill sediments in SVPA. Many basins within the Basin and Range tectonic province consist of a downthrown structural region bounded by normal faults (Spencer and Reynolds, 1989; Pool, 1986; Shafiqullah, 1980). These downthrown blocks are referred to as grabens. Basin asymmetry is common and can be the result of multiple half-grabens or rotated fault blocks at depth, as is the case in SVPA between the Higley and Elephant Butte faults. The graben is usually much smaller in size than the physiographic basin observed at the surface, because the mountain ranges of this region have been eroded and partially buried by sediment during the approximately 5 to 10 million years (My) since substantial faulting ceased (Menges and Pearthree, 1989).

The Higley Basin trends west-northwest and east-southeast with a maximum depth of over 11,200 ft-bls (3,400 m) immediately west of SVPA (ADWR, 2013). The axis of the Higley basin extends southeast into the southern SVPA and is complicated by a narrowing of bedrock topography between the Santan Mountains and Mineral Mountains where early basin-fill deposits and basaltic flows and cones are widely exposed at the surface and encountered by numerous wells in the subsurface near the Town of Queen Creek. Basaltic flows and cinders are interbedded with basin-fill deposits west of Mineral Mountains and are partially exposed at the surface, and in the Far West subsurface (see eastern portion of cross-section LL', Figure 7). Underlying basin-fill deposits in some of the FW wells is the Apache Leap tuff. From the Queen Valley area northeast of Florence Junction southward along the Mineral Mountains, the hanging wall of the Elephant Butte fault system is occupied by early basin-fill sequence, interpreted to represent a fanning-dip sequence tilted to the east, moderately to gently up-sequence, against west-dipping moderate to high-angle faults (see cross-sections CC2, KK' and LL', Appendix E). The age of basalts between Queen Valley and the southern end of the Far West area is not known. Basalt and cinder interbedded with similar basin-fill deposits in the Florence area are approximately 6 to 8 Ma old (Reynolds et al., 1986), possibly younger. Faulting is interpreted to be contemporaneous to post-depositional, 6 to 8 Ma prior to deposition of the Middle Alluvial Unit. Similar relationships between late Miocene (LAU) and early Pliocene (MAU) deposits along the Higley fault northeast of the Santan Mountains, south of SVPA are postulated based on subsurface well and seismic control (Warren, 2009). In the southwest part of cross-section CC2, two bedrock highs coincide with shallow lava flows and may represent buried crystalline bedrock highs capped by lava flows on the eastern margin of the Santan Mountains outside SVPA. The buried bedrock highs may be the result of paleo-erosion, block faulting or both.

Near the southeastern margin of the Higley basin, all geologic units and bedrock approach the surface. The basin-fill deposits appear to dip gently to the northwest and are interpreted to be faulted blocks. The abundant wells drilled through nearby basalt flows have allowed better resolution into the structure and stratigraphy of this part of the basin, although it is unclear what the orientation of these structures are along strike and at depth. Further investigation into lava flow stratigraphy would provide more control on the geological framework in this part of the basin.

In western SVPA several high-angle normal faults have been inferred from facies mismatches observed in well data (Laney and Hahn, 1986). AZGS (2008) interpreted similar mismatches in facies types and thicknesses as faults. Faults are plotted in Figure 8. Most faults inferred from shallow well data appear to be restricted to the LAU. The UAU and MAU appear to be largely non-deformed, while the LAU is gently tilted and moderately faulted.

4.3.2.1 Lower Alluvial Unit and Bedrock

The Lower Alluvial Unit (LAU) (Corkhill et al., 1993) is traditionally considered a hydrogeologic unit in ESRV that was deposited during Basin and Range tectonism. This nomenclature is adopted in this report, where the LAU is equivalent to other previously recognized units in ESRV (Table 3), a basin-fill unit that was deposited prior to, during and following Basin and Range extensional tectonism between approximately 15 and 6 million years ago (Ma) (Shafiqullah et al., 1980; Eberly and Stanly, 1976; Nason et al., 1982).

The depositional setting for the LAU in SVPA and eastern ESRV consisted of a closed basin, with one or more depositional sub-basins asymmetrically centered and primarily structurally-controlled by the Higley fault on the southwestern side of the basin. Earliest deposits associated with the LAU may have had depositional boundaries slightly different than delineated on previous depth-to-bedrock maps. In general the LAU consists of coarse-grained gravel and sand along basin margins which grade into finer-grained sand, silt, clay, and

evaporites towards basin centers. Of note, no evaporite deposits have been penetrated in SVPA. The base of the LAU is interpreted to unconformably overlie mid-Tertiary volcanic rocks and Proterozoic basement rocks in the subsurface throughout much, if not all, of the SVPA.

Basalt volcanic centers and flows were contemporaneous with sedimentation and tectonism in the southern, eastern and northern parts of SPVA (Ferguson and Skotnicki, 1995 and 1996; Richard and Spencer, 1997). Multiple horizons of basalt flows interbedded with basin-fill sediments were observed in outcrops in southern SVPA (Richard and Spencer, 1997; Ferguson and Skotnicki, 1996), and recorded in wells and cores between the Towns of Queen Creek and Florence (Nason et al., 1982; Richard and Spencer, 1997; AZGS, 2008; Gootee, 2013). Basalt interbedded with volcaniclastic sediment in the Florence area has been dated from 5.9 to 8.9 Ma (Shafiqullah et al., 1980; Reynolds et al., 1986; Nason et al., 1982) and is interpreted in this study to represent the uppermost LAU age. The age of the lower LAU is not well constrained, nor are ages of the LAU north of Florence and north of boring C3a1. Sedimentation of the LAU in response to uplift and subsidence is not well understood, but in general is considered to have been continuous without significant unconformable stratigraphic breaks in depositional centers. Along basin margins unconformable conditions may or may not be present depending on the effects of localized basin subsidence and uplift of bedrock ranges. Sedimentary facies in all basin-fill units are controlled by topography and bound by adjacent ranges and the valley floor. In ESRV and SVPA the base of the LAU is considered to lie completely in the subsurface, therefore physical characteristics of the LAU are based completely on drilling and seismic data. Determining strict criteria and physical character of the LAU remains challenging since there are few surface outcrops of the LAU or its boundaries.

Results from drilling and seismic analysis conducted as part of this study have significantly affected interpretation of the LAU. Bedrock was encountered in three of the six borings, and significantly increased depth-to-bedrock (base of the LAU) in SVPA (summarized in Section 2 and Table 4,). Calibration of data from six previously unevaluated seismic lines, and re-interpretation of four previously used seismic lines significantly aided in evaluating depth-to-bedrock (summarized in Section 3, Table 5, and Appendix D).

The revised depth to base of LAU is shown in Figure 9. Depth to bedrock and the base of the LAU were increased in most areas of SVPA in comparison to ADWR-modeled depth to bedrock derived from gravity surveys (ADWR, 2013; Gootee, 2013) (see subset of Figure 9). Differences in bedrock depths from ADWR (2013) data and Gootee (2013) were projected into each of the cross-section. In general, areas with relatively shallow bedrock (less than 1,000 ft in depth), bedrock depth and geometry determined from seismic and gravity methods did not correlate closely. This is especially true in areas where basalt is interbedded with basin-fill, is widespread, and is thick. It is possible that the extent and apparent multiple lava flows in the LAU may be the cause for consistently underestimated depth to bedrock modeled from gravity. At greater depths toward the basin center in central SVPA, gravity and seismic correlated relatively well with basin shape and geometry.

In the Superstition Mountains piedmont area, new boreholes A1, A2, and C1 penetrated bedrock and provide good calibration data and correlation to adjacent seismic lines. In each of these areas, the base of the basin-fill LAU deposits were increased approximately 400 to 700 feet compared to the ADWR modeled gravity data. The increase in DTB at A1 and A2 may reflect a broader area of the Superstition Mountains piedmont between Hawk Rock high and the Florence Junction area, which was indicated earlier in a previous analysis of existing well driller logs by SRP (SRP, 2014). The relatively uniform reflector seen in seismic lines (PW7, PW9 and CX18; Appendix D) transverse to the Superstition Mountains and trending towards basin center suggests the presence of a broad, uniform, gently southwest-dipping bedrock piedmont. The main concern with this reflector is what the material underlying the reflector represents. At A1

and A2 the reflector represents basin-fill overlying bedrock (Proterozoic Pinal schist), confirmed by the A1 and A2 borings. Mineral analysis of these wells implies bedrock sources of sediment, such as Proterozoic quartzite, diorite, and granodiorite, mid-Tertiary felsic and intermediate volcanics and indurated conglomerate (likely mid-Tertiary); geochronological dating of samples from the A1 and A2 borings is part of a separate study (Skotnicki et al., in progress). Basinward, the "bedrock" reflector may represent younger basin-fill overlying older basin-fill, or an unconformity of unknown duration, for example, MAU unconformably overlying older LAU. This is the most likely interpretation resulting from in this study, as exemplified in cross-sections GG', II' and JJ', and in seismic lines PW7 and PW9 (Table 5). The reflector in PW7 and PW9 suggests this boundary would have been encountered in boring A3a around 1,200 to 1,300 ft-bls; however, there is no supporting evidence based on the borehole analysis, i.e. no obvious changes in mineralogy, velocity or lithology were observed. Thus, the reflectors west of Hwy 60 at depths below approximately 1,000 ft-bls remain poorly understood and raise questions about the extent and thickness of the LAU proper along the Superstition Mountains piedmont between Hawk Rock and Florence Junction. The Superstition Mountains pediment ranges from 5 km wide near Florence Junction, to 12 km wide along cross-section JJ', and trends northwest-southeast, ranging from 500 to 1000 ft-bls in depth, with likely isolated bedrock paleo-topography (hills and valleys).

In the vicinity of Queen Valley, Florence Junction, and boring C1, the depth to base of LAU is structurally more complex. Excellent lithologic control at the two AWC wells along Queen Creek northeast of Hwy 60, including boring C1 and FW wells, and seismic control along PW2 and PW20 point to structural relief in basin-fill sediments and bedrock topography controlled primarily by the Elephant Butte fault and related faults. In these areas, the LAU has been interpreted to be structurally offset by multiple faults. Some, or perhaps most of the faults, are interpreted to be moderate to high-angle, with basin-fill deposits and interbedded basalt flows east-tilted 15 to 25 degrees against the faults. Basin-fill deposits in these structural areas are also interpreted to have a fanning-dip sequence where the older deposits are progressively more tilted than overlying younger deposits. In the Queen Valley area basin-fill deposits that post-date the mid-Tertiary sequence are interpreted to represent one of these fanning-dip sequences (Ferguson and Skotnicki, 1995); however, these deposits appear to have a high degree of consolidation and cementation where present at the surface and subsurface in the FW area. In borehole C1, the density in the LAU below 500 ft-bls was relatively uniform, at 2.1 to 2.2 grams per cubic centimeter (g/cm^3), while drilling penetration rates ranged from 2 to 11 minutes per foot (see Figure 7 and Appendix B, density and penetration rates). Thus, the LAU can exhibit a higher degree of consolidation and cementation, however, the lateral extent and heterogeneity of cementation in these deposits is not well defined.

Further south along Elephant Butte fault, basalt interbedded with conglomerate equivalent to the LAU is interpreted to be in the FW subsurface and exposed at the surface in the Florence area and southernmost SVPA (geologic units Tcy, Tb and Tbu; Plate 2). Tilting of surficial units in this southern area is not known. Depths to the base of the LAU are not well constrained. Gravity data in this area suggests depths to the base of the LAU are similar those modeled in the Far West area.

Wells in the Town of Queen Creek are interpreted to be screened in interbedded basalt and alluvium equivalent to the LAU. The basalt flows in these wells are interpreted to originate from volcanic centers to the northeast (C3a1), east and southeast; although structurally complicated by subsequent faulting (see cross-sections CC2 and KK'). Analysis by Warren (2009) and UA seismic group in this study identify reflectors along CX19 and PW20 as representing lava flows overlying Proterozoic basement, faulted down to the northeast along the Higley fault. These relationships were used to define and control the base of the LAU in the

southwestern extent of SVPA. Along seismic line PW3, a reflector thought to represent a horizon with basalt flows tilts northwest to west from the area of C3a1 towards A3a, and may control, at least in part, the direction of groundwater flow in this area. A second reflector is seen below and is interpreted to represent the base of the LAU.

The remainder of the base of the LAU in central and western SVPA is based on gravity data, while being tied to bedrock control revised in this study along the margins, with progressively deepening depths towards the gravity low located in the southern half of Township 2 South, Range 8 East (Figure 8). Based on these new findings the isopach (thickness) map of the LAU is shown in Figure 10. The zero-thickness contour represents the maximum lateral extent of the LAU, taken from the zero depth to base of LAU shown in Figure 9. However, because the LAU is faulted and eroded, thickness of the LAU may vary considerably across faulted areas, especially over short distances. In areas where faults are known to offset the LAU, such as areas along the Elephant Butte and Higley faults, thickness contours of the LAU were spaced accordingly depending on the quality and proximity to adjacent data.

Sedimentary and mineralogical facies in the LAU could not be determined spatially based on new exploratory boring data from this study. Detailed mineralogical analysis by AZGS and Steve Skotnicki of deposits in C1, A3a and B2a, boreholes considered to have penetrated the entire LAU or uppermost LAU do indicate bedrock is sourced from adjacent mountains. Given the structural complexity associated with the LAU, we would expect the distribution of lithology and mineralogy to vary locally considerably.

Much of the LAU is saturated, although the top of the aquifer is predominantly located in the MAU. Fracturing in the LAU was observed in C1 from the acoustic televiewer log, although distinctions between bedding planes and fractures were not well defined. Fractured basin-fill sediment and especially basalt flows were observed in some of the cored SG and OG wells in SVPA, as well as tilted bedding (Arizona Geological Survey Oil and Gas Commission records, and Bureau of Reclamation Salt-Gila (SG) well logs). These properties may locally affect groundwater transmissivity and storage.

4.3.2.2 Middle Alluvial Unit

The Middle Alluvial Unit (MAU) is part of a basin-fill sequence that post-dates tectonism and volcanism associated with the LAU, and generally overlies the LAU unconformably along basin margins and conformably toward basin centers (Table 3). The MAU was deposited in a restricted basin between about 6 and 2.5 Ma, before the development of through-going drainage on the Salt River and its tributaries occurred (Skotnicki et al., 2016). Facies in the MAU exhibit coarser grained deposits near the basin margins and finer grained deposits towards basin center in the central western SVPA. Depositional environments include alluvial fan and playa systems in a closed setting, but unlike the LAU, the MAU does not appear to contain massive or bedded evaporites such as gypsum or anhydrite (Laney and Hahn, 1986). The MAU is generally unconsolidated although cementation and compaction varies laterally and increases with depth. Like the LAU, the top and bottom of the MAU are not recognized in surface exposures; therefore, criteria used to characterize this unit in the subsurface is limited mostly to pronounced lithologic changes or distinct changes in geophysical logs.

In this study the MAU was identified as being generally finer-grained than the overlying UAU and exhibiting a lower degree of consolidation and cementation than underlying LAU. Clay content varied and appeared to be restricted to medium to thick beds alternating with silt and fine sand, typical of basin-fill alluvial fan deposition. The MAU was arbitrarily defined by these criteria. Seismic imagery used in this study lacked adequate spacing and resolution to define stratigraphy and sedimentary facies of the MAU at shallow depths. In seismic lines PW7 and

PW9 reflectors calibrated to A2 and A1, respectively, extend basinward where A3a and B2a, respectively were projected to have encountered bedrock, although they did not. This reflector is interpreted to represent an unconformity between the base of the MAU and LAU, although there is no evidence to support an unconformity based on analysis of the borehole data. The consensus of the MAU in this setting was described by Warren (2009) and Gootee (2013) as follows: Following the peak of faulting in SVPA, sedimentation continued to aggrade near basin centers as bedrock source areas in the Superstition, Santan and Mineral Mountains were eroded and embayed. Deposits associated with early MAU eroded LAU along basin margins followed by aggradation in these embayed piedmonts. This relationship between the MAU and bedrock along basin margins and MAU over LAU is thought to be present in SVPA, but likely not everywhere and is not well defined. Basinward this relationship should transition into a conformity, but identifying this contact is difficult and may be impossible to distinguish as it nears bedrock areas because the source areas for LAU and MAU deposits are the same and such contacts are completely in the subsurface.

Based on experience and criteria typically used to define all alluvial unit boundaries, the MAU top and bottom were selected and mapped in SVPA. The base of the MAU is shown in Figure 11. The MAU is thought to be relatively thin near basin margins and to thicken toward basin centers.

Along the Mineral Mountain and Florence areas deposits associated with the LAU are exposed at the surface (units Tsy, Tb and Tbu; Plate 2), thus the MAU has zero thickness here. Closed contours in the depth to the bottom of MAU contour map represent unconformable paleo-topography or inselbergs that have either been buried or are nearly buried. Generally, the MAU is thought to be non-deformed or slightly deformed by low-relief gentle tilting related to subsidence and/or low-magnitude infrequent faulting. Such faults are older faults in underlying bedrock and basin-fill deposits that propagate upwards into overlying units. Faults such as these have been interpreted by Laney and Hahn (1986), shown in Plate 2, Figure 8 and all cross-sections. Seismic imagery used in this study were unable to detect many of these interpreted faults at shallow depths.

The isopach (thickness) map for the MAU is shown in Figure 12. The thickest MAU deposits are along the western SVPA, similar to the LAU, and are thought to represent the main depocenters. North of Hawk Rock is another area of MAU deposition. Along the southernmost SVPA boundary with the Gila River, MAU and LAU deposits may be tilted fault blocks, although this remains unconfirmed by borehole or seismic data surveys (AZGS, 2008).

Sedimentary and mineralogical facies in the MAU were successfully evaluated in this study and are discussed in Section 4. Hydraulic connectivity and water quality as they relate to mineral or lithology facies in the MAU were not extensively evaluated in this study. The MAU is mostly saturated basinward, and becomes progressively less saturated and unsaturated along bedrock piedmonts to bedrock margins.

4.3.2.3 Upper Alluvial Unit and Queen Creek

The Upper Alluvial Unit (UAU) is the uppermost part of the basin-fill sequence defined by an integrated Queen Creek system in SVPA. Queen Creek originates in the Superior area from a watershed roughly the same size as the SVPA, and drains southwest across multiple bedrock divides into and continues westward along the flank of alluvial fan toes emanating from the Santan Mountains, then contours west and south along the Santan Mountain before connecting to the Gila watershed. All tributaries in SVPA are integrated with Queen Creek, and deposits associated with the UAU are thought to represent this modern drainage system, and associated landforms and landscape.

The UAU is composed of channel, flood plain, terrace, and alluvial fan deposits, which consist of gravel, sand, and silt with relatively minor clay. The UAU represents Quaternary and Holocene deposits formed over the last 2.5 million years (Skotnicki et al., 2016). The UAU is mostly unconsolidated except in piedmont areas where caliche cementation is more prevalent (Laney and Hahn, 1986; Pearthree et al., 2015). As with the MAU and LAU, the base of the UAU has not been documented from surface exposures with underlying MAU or LAU deposits, thus correlating relationships between the two units across the basin is very difficult without more definitive subsurface data.

During this study the UAU was characterized from borehole logs as predominantly coarse-grained deposits overlying fine-grained deposits of the MAU. UAU deposits are too shallow to be imaged from vintage seismic line data. Mineralogical analysis by AZGS and Steve Skotnicki in this study shows no apparent change in mineralogy between the UAU and older alluvial units in the SVPA. This suggests source areas for the Queen Creek valley and underlying deposits have been similar throughout its depositional history. As a result, mineralogical analysis alone could not be used to differentiate the base of the UAU.

Recent work by Skotnicki et al. (2016) indicate the Salt River arrived suddenly in the western portion of ESRV west of SVPA around 2.5 Ma. The age and development of the Gila River in this region, of which the modern Queen Creek is integrated with, is not known. Below Salt River deposits west of the Laney and Hahn line (Laney and Hahn, 1986; Skotnicki et al., 2016) the MAU consists of deposits very similar in mineral content to material logged in borings C1, A3a and B2a at all depths to approximately 1,500 ft-bls (Skotnicki, this study and personal communication). Based on these findings Steve Skotnicki has hypothesized that source areas similar to deposits observed in SVPA were present prior to the arrival of the Salt River, further complicating a distinction between the UAU and older units. More research on the age and mineralogy of deposits in the UAU, MAU and upper LAU sequences is needed to refine basin-fill sequence stratigraphy. Additional samples from the SRP exploratory borings were collected for this purpose (Skotnicki et al., in progress).

Based on estimated contacts between the UAU and MAU made in each of the exploratory borings in SVPA, a depth to base of UAU map was constructed, shown in Figure 13. There is no evidence of brittle deformation or faulting in the UAU, thus these deposits are interpreted to mimic much of the present-day alluvial topography, draining towards the modern Queen Creek channel. However, ADWR continues to monitor ground-surface subsidence related to groundwater withdrawal, a subsidence feature identified as the “Hawk Rock Subsidence Feature” in the western one-third of SVPA since 1992 (ADWR, 2016). The thickest deposits associated with the UAU are estimated to be between 400 and 500 ft-bls in the western SVPA. The slope of the base of the UAU is subparallel to, and slightly steeper than the modern alluvial slopes (see cross-sections AA2’, LL’ and KK’, Appendix B, Plate 2), one factor used to constrain the base of the UAU.

The Queen Creek channel may have laterally diverted during UAU time in the Queen Valley area. Quaternary deposits in the Queen Valley area are relatively thin, less than 100 ft thick, and overlie hard conglomerate interpreted to be LAU-equivalent. Combined with the bedrock narrows immediately southwest of Queen Valley, this suggests that the Queen Creek channel may be relatively young through this bedrock corridor (section LL’, Figure 7). One possible flow path of an ancestral Queen Creek may have been south from Whitlow Dam area into the Far West area, then westward and basinward. The geomorphic landscape in that area and apparent lack of alluvial terraces related to Queen Creek appears to lend credence to this untested hypothesis.

In the far southeastern corner of SVPA the modern Gila River has captured drainages from Mineral Mountain that previously flowed westward toward the Queen Creek system. Only a thin veneer of Quaternary deposits cap remnants of older MAU and LAU deposits, including isolated cinder cone remnants. Effectively, the zero-thickness contour line for the UAU was drawn to isolate what are now largely LAU-equivalent deposits at the surface between Far West and Florence.

Aggregate operations are present in multiple locations along the modern Queen Creek channel between Florence Junction and the westernmost SVPA boundary. Boring A3a, located immediately north of the modern channel encountered atypical coarse-grained sand and gravel through much of its 1,500 ft depth. The mineralogy was also relatively uniform and representative of the Queen Creek system, which suggests a relatively consistent source area for these deposits. An analysis of the Queen Creek watershed upstream of boring C1 was conducted to evaluate the distribution of units mapped at the surface with those observed in C1, and in A3a. Although many similarities in rock type and mineralogy exist between the surface units in upper Queen Creek and subsurface in C1, a correlation was not force-fit because there are conglomerate units in this upper Queen Creek watershed that may skew an accurate analysis (contamination via recycling older clastic deposits). A precursory geomorphic analysis of the watershed however shows multiple lines of evidence for a slowly-evolving process of stream capture through headward erosion and knickpoint retreat, which would support a long history of basin-fill sedimentation in ESRV supplied by source areas rich in Proterozoic and mid-Tertiary volcanic rocks. The UAU is mostly dry in the SVPA, except for areas near the western edge of the SVPA.

4.4 Basin-fill Facies and extent of interbedded basalts

Based on mineral analysis conducted by Steve Skotnicki and AZGS for each of the six borings in SVPA, a generalized mineralogical facies map was constructed (Figure 14). Three separate mineral facies in SVPA were recognized based on the six borings labeled as the Superstition Mountains, Queen Creek and Mineral Mountain facies. All AZGS mineralogical logs are presented in Appendix B and independently by Steve Skotnicki in Appendix C. Both datasets are summarized below. A fourth facies sourced from the Santan Mountains is hypothesized based on limited subsurface well data and geologic reconstruction of alluvial units.

The purpose of the mineralogical analysis was to identify provenance of drill cuttings deposited at the drill sites. This aids in an understanding of the source area(s), history and evolution of erosion and deposition. Interpretations of mineral data are limited however. Identifying sand-size grains disaggregated during the drilling process is time consuming and requires experience and knowledge of the surrounding geology and rock types combined with drilling methods and operations at each specific drilling site. Proximity to bedrock margins and outcrops can also limit the usefulness of this technique. In addition, erosion of older basin-fill deposits along the eastern and southern SVPA margins may skew younger deposits through recycling of older mineral material. The SRP borings drilled in this study are located relatively distant from bedrock sources, therefore it is believed their mineral makeup is fairly representative of the basin-fill deposits encountered at the drilling site. Boundaries between facies most likely overlap spatially and with depth since the position of streams and stream networks (e.g. fans and playas) often change over time. Below is a summary of each mineral facies in SVPA that one might expect to find in the UAU and MAU. Due to the structural complexity of the LAU, a facies distribution for the LAU may likely be very different from that of the overlying units, therefore interpreting facies of the LAU was not constructed. Given the extent of volcanism associated with the LAU, it is very likely that basalt flows disrupted drainage

patterns between source areas and depositional areas that existed at that time. Thus, caution should be used to characterize mineralogy of deposits in this area in deposits of the same age.

The Superstition Mountain facies is dominated by granite and Tertiary felsic volcanic rocks with minor percentages of Pinal schist, intermediate volcanics, quartzite, and quartz. Quartz grains are most likely derived from Pinal schist vein quartz and granite. The quartzite clasts are all very dark reds and grays and are very fine-grained. Their source is more uncertain. In boring A1, mineralogy consisted of primarily schist, granite and felsic volcanic clasts. Percentages of schist decreased up-section while felsic volcanic and granite constituents tended to increase. Percent quartzite appeared to remain the relatively constant. Quartzite and schist clasts were noticeably more well-rounded than other types. In A2, clasts below 390 ft-bls are dominated by Pinal schist; however, above this depth samples consist of felsic volcanics and granite with minor amounts of other mineral types. One interpretation is that the upper assemblage in A2 represents a stream-capture event from the valley east of the Peralta Trailhead (Coffee Flats area) toward site A2. Morphology of the modern streams and landscape are consistent with this hypothesis if sediment in that valley had nowhere else to go, overspilling a bedrock divide and draining southward towards A2.

The Queen Creek facies consists of nearly equal percentages of Pinal schist, quartzite, quartz and felsic volcanics, with minor percentages of basalt and granite at spotty intervals. Borings B2a, A3a, and C1 have this similar sample mineralogy throughout their entire depth. These similarities suggest that deposits in these borings were exposed to areas dominated by Tertiary volcanic rocks and Pinal schist basement derived from bedrock source areas north of Mineral Mountain and east of the Superstition Mountains which contains mostly bedrock of Pinal schist overlain locally by Tertiary felsic volcanic rocks and lie within the Queen Creek watershed. Some intervals in boring B2a also appear to represent mineralogy seen in boring A1. Given the mineral facies in B2a appears to reflect both aspects of mineralogy seen in C1 (Queen Creek facies) and A1 (Superstition Mountains facies), mineral facies at site B2a may represent an area of the basin, such as a playa, which received sediment from both source areas where streams and distributary channels overlapped.

The Mineral Mountain facies contains roughly equal parts of Pinal schist, granite, vein quartz, and Tertiary felsic volcanic rocks. This is based on only one boring C3a1 above basalt encountered at 620 ft-bls. Quartzite is present but is generally less abundant. Limestone is also present but at trace percentages and is interpreted to represent carbonate-rich portions of basement similar to Pinal schist in age (often referred to as calc-silicate rocks). The granite observed in boring C3a1 was derived from the coarse-grained Grayback Granite exposed a few miles to the southeast, along the Gila River east of Florence. The LAU in this area is interpreted to be exposed at the surface, which may imply that portions of the UAU and MAU may have eroded and recycled LAU deposits.

The Santan Mountains facies was not evaluated or quantified in this study. Based on limited well data and geologic mapping in the Santan Mountains this facies should consist of varying percentages of Proterozoic granite, schist, and diorite, mid-Tertiary volcanics and Pliocene basalt (LAU) derived solely from eastern parts of the mountain range.

The extent of basalt flows interbedded with basin-fill deposits is also shown in Figure 14. This extent was based on surface exposures of Pliocene basalts interbedded with the basin-fill sequence in the eastern and southern portions of SVPA (Plate 2), and from well records that reported basalt in the subsurface, especially those from the Town of Queen Creek and deeper, “Salt Gila” (SG) wells (Bureau of Reclamation Salt-Gila well logs). Basalt flow horizons were imaged in vintage seismic lines, especially PW3, and were used to infer the extent of basalts in the subsurface. Well records provided by Resolution Copper in the Far West area also

contributed to defining the extent of basalt and conglomerate in the subsurface, and found in the hanging wall of the Elephant Butte fault. Based on the wide distribution of basalts and multiple generations of flows, depths to bedrock modeled from gravity may have underestimated true depths to bedrock. Further drilling and mineral analysis in these deposits associated with the LAU would improve our understanding of structure and basin-fill stratigraphy in what may represent a thick and extensive stratigraphic sequence in SVPA.

5.0 Aquifer Test and Water Quality Analysis

5.1 Introduction

One of the primary objectives of the Phase II Superstition Vistas investigation was to further characterize the groundwater system in the study area. To better delineate aquifer properties and fill data gaps, transmissivities were estimated from aquifer tests conducted at three existing wells, including one ASLD well located near the center of the study area and two Arizona Water Company (AWC) wells located in the eastern portion of the study area. In addition, transmissivity values were estimated from aquifer testing conducted at Test Well B2a, a new test well drilled and completed in the northern portion of the study area during the Phase II investigation. A second test well, also involving aquifer testing, was originally planned to be completed at exploratory boring A3a in conjunction with this phase of work. However, due to borehole plumbness and alignment issues, it was decided not to construct a test well at this location. Detailed information on the aquifer tests of the ASLD well, AWC wells, and Test Well B2a, can be found in Appendices F, G, and H, respectively. Table 6 summarizes the pertinent well data and the aquifer test results for the wells tested during the Phase II study. A brief summary and discussion of the aquifer testing program is provided below.

5.2 Aquifer Testing and Water Quality Sampling Summary

5.2.1 ASLD Well

SRP, in coordination with ASLD, conducted constant-rate aquifer testing at the ASLD well, known as the Queen Creek Pit well. This well is located near the Queen Creek Wash and is being utilized by ASLD's lessee, Queen Creek Pit LLC, in conjunction with its sand and gravel operation. The cadastral location of this well is D(2-9)15DBB (ADWR Reg. No. 55-209685). Drawdown and recovery data from five separate pumping intervals between December 23, 2014 and January 17, 2015 were analyzed. The pumping interval of the five tests ranged from approximately 350 minutes (approximately 6 hours) to 2,139 minutes (approximately 36 hours). The same constant pumping rate of 189.5 gallons per minute (gpm) was utilized for each of the test analyses. All the aquifer tests yielded a consistent specific capacity of 27 gallons per minute per ft of drawdown (gpm/ft). The estimated average of the transmissivity values from the five tests at the Queen Creek Pit well was 296,100 gallons per day per ft (gpd/ft) (Table 6).

Water quality sampling of the Queen Creek Pit well had been conducted earlier during the Phase I Investigation in 2014 (SRP, 2014). Therefore, no groundwater samples were collected during the 2016 aquifer testing activities. The previous sampling results showed the groundwater to be of generally good quality, with levels of nitrate, fluoride, and arsenic below MCLs (SRP, 2014).

5.2.2 AWC Wells

Clear Creek Associates (Clear Creek) was retained by AWC to conduct evaluations of AWC's Apache Junction Ranch 160 Wells No.1 and No.2 ("East Well" and "West Well" respectively), including aquifer testing and water quality sampling and analyses. The East Well, located at D(02-10)05CCD (ADWR Reg. No. 55-583450) involved both step-rate and constant-rate tests. The step-rate test was performed on December 13, 2016, and consisted of 5 steps with each step lasting about 1.5 hours. The pumping rate was gradually increased approximately 150 gpm between steps, with pumping rates of 400, 550, 700, 850, and 1,000 gpm, respectively. Following completion of the step-rate test and water level recovery, a 25-hour constant rate test was conducted at the East Well on December 14, 2016 at a pumping rate of 990 gpm. During the test, water level responses were collected at both wells. The specific

capacity of the East Well at the end of the constant rate test was calculated to be 9.6 gpm/ft. A Cooper-Jacob analysis of the constant rate drawdown data yielded an aquifer transmissivity of 65,340 gpd/ft. Recovery data was also collected, following cessation of pumping, with water levels recovering 97.5% in 8 minutes and 99.7% after 4 hours. An aquifer transmissivity value of 137,555 gpd/ft was calculated from the East Well recovery data. An average aquifer transmissivity of 101,450 gpd/ft (Table 6) was reported in the Clear Creek report based on drawdown and recovery data analysis at the East Well.

Clear Creek had previously attempted to conduct an aquifer test at the West Well on October 11, 2016. The West Well is located at D(02-10)06DDD (ADWR Reg. No. 55-588620). The well was pumped for approximately two hours before being shut down due to excessive drawdown. Additional development consisting of pumping and surging was subsequently performed at this well in an effort to enhance well performance. Based on data collected during the aborted test and the results of the pump and surge activity, it was determined that the poor well performance was related to limited aquifer transmissivity rather than due to a well efficiency issue. Due to excessive drawdown and instable pumping rate, the Cooper-Jacob drawdown analysis was not performed. However, the late-time recovery data were analyzed to derive a transmissivity estimate and it was calculated to be 1,232 gpd/ft. The Clear Creek study concluded that the aquifer in the vicinity of the West Well exhibited a very low transmissivity and further that the East Well and West Well are hydrologically disconnected based on the differences exhibited in water quality and the minimum water level responses observed at the West Well during aquifer testing of the East Well.

Well discharge samples were collected during the step-rate and constant rate testing at the East Well. These samples were analyzed for specific constituents, including arsenic, fluoride, nitrate as nitrogen (N) other major ions, and total dissolved solids (TDS). Laboratory analyses of these samples reported consistent results which did not vary significantly with time. The sampling results indicated that no analytes exceeded their respective Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL). Analyses of the well discharge sample collected at the end of constant rate test reported concentrations of arsenic, nitrate (as N), and TDS as 0.0012 milligram per liter (mg/L), 1.6 mg/L, and 440 mg/L, respectively; fluoride concentration was less than 0.4 mg/l (Table 7). Discharge samples were also collected at the West Well; and analyses reported the concentrations of arsenic, nitrate (as N), and TDS as 0.0043 mg/L, 0.54 mg/L, and 350 mg/L, respectively; fluoride concentration was less than 0.4 mg/l. Groundwater quality of both wells meet the Primary Drinking Water Standards for the constituents analyzed. However, a number of distinct differences were noted in the concentrations of major ions between the two wells, which further supported the conclusion that these two wells are not in hydraulic communication.

5.2.3 Test Well B2a

The Test Well B2a is located on ASLD Trust land approximately 5.2 miles northwest of the Queen Creek Pit Well and 1.3 miles east of the Central Arizona Project (CAP) canal. The cadastral location of this well is D(1-8)36CCC (ADWR Reg. No. 55-226297). SRP conducted both step-rate and constant-rate aquifer tests at this well. The step-rate test, conducted on November 14, 2016, consisted of three 2-hour steps at time-weighted pumping rates of 412, 625, and 816 gpm, respectively. AQTESOLV Pro was used to analyze step-rate test drawdown and recovery data, and the transmissivity values were calculated to be 10,620 gpd/ft, and 8,694 gpd/ft, respectively.

A constant-rate test was performed at Test Well B2a on November 15-16, 2016. The well was pumped at an average rate of 768 gpm for 1446 minutes (approximately 24 hours). The maximum drawdown at the end of test was 183.52 ft, resulting in a specific capacity of 4.2

gpm/ft. The drawdown and recovery data were analyzed using AQTESOLV Pro and yielded transmissivities of 11,120 gpd/ft and 8,892 gpd/ft, respectively.

Though the analysis of recovery data from both tests resulted in slightly lower transmissivities than that calculated from the drawdown data, the differences between them were not considered significant. As a result, the average transmissivity from all of the estimates, 9,832 gpd/ft, was determined to be representative of the transmissivity in the vicinity of Test Well B2a (Table 6).

During the test, depth-specific water quality sampling was performed at Test Well B2a. A water sample was also collected from the pump discharge to represent the composite groundwater quality at the test well. The water samples were analyzed for TDS, metals, inorganics, anions, and volatile organic compounds (VOCs). Based on the laboratory results, there were no EPA MCL exceedances for the constituents analyzed. The groundwater from Test Well B2a was determined to be of a sodium-calcium-bicarbonate type, similar to other groundwater samples collected from wells north of Queen Creek Wash during the Phase I study (SRP, 2014). The water quality was also not found to vary significantly with depth. The laboratory analyses for arsenic, fluoride, nitrate as N, and TDS reported concentrations of 0.00227 mg/L, 0.187 mg/L, 1.97 mg/L, and 230 mg/L, respectively (Table 7). Overall, the water quality in Test Well B2a appeared to be very good, and met EPA Primary Drinking Water Standards.

5.3 Discussion

5.3.1 Three Aquifer Test Results

During Phase II, several exploration boreholes were drilled to better characterize the geologic and hydrogeologic conditions of the study area. Results of these borehole lithologic logs and geophysical survey logs were utilized in the interpretation of the aquifer test results.

Site A3a was originally chosen as a test well site to investigate a data deficient area adjacent to Queen Creek Wash near the center of the study area. It was also expected that the aquifer test results from this test well could help corroborate the aquifer test results obtained at the Queen Creek Pit well, which is also located along the north side of Queen Creek Wash approximately 1.6 miles east-northeast of A3a. Though the exploratory boring at A3a was intended to be drilled and converted to a test well, it was not able to be completed as planned, due to plumbness and alignment issues. The boring at A3a was drilled to a depth of 1,500 ft, bls, penetrating basin-fill sediments, which consisted of sand, silty sand, and gravelly sand with minor clay. In general, A3a was found to be relatively coarse-grained throughout the entire borehole (see section 2.5.5). The presence of the coarse-grained formation at this location appears to justify the unexpectedly high transmissivity value of 296,100 gpd/ft derived from the previous aquifer test results from the Queen Creek Pit well. These results were considered to have been overestimated, as discussed in the initial aquifer test report (Appendix F), partially due to the small water level declines observed during aquifer testing utilizing the existing well pump.

Test Well B2a was drilled at a site located further away from the Queen Creek Wash, approximately 4.25 miles northwest of A3a, and 5.2 miles to the northwest of the Queen Creek Pit well. Test Well B2a penetrated basin-fill sediments to the total depth of the boring at 1,500 ft. Overall, this sequence was interpreted to consist of uniformly fine-grained sand, silt, and clay, averaging 45% fines, 48% sand, and 7% gravel (see Section 2.5.6). The spinner flowmeter survey conducted in the completed well showed that groundwater production occurred throughout the screened interval of the well. The aquifer test results of both step-rate and

constant rate yielded a consistent transmissivity, which was averaged to be 9,832 gpd/ft. This test result was found to correlate well with the underlying lithology present at this boring site.

The AWC aquifer test results indicated that the aquifer between the East and West wells are not hydrologically connected. Though the two wells are located only 1,500 ft apart, the East well can be pumped at 990 gpm with estimated transmissivities ranging from 65,340 gpd/ft to 137,555 gpd/ft, and the average transmissivity was calculated to be 101,450 gpd/ft. In contrast, the West well exhibited excessive drawdown when pumped at only 100 gpm and was incapable of sustaining even that pumping rate for more than 2 hours. The aquifer transmissivity at the West well site was considered by Clear Creek to be very low due to the previously described low production capacity and associated excessive drawdowns and estimated to be 1,232 gpd/ft. In addition, the distinct differences observed in water qualities at the two wells helped to confirm the lack of hydraulic communication between the two wells.

Hydrogeologic Cross Section LL' (Figure 7 and Plate 2) also helps to explain the significantly different aquifer responses to pumping at the two wells. The Lower Alluvial Unit (LAU) has been interpreted to occur in this area, and as shown in the cross-section, the East well appears to penetrate a much larger thickness of sand and gravel from this unit than the West well. In contrast, the West well appears to penetrate a much larger thickness of basalt interbedded with conglomerate sediments. The East well also appears to be located in an area containing a number of faults and/or connected fractures, increasing the aquifer transmissivity in comparison to the portion of the aquifer where the West well is completed.

5.3.2 Transmissivity Distribution in the Study Area and Vicinity

During Phase I of the Superstition Vistas study, previous investigations and ADWR imaged records were reviewed to obtain the available aquifer test data in the study area and vicinity. These aquifer test results and locations, including the transmissivity values from the three tests conducted as part of the current investigation, as well as other transmissivity data provided by SRP, AWC, and RC, are presented in Figure 15. As shown, the highest transmissivity values are found in the center of the study area adjacent to the Queen Creek Wash.

5.3.2.1 Transmissivity Trends North of Queen Creek Wash

The highest reported transmissivity (296,100 gpd/ft) was observed near the Queen Creek Wash at the Queen Creek Pit well and appears to be limited primarily to the coarser grained deposits underlying and in proximity to the Wash. Transmissivity is then believed to decrease north of the Wash toward B2a, with a reported transmissivity of 9,832 gpd/ft.

Approximately 6.5 miles north-northwest of Test Well B2a, at the northern boundary of the study area, an Apache Junction Well No. 6 (ADWR Reg. No. 55-554006) at D(01-08)04BAA, was reported to have a specific capacity of 3.83 gpm/ft (Icon Consultants USA, 1996). This correlates closely to the specific capacity of 4.2 gpm/ft found at B2a and indicates that the specific capacity and associated aquifer transmissivity may be relatively consistent over much of the northern portion of the study area.

The AWC East well is located approximately 4 miles northeast of the Queen Creek Pit well and near Queen Creek Wash. Though Clear Creek reported an averaged transmissivity of 101,450 gpd/ft, results ranged from 65,340 gpd/ft to 137,555 gpd/ft (Figure 15). In contrast, the AWC West well, located 1,500 feet to the west, was unable to sustain a minimum test pumping rate of 100 gpm and exhibited a very low transmissivity of 1,232 gpd/ft. This suggests the presence of a hydrologic discontinuity between the two wells. Based on the updated geologic interpretation, both AWC wells may be located in a localized aquifer system (Figure 7).

5.3.2.2 Transmissivity Trends South of Queen Creek Wash

Approximately 3.5 miles south of Queen Creek Wash, AWC and RC wells along the Magma Arizona Railroad Company (MARRCO) corridor reported transmissivity values ranging from 105,000 to 140,000 gpd/ft. Further to the southwest, outside of the study area, an SRP well in the New Magma area reported a transmissivity of 159,000 gpd/ft. This indicates that while transmissivities south of Queen Creek Wash also decline somewhat with distance from the Wash, they appear to remain significantly higher than present north of the Wash, with perhaps some of the highest transmissivities occurring in the southwestern section of the study area.

In the eastern portion of the study area, south of Hwy 60 and east of Highway SR-79, Resolution Copper (RC) has installed a number of test wells in an area identified as the Far West well field. Aquifer tests conducted at a number of these wells reported very low transmissivities, ranging from 2 gpd/ft to 2,174 gpd/ft. In this area, the LAU predominantly consists of basalt interbedded with conglomerate and is interpreted to be relatively thick. However, according to the aquifer test results from the RC wells, these formations likely comprise hydrogeologic bedrock in this area.

5.3.3 Water Quality Sampling Results

During the Phase I investigation, five ASLD wells were sampled and analyzed for major ions, metals, and volatile organic constituents (SRP, 2014). During Phase II, groundwater samples were collected during both the AWC East aquifer test and the aborted test at the West well. In addition, samples (including depth specific samples) were obtained during the Test Well B2a aquifer test. Figure 16 presents Stiff diagrams for wells sampled in both Phase I and Phase II. Stiff diagrams are a graphical representation of the major ion water chemistry. As shown in the figure, the groundwater in the study area can be divided into three distinct types. Groundwater north of the Queen Creek Wash is predominantly of a sodium bicarbonate type. Total dissolved solids (TDS) levels ranged from 140 mg/l to 230 mg/l in this area (Table 7). In the vicinity of the Queen Creek Wash, groundwater from the ASLD Queen Creek Pit Well and AWC East well is comprised of a calcium bicarbonate type water. It is interesting to note that the wells AWC East and AWC West both located close to Queen Creek Wash, exhibited slightly different water chemistries, the West well similar to that of wells to the area north of the Wash and the East well characteristic of the groundwater in the vicinity of Queen Creek Wash. TDS levels for samples from the wells near the Wash were slightly higher (260-440 mg/l) than for wells north of the Wash. Based on a sample from a single well (55-615305), groundwater south of Queen Creek Wash, near the southern study area boundary and north of the Gila River, was determined to be of a calcium-sodium chloride water type, with a TDS concentration of 530 mg/l. These differences in water chemistry suggest that groundwater in the study area is subject to a number of different recharge sources and flow paths for the northern and southern parts of the study area.

The lowest arsenic concentrations (<1.0 and 1.2 ug/l) in the study area appeared to be associated with proximity to Queen Creek Wash, as indicated by reported arsenic levels in the Queen Creek Pit well and the AWC East well (Table 7). The highest arsenic concentrations (7.93 and 4.3 ug/l) were found in wells to the west and northwest of the AWC East well (AWC West well and 55-615234, respectively). The remaining arsenic levels in well samples were of intermediate concentrations (2.7-3.77 ug/l). Levels of fluoride for all wells sampled were generally less than 1 mg/l, ranging from 0.122 mg/l to 0.614 mg/l. The lowest nitrate-N concentrations in the study area were found in the AWC West well (0.54 mg/l) and well 55-615305 (0.475 mg/l) located near the southern boundary of the study area. The remaining nitrate-N concentrations in well samples, all either near the Wash or north of the Wash, ranged from 1.6 mg/l to 2.55 mg/l.

Based on the sampling results (Table 7), there were no primary EPA MCL (Maximum Contaminant Level) exceedances for the constituents analyzed during the Phase I or Phase II sampling events. One sample (from well 55-615305) was found to slightly exceed the secondary MCL for TDS. Overall, the groundwater quality from the wells sampled within the SVPA appears to be very good.

6.0 Recommendations for Additional Investigation

Results from this study successfully improved the understanding of hydrogeology in SVPA. During the investigation several areas lacked sufficient type, quantity or quality of data and were noted. The following is a list of some areas and specific tasks identified for further data collection, analysis and investigation:

- Remodel gravity data throughout SVPA based on new data presented in this study.
- Develop additional criteria for determining hydrogeologic units and boundary conditions in ESRV as it relates to SVPA.
- Further explore the hydrogeologic properties and water quality as it relates to mineral facies distribution in the MAU.
- Correlate LAU-age conglomerate to similar units exposed in the Queen Valley, Far West and along Elephant Butte fault south towards Florence through new drilling and mineral analysis from surface outcrops.
- Drill past basalt horizons and basalt flows interbedded with basin-fill deposits to determine hydrogeologic properties of sediment in LAU.
- Determine presence, thickness and extent of LAU in the Superstition Mountains piedmont area.
- Conduct geochronological analysis of sediments from borings drilled in this study and identify new areas where dating of deposits can be applied, for example in the Far West area where LAU is present.
- Perform evaluation of the historical or ancestral positions of Queen Creek deposits between Whitlow Dam and Far West areas.

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Tables

Table 1. Well site selection and location for exploratory borings

Well ID	Registry ID	Cadastral location	Criteria for Selection	Site Elevation (ft-amsl) (USGS Topo)	Total depth completed (ft-bls)	Drill completion date	UTM Easting (NAD83) (meters)	UTM Northing (NAD83) (meters)	Latitude (WGS84)	Longitude (WGS84)
A1	55-225371	D(1-9)20CCC	Uncertainty in depth to bedrock (DTB), subsurface-data gap, intersecting seismic lines, and road access.	1727	1045	1/20/2016	457261	3687150	33.322639	-111.459194
A2	55-225372	D(1-9)22DDC	Poor DTB control, intersecting seismic lines, and road access.	1840	824	2/2/2016	461811	3687214	33.323389	-111.410306
C1	55-225373	D(2-10)18CCA	Lack of well control in area, poor DTB control, subsurface-data gap, intersecting seismic lines, and road access.	1833	1540	3/8/2016	465613	3679359	33.252667	-111.369167
C3a1	55-225374	D(3-10)18DDD	Large data gap, near DTB boundary condition, interbedded basalt and LAU within modeled depth, intersecting seismic lines, and road access.	1740	941	3/30/2016	466881	3669303	33.162005	-111.355186
A3a	55-225615	D(2-9)17DDD	Projected DTB between 1600 and 800 ft at margin with boundary condition, subsurface data gap, and road access.	1690	1500	4/18/2016	458893	3679069	33.249816	-111.441293
B2a	55-226297	D(1-8)36CCC	Subsurface-data gap, intersecting seismic lines, near 1600 ft DTB boundary condition, and road access.	1618	1500	9/19/2016	454007	3683886	33.29307	-111.49398

Table 2. Sample repositories for SVPA boreholes.

Well ID	Registry ID	Sample type, size and location stored				
		Chip trays	Hubco (500g)	Mineral Analysis (300-500g)	Sieve samples (500-1000g)	Cosmogenic/detrital zircon (500g-2kg)
A1	55-225371	AZGS and SRP	2x, AZGS	AZGS	ADOT, discarded	SRP and ASU
A2	55-225372	AZGS and SRP	2x, AZGS	AZGS	ADOT, discarded	SRP and ASU
C1	55-225373	AZGS and SRP	2x, AZGS	AZGS	ADOT, discarded	SRP and ASU
C3a1	55-225374	AZGS and SRP	2x, AZGS	AZGS	ADOT, discarded	SRP and ASU
A3a	55-225615	AZGS and SRP	2x, AZGS	AZGS	ADOT, discarded	SRP and ASU
B2a	55-226297	AZGS and SRP	2x, AZGS	AZGS	ADOT, discarded	SRP and ASU

Note: sample size and depths vary. Some Hubco samples have been used for secondary sampling.

Table 3. Hydrogeologic units in SVPA.

USBR (1977)	Eberly and Stanley (1978)	Laney and Hahn (1986)	Anderson et al. (USGS, 1992)	Corkhill et al. (ADWR, 1993)	Gootee and Young (AZGS, 2008)	Warren (2009)	This study (2017)	Description of Hydrogeologic Units in SVPA
Upper Alluvial Unit	Unit II	Upper Unit (Qs) Middle Unit (QTs)	Upper Basin-Fill (UBF)	Upper Alluvial Unit (UAU)	UAU	Upper sequence	**UAU**	Early Pleistocene to present (~2.5 Ma to present): Fine- and coarse-grained sediment. Greater than 60% fine sediments grades laterally to coarser grade materials near mountain fronts. Deposited by tributaries to the Salt and Gila Rivers, including the main modern tributary Queen Creek. Maximum thickness 200 to 400 ft, averaging 150 to 200 ft.
Middle Fine-Grained Unit		Lower Unit (upper) (Tsu)		Middle Alluvial Unit (MAU)	MAU		**MAU**	Latest Miocene to early Pleistocene (~6 to ~2.5 Ma). Extensive fine grained deposits of clay, silt, mudstone and gypsiferous mudstone, sand and gravel and conglomerate. Weakly to well-cemented with variably-dissemenated calcium-carbonate cement. Fine-grained near basin centers, grading laterally into coarse-grained sediments near mountain fronts. Deposits derived from ancestral Queen Creek and tributaries. Clasts are predominantly schistose, granitic and volcanic depending on facies and adjacent bedrock provinces. This sequence is interpreted to truncate underlying lower basin-fill deposits along basin margins. Maximum thickness ~1,000 ft, averaging 400 to 600 ft.
Lower Conglomerate Unit		Lower Unit (lower) (Tsl)	Lower Basin-Fill (LBF1)	Lower Alluvial Unit (LAU)	Upper LAU		**LAU**	Middle(?) Miocene to late Miocene (~17 to ~6 Ma). Semi-consolidated to consolidated, moderate to well-cemented sandstone and siltstone grading upwards into mudstone and siltstone with massive evaporite (gypsum and anhydrite) and gypsiferous deposits towards basin centers. Locally interbedded with basalt flows. Clasts are predominantly schiistose, granitic and volcanic although may vary significantly due to structural complexity. This sequence is interpreted to truncate the underlying mid-Tertiary sequence (Wagner, 2009). Deposited prior to, during and later Basin and Range faulting (~14 to 8 Ma).
Lower Conglomerate Unit			Lower Basin-Fill (LBF2)		Lower LAU			
(Red Unit)	Unit I	Red Unit (Artega et al., 1968)	Pre-Basin and Range (PBR)	Red Unit	Red Unit	Lower sequence	Bedrock	Late(?) Oligocene to middle(?) Miocene (~25 to ~17 Ma). Red-brown, well-cemented breccia, conglomerate, sandstone and siltstone composed of granitic and volcanic detritus. Lava flows and tuffs are interbedded with sediments. Equivalent to redbed-deposits in Tempe and Papago Park (Christensen et al., 1976; Schulten et al., 1979; Cordy et al., 1978) and Superstition volcanic deposits (Tv and Tvs). Unconformably overlain by middle or lower unit (Laney and Hahn, 1986). Thickness unknown but estimated to be approximately 1,500 to 2,000 m (4,900 to 6,600 ft).
Bedrock	Bedrock	Bedrock	Bedrock	Bedrock	Bedrock	Bedrock		Proterozoic to early Tertiary intrusive igneous and metamorphic rocks, including granite, granodiorite, gneiss, schist and diabase.

Table 4. Summary of hydrogeologic boundaries determined from boring and well analyses.

Depths (ft below land surface)	**A1**	**A2**	**C1**	**C3a1**	**A3a**	**B2a**
Drilled Depth (ft)	1045	824	1540	941	1500	1500
Old Depth to Bedrock (ADWR, 2011) (ft)	300	200	750	1400	2800	2000
Revised Depth to Bedrock (ft)	946	588	1455	3000-3200	3500-4000	2700-3000
DTB Change (ft)	+646	+388	+705	+1600-1800	+700-1200	+700-1000
Depth to Water (ft)	540	320	660	523	488	447.5
Depth to base of UAU (ft)	270	220-280	280-380	290-300	290-350	350-400
Depth to base of MAU (ft)	580	400	500-620	620	530-750	890
Depth to base of LAU (ft)	946	588	1376 or 1455	>941	>1500	>1500
Bedrock at Depth	Pinal Schist	Tertiary conglomerate on Pinal Schist	Rhyolite flow. Conglomeratic LAU 1376-1455'.	unknown	unknown	unknown
New Findings	Change in DTB. New DTW. Possible stream capture at 110' (Coffee Flats)	Change in DTB, DTW. Possible stream capture between 300 and 380 ft. (Coffee Flat fan facies)	Mineral facies consistent with B2a and A3a. Change in DTB. DTW.	Extent and thickness of basalt and cinder. DTW. Possible stream capture above 120' from Gila River.	New DTW. Mineral facies consistent with C1 and B2a.	Mineral facies consistent with C1 and A3a.
Recommendations for future work	Use gravity data to remodel this piedmont	Use gravity data to remodel this piedmont	Correlation of older conglomerates Tqv, Tby, Tso, Tsy in this area and correlation to Far West	Penetrate past basalts to determine LAU properties	Recalibrate with seismic sections PW7 and PW3	none

Table 5. Summary of observations and interpretations from vintage seismic data.

n/a = not available or visual	Vintage seismic lines processed in this study						Previous studies (AZGS, 2008; Warren, 2009)			
	PW1	**PW2**	**PW6**	**PW7**	**PW9**	**CX18**	**PW20**	**PW3**	**CX19**	**PW8**
Overall quality	Good	Moderate	Good	Moderate to good	Good	Poor-moderate	Good to moderate	Moderate	Moderate to good	Poor
Depth to base of UAU	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Depth to base of MAU	n/a	At reflector and contact with basalts encountered in C3a1	n/a	n/a	400-600'?	n/a	Top of basalts?	?	n/a	n/a
Depth to basalts	n/a	620 ft, Calibrated in C3a1.	n/a	possible in A3a at 0.6 and 0.8 seconds, between shot points 300-400 distance in seismic profile PW7.	~1200?	n/a	Visible throughout western portion of section. Structural topography similar upper and lower boundaries, less deformed at top. Hinges with bedrock at Santan Mts, consistent with well data.	Strong in SE portion of line. Consistent with borings and outcrops.	Possibly continuous across deep part of basin.	n/a
Bedrock	Good overall, consistent with A1 and C1 when projected. Shape of DTB consistent with outcrops, wells and x-sections. Consistent with erosional pediment. Type of bedrock unknown.	Possibly lower reflectors below area of C3a1? Bedrock encountered in C1 not visible in section. Estimated DTB from gravity along PW2 is ~1600 along length.	Well calibrated with A1 and A2. Shallow-dipping pediment ; strong bedrock reflector. Slight high relief	Calibrated in A2, but not in A3a where projected. Relatively uniform, erosional pediment with some paleo-topography and possible fault at 325 distance (also interpreted in PW8,	Calibrated well at A1. Traceable near bedrock to NE and into basin near SG-10 and proposed well B2. Shallow erosional pediment; no apparent	Starts at A1, but not imaged. Reflector matches to northeast. Most important bedrock feature is a gentle-graded pediment.	Strong structural topography. Shape of bedrock interpreted agrees very well with well data on both margins of the basin, especially RC wells in Far West to NE.	Calibrated to A1, but not A3a. See AZGS (2008) for discussion of PW3. Fault along NE side of Hawk Rock high extends towards A1/A2 but not apparent in CX18 or PW8 near US60. Bedrock pediment on NW side remains apparent. .Toward basin DTB is irregular consistent with	Relatively shallow embayed pediments on both Santan and Superstition margins, down near elevation of basalt/LAU reflector. Higley Fault defines master low-angle detachment fault and DTB on western margin of basin, with strata dipping southwest, fault dipping	Shallow pediment of unknown depth. Upper/Lower Sequence hinged on fault-controlled bedrock pediment (Warren, 2009).

n/a = not available or visual	Vintage seismic lines processed in this study						Previous studies (AZGS, 2008; Warren, 2009)			
	PW1	**PW2**	**PW6**	**PW7**	**PW9**	**CX18**	**PW20**	**PW3**	**CX19**	**PW8**
			west of A1, likely an extension of Hawk Rock high. Agrees with shape of current DTB, but not depth.	Warren, 2009).	faults or relief.			structural topography. Axis of DTB consistent with modeled DTB from gravity. DTB unclear on SE margin.	northeast (Warren, 2009).	
Other observations	Shallow dip to east. Slight hummocky topography; likely buried paleo-topography. Bedrock highs on either side of C1 consistent with erosional trough, rather than structural. No apparent faults or basalts.	Dip of reflector to north, with axis a few km south of Florence Junction. Groundwater elevation contour map follows this gradient as well.	No apparent basalt horizon seen in PW9. No apparent faults; however, one possible at 240 distance.	One to two horizons above interpreted bedrock may coincide with basalt and/or MAU/LAU boundary. Interpreted fault and hinge of Upper/Lower Sequence (Warren, 2009) as an unconformity at ~325 distance is consistent here too.	Second potential reflector between 340 and 320 distance at 1 to 1.5 seconds Queen Creek channel?. Calibrated with PW6 and A1/A2 connection. Where PW3/9 meet a NE dipping, NW/SE striking fault is apparent, but not well	No faults or prominent paleo-topography apparent.	None	Basalt horizon has strong reflector, but not apparent in A3a cuttings.	Antithetic faults dipping towards Higley Fault may have 100+ meters displacement on them.	Bedrock pediment is ~8 to 10 km wide. Upper/Lower sequence on deep basin-fill margin is consistent with basalt horizon seen in PW3 where PW8 intersects.

n/a = not available or visual	Vintage seismic lines processed in this study						Previous studies (AZGS, 2008; Warren, 2009)			
	PW1	**PW2**	**PW6**	**PW7**	**PW9**	**CX18**	**PW20**	**PW3**	**CX19**	**PW8**
					seen here. A low-relief swale is imaged and is consistent with modeled DTB from gravity.					
Problems/discrepancies	None apparent.	Bedrock below C3a1 and around C1 not visible.	None	Bedrock projected in A3a, but not encountered. Basalts not encountered but mineral analysis suggest possible. Unconformity between MAU and LAU is favored interpretation.	None	None	None	A3a is less calibrated than in PW7. Uppermost reflectors interpreted to represent top of LAU, unconformably overlain by MAU.	Upper depths along margin not as deep as 1 km. Depths need further calibration.	None
Recommendations for future work	Calibrate to CX18, PW7, 8 and 9.	Confirm thickness of basalt/conglomerate interbedded sequence and depth to mid-Miocene and older bedrock.	None	None	Calibrate with SG10 and proposed well B2.	None.	Focus on faults within MAU and upper LAU to better understand facies and groundwater flow. Model structural history to explain Tal on both sides of basin with resulting DTB.	None	Needs to be recalibrated based on recent data?	None

Table 6. Summary of Phase II Aquifer Test Results: Well Pertinent Data and Transmissivity.

Well Name	Well Owner	ADWR Registry	Cadastral	Well Depth (ft)	Well Dia (inch)	Perf Top (ft)	Perf Bottom (ft)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)	Analytical Method
Queen Creek Pit Well	ASLD	55-209685	D(2-9)15DBB	815	8.625	610	690	27	296,100	Theis Recovery
Ranch 160 No.1 (East Well)	AWC	55-583450	D(2-10)5CCD	1330	12	780	1140	9.6	101,450	Cooper Jacob & Theis Recovery
Ranch 160 No.2 (West Well)	AWC	55-588620	D(2-10)6DDD	1255	16	560	1240	0.4*	1,232	Theis Recovery
Test Well B2a	ASLD	55-226297	D(1-8)36CCC	1228	12.75	700	1200	4.2	9,832	Theis & Theis Recovery

* Source: ADWR Pump Installation Completion Report, dated 8-26-2002.

Table 7. Summary of Groundwater Quality, Superstition Vistas.

Well Owner	Location Description	ADWR 55ID	Cadastral	Well Depth (ft)	Perforation Interval (ft)	Sample Date	Arsenic (As)	Fluoride (F)	Nitrate as Nitrogen (NO3-N)	Total Dissolved Solids (TDS)
							MCL= 10 ug/l	MCL=4 mg/l	MCL= 10 mg/l	SMCL = 500 mg/l
Phase I Sampling										
ASLD	North of QC Wash	522742	D(1-9)28ABA	960	660-960	4/1/2014	2.64	0.535	2.55	180
ASLD	North of QC Wash	574909	D(1-9)28AAD	1000	640-1000	4/1/2014	3.36	0.614	1.95	140
ASLD	North of QC Wash	615234	D(2-9)01ABB	860	560-860	4/2/2014	7.93	0.52	2.33	220
ASLD	Near QC Wash	209685	D(2-9)15DBB	690	610-690	4/1/2014	<1.0	0.122	2.23	260
ASLD	South of QC Wash	615305	D(3-10)34CAC	N/A	N/A	4/2/2014	3.77	0.368	0.475	530
Phase II Sampling										
AWC W	Near QC Wash	588620	D(2-10)6DDD	1250	560-1240	10/11/2016	4.3	<0.40	0.54	350
AWC E	Near QC Wash	583450	D(2-10)5CCD	1150	780-1140	12/14/2016	1.2	<0.40	1.6	440
ASLD (B2a)	North of QC Wash	226297	D(1-8)36CCC	1220	700-1200	12//2/2016	2.27	0.187	1.97	230

Notes:

QC - Queen Creek

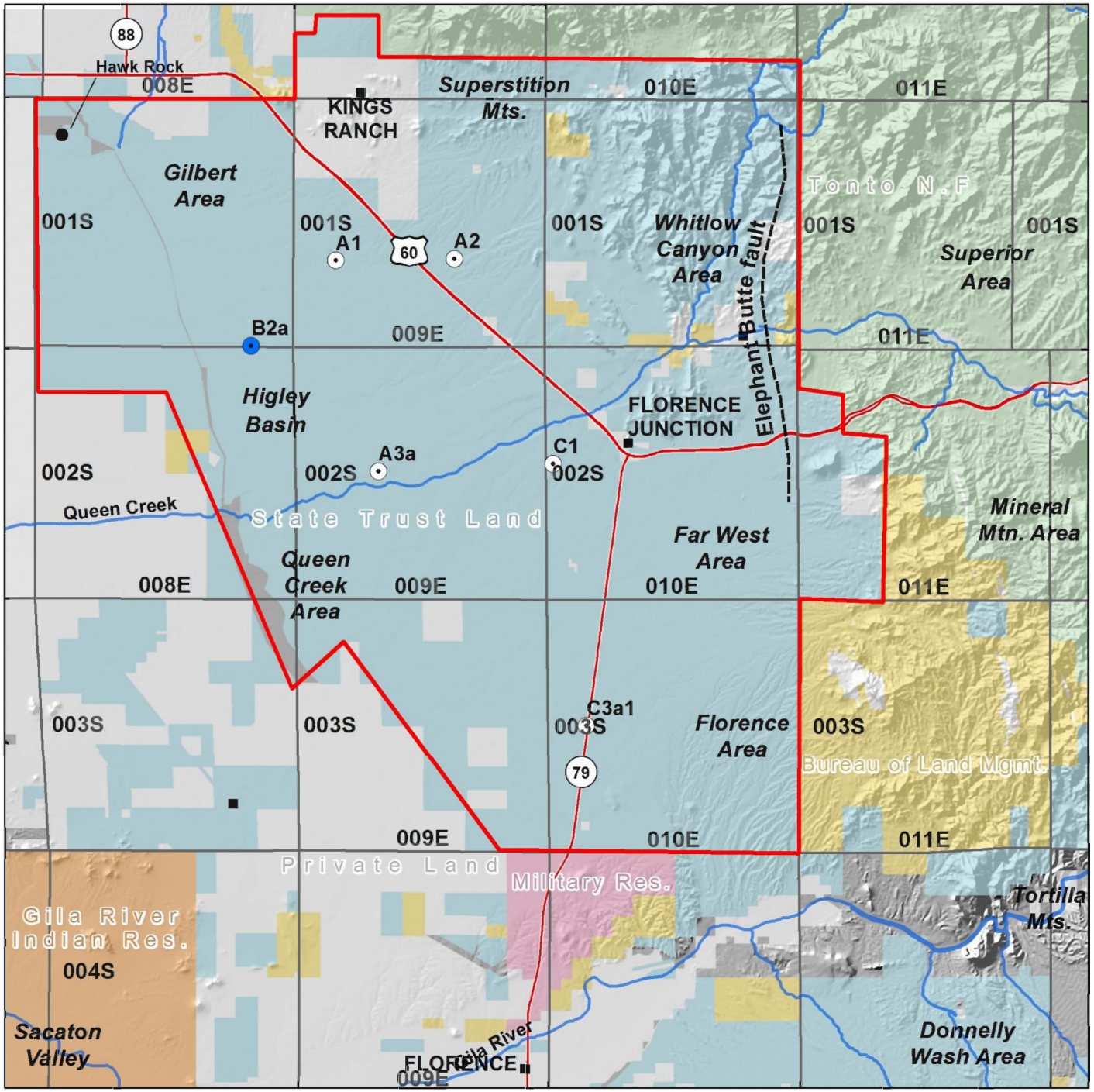
N/A - Not Analyzed

MCL - Maximum Contaminant Level

SMCL - Secondary Maximum Contaminant Level

Figures

Figure 1. Superstition Vistas Planning Area Map



Borings/Test Well in this study

- Borings
- Test Well

Land Ownership

- BLM
- Forest
- Indian Res.
- Military
- Private
- State Trust
- *Superstitions Vistas Planning Area*
- *Township (N/S) and Range (E/W)*
- *Major drainages*
- Roads - Secondary

Shaded Relief Map

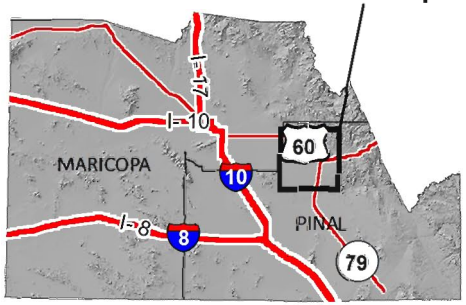
High : 254

Low : 0

0 1 2 3 4 Miles

N

Index map

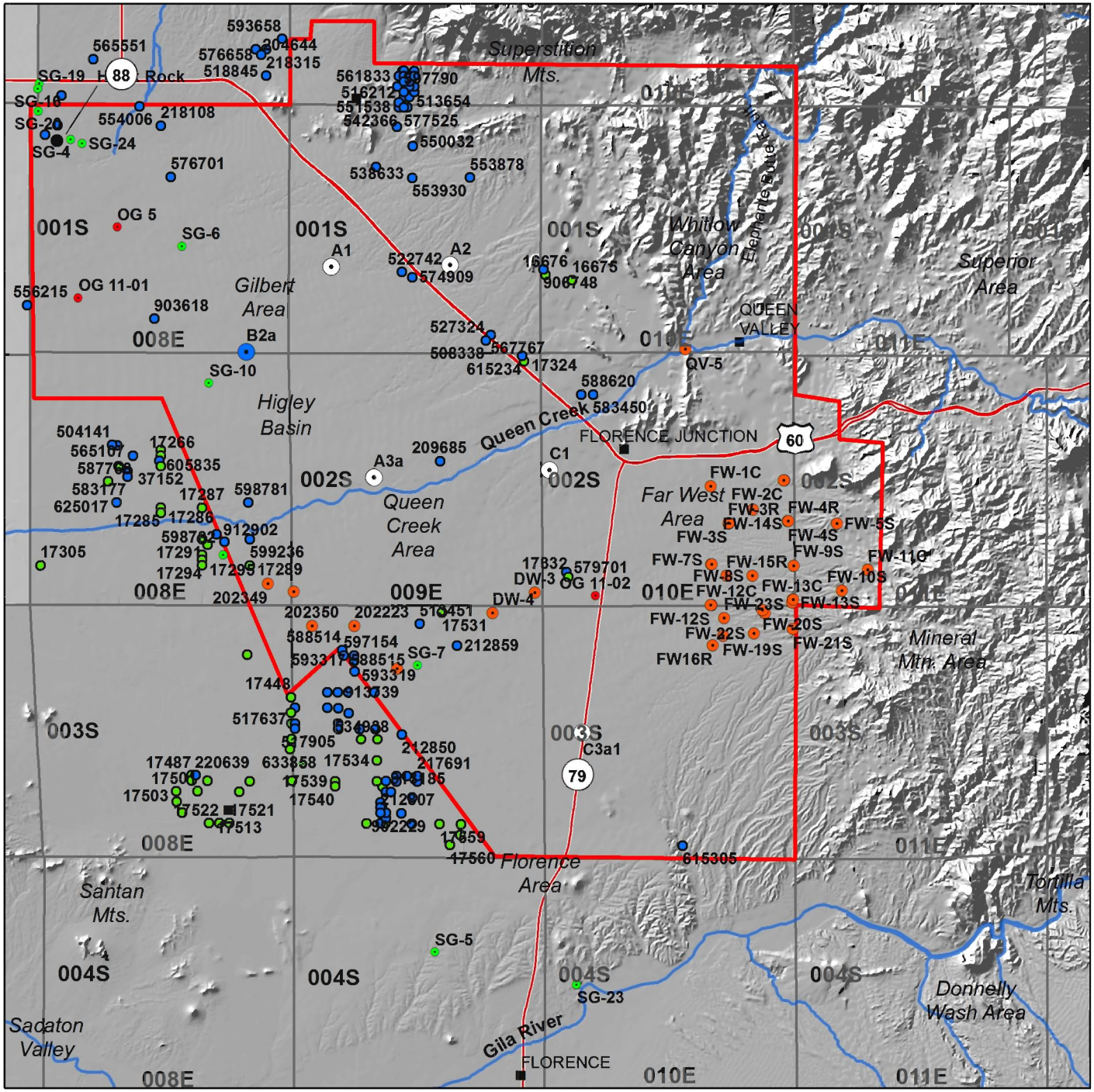


Location: C:\Data\Current Projects\SRP\projects\Figure 1 SVPA Map.mxd

Last updated: 4/26/2017

Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Figure 2. Well Location Map



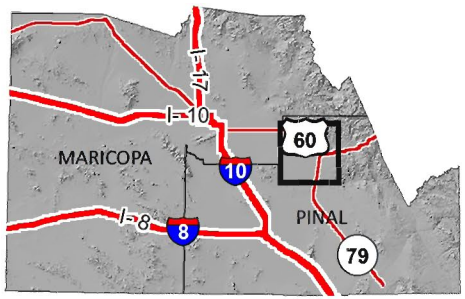
Wells/Borings in SVPA and vicinty

- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Superstitions Vistas Planning Area*
- *Major drainages*
- *Township (N/S) and Range (E/W)*
- Roads - Secondary

Miles
0 1 2 3 4

N

Index map



Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Location: C:\Data\Current Projects\SRP\projects\Figure 2 well location map.mxd

Last updated: 4/26/2017

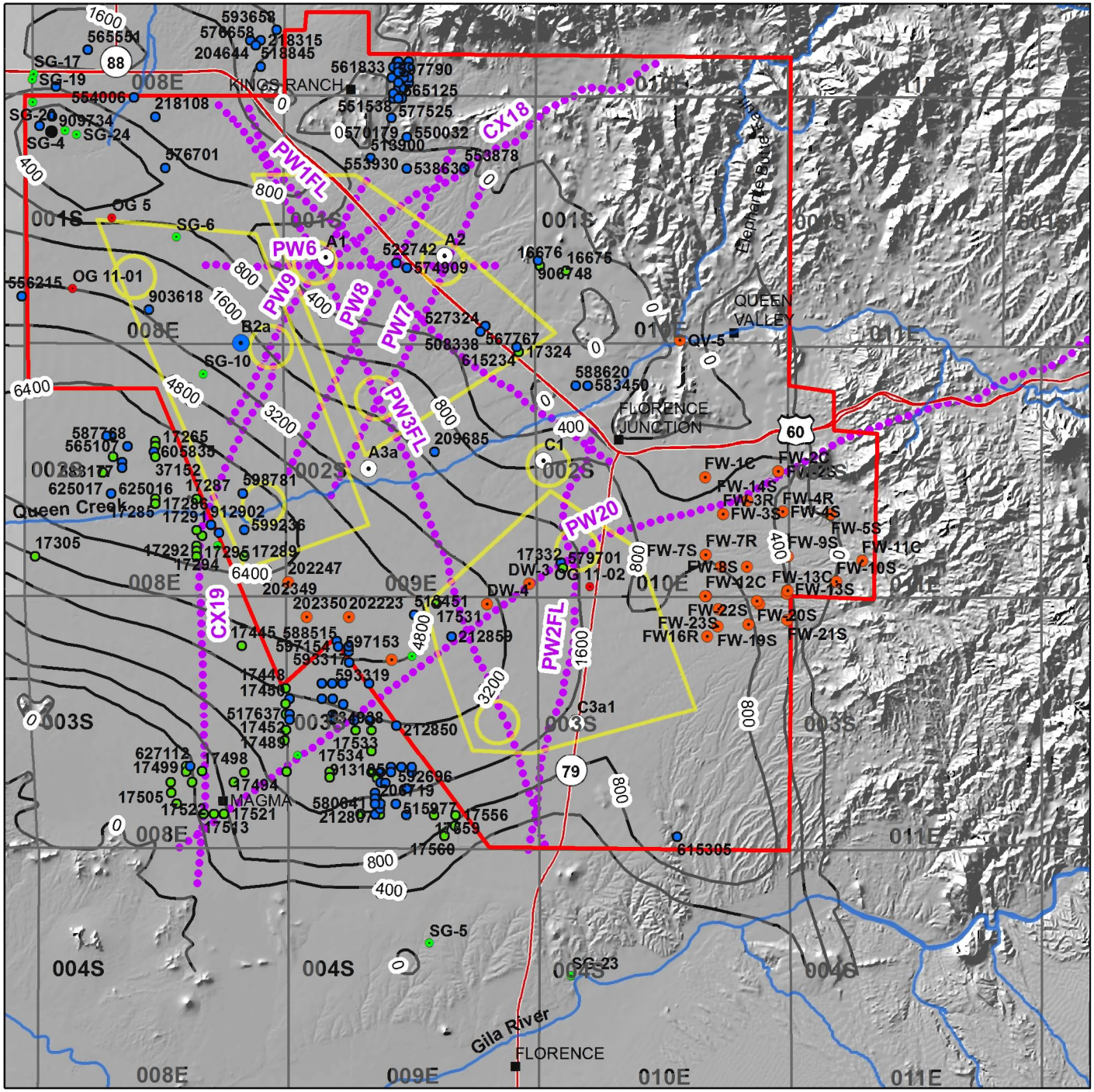


Figure 3. Site Selection Areas

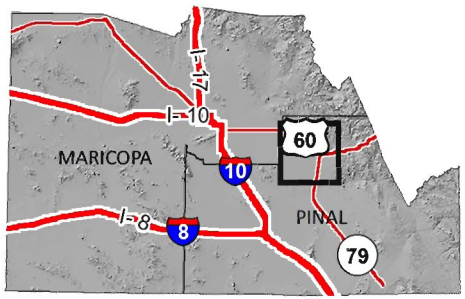
Wells in SVPA and vicinty

- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Areas and sites of interested for further exploration*
- *Superstitions Vistas Planning*
- *Township (N/S) and Range (E/W)*
- Roads - Secondary
- *Major drainages*
- *Vintage seismic lines used in this study, processed and analyzed by University of Arizona seismic group, 2008 and 2016.*
- *Depth-to-bedrock contour (ft-bls) (ADWR, 2011; AZGS, 2012)*

0 1 2 3 4 Miles

N

Index map

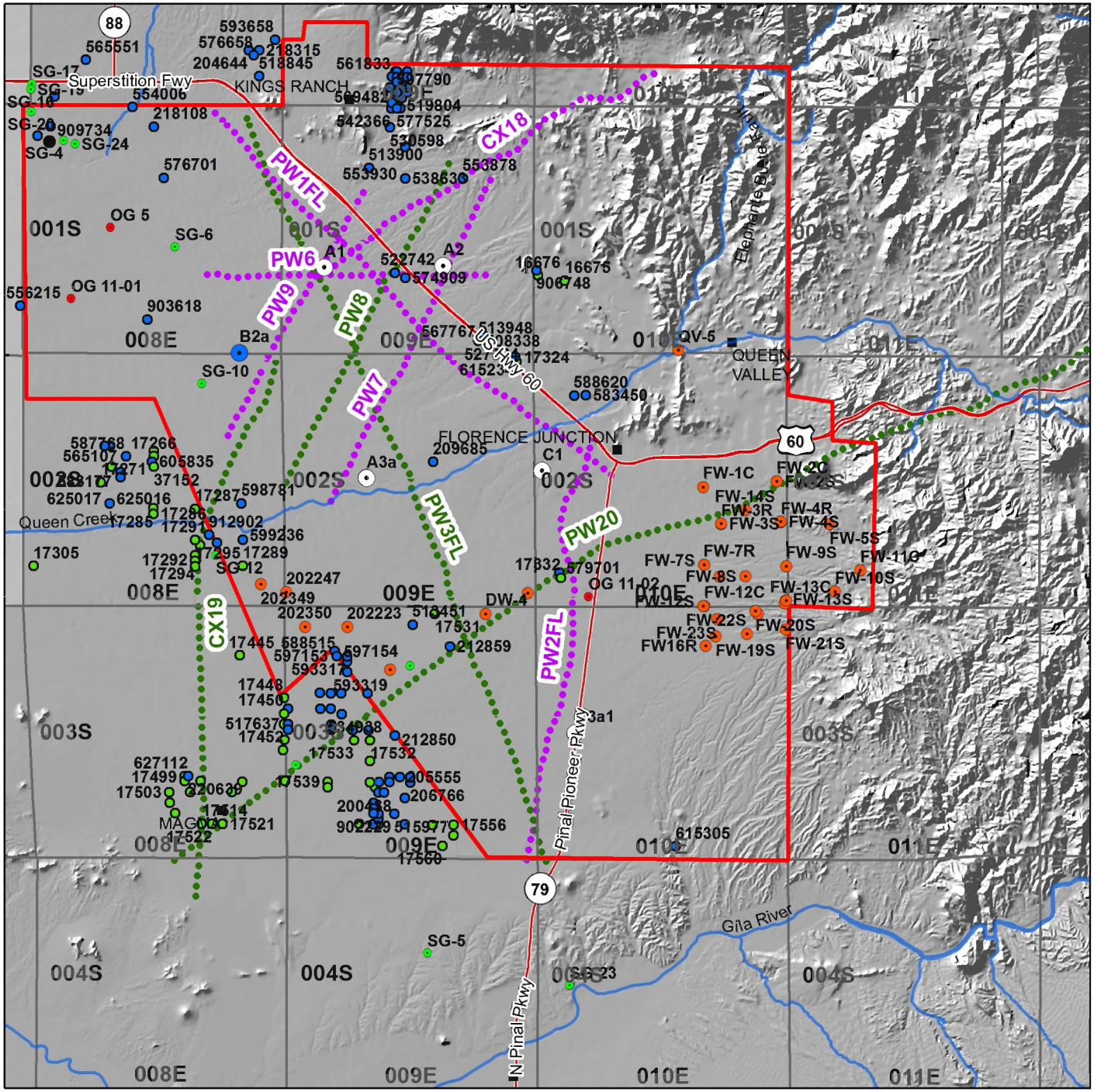


Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Location: C:\Data\Current Projects\SRP\projects\Figure 3 site selection areas.mxd

Last updated: 4/26/2017

Figure 4. Vintage Seismic Lines Used in this Study



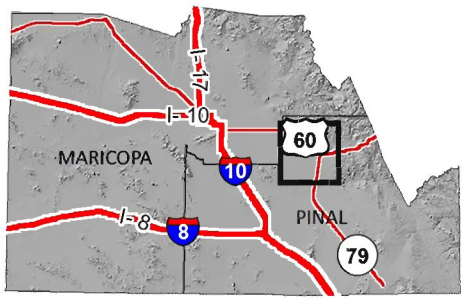
Wells in SVPA and vicinty

- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Superstitions Vistas Planning*
- *Township (N/S) and Range (E/W)*
- Roads - Secondary
- *Major drainages*
- *Vintage seismic lines used from AZGS (2008) and Warren (2009)*
- *Vintage seismic lines used in this study*

N

0 1 2 3 4 Miles

Index map

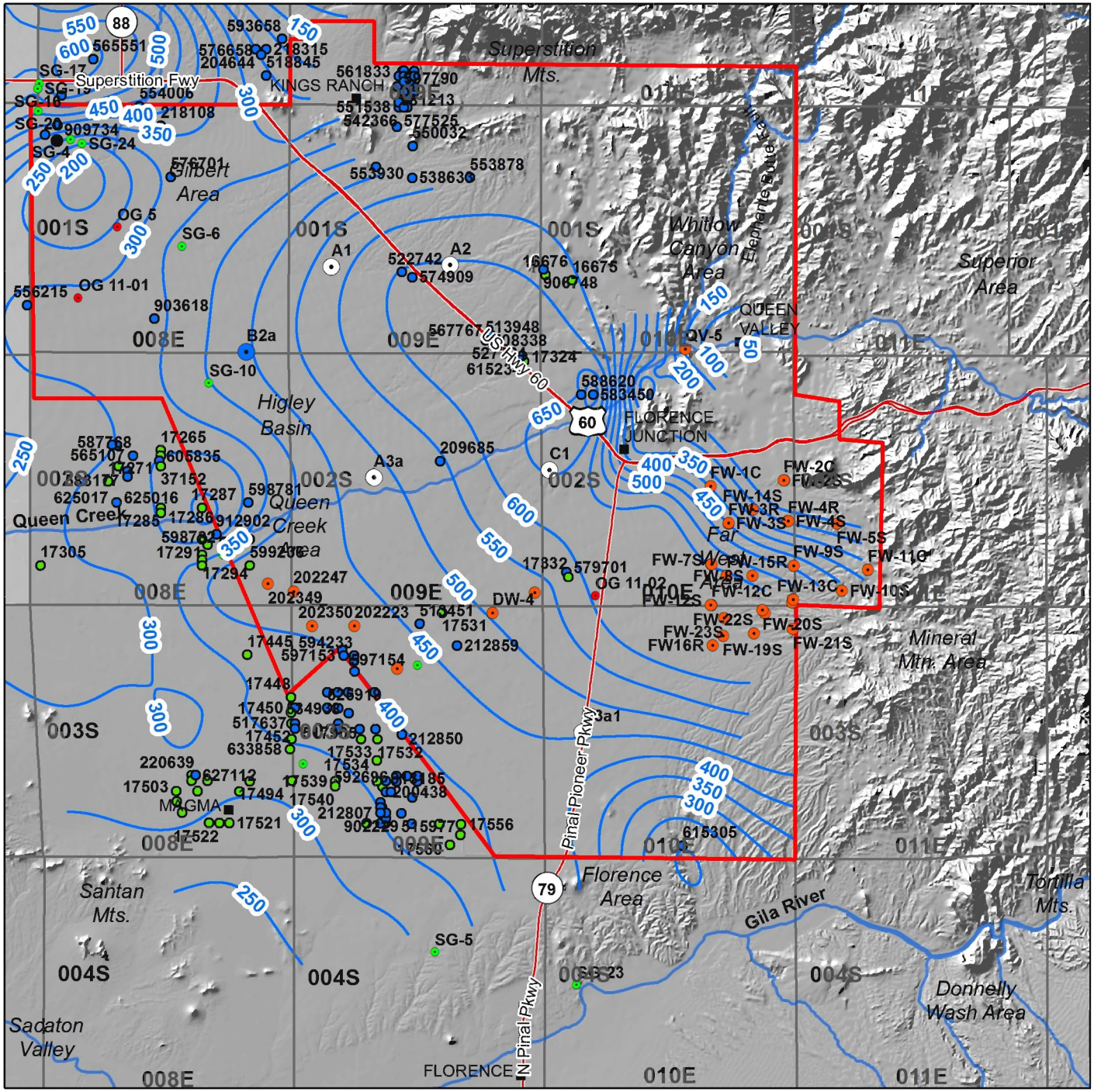


Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Location: C:\Data\Current Projects\SRP\projects\Figure 4 seismic lines SVPA 2016.mxd

Last updated: 4/26/2017

Figure 5. Depth to Groundwater Contour Map (SRP, 2014)



Depth to groundwater

- *Depth to Groundwater (ft-bls) (contour interval = 50 ft)*

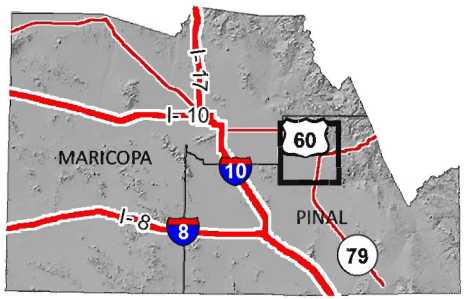
Wells/Borings in SVPA and vicinty

- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Superstitions Vistas Planning Area*
- *Major drainages*
- *Township (N/S) and Range (E/W)*
- Roads - Secondary

0 1 2 3 4 Miles

N

Index map



Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Location: C:\Data\Current Projects\SRP\projects\Figure 5 depth to groundwater.mxd

Last updated: 4/26/2017

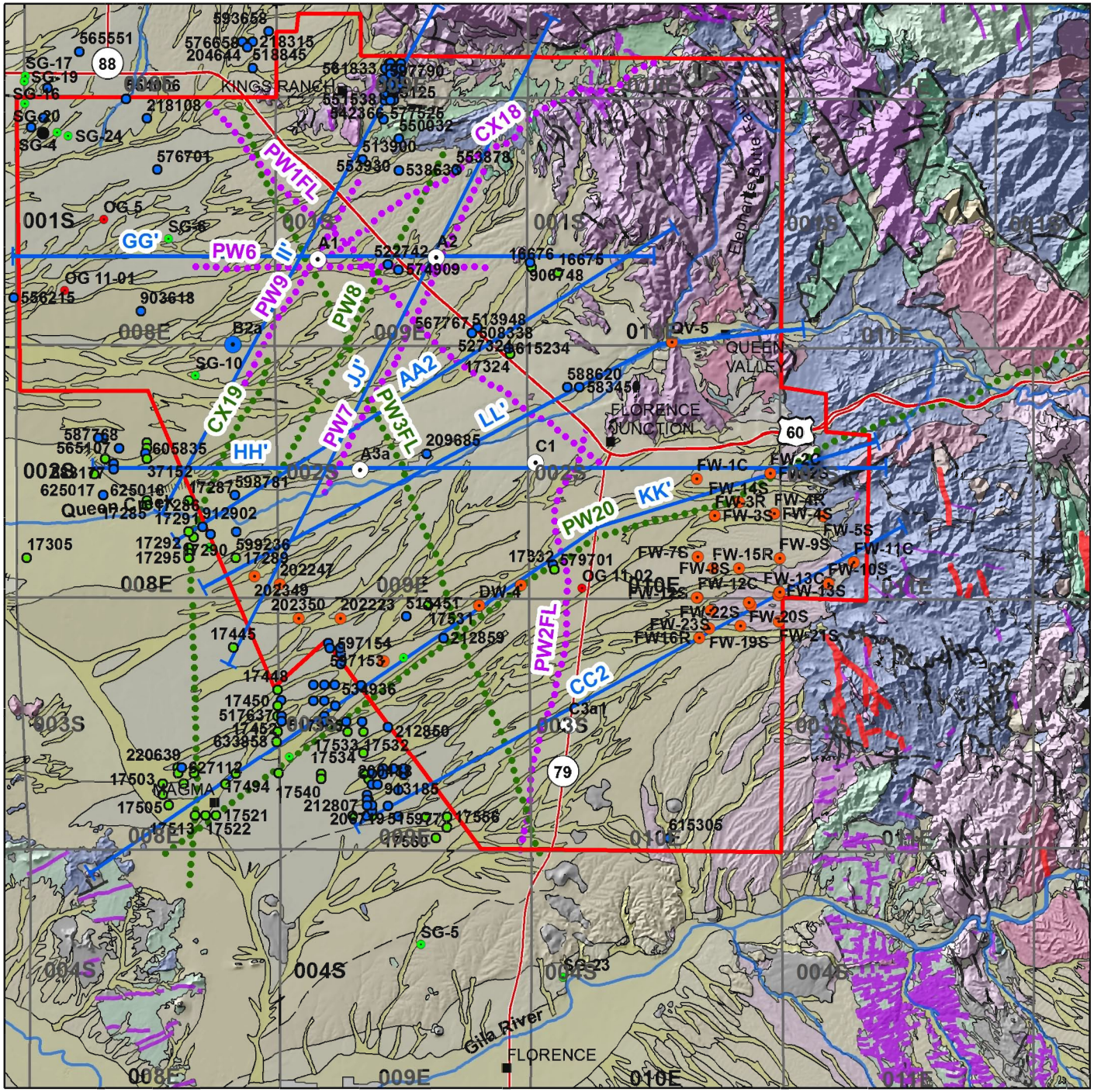


Figure 6. Location of Hydro-geologic cross-sections

Wells in SVPA and vicinty

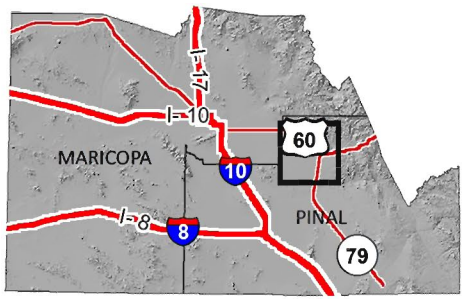
- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Superstitions Vistas Planning Area*
- *Township (N/S) and Range (E/W)*
- Roads - Secondary
- *Major drainages*
- *Vintage seismic used from AZGS (2008) and Warren (2009)*
- *Vintage seismic data used in this study*
- *Geologic cross-sections (this study)*

Geologic map compiled from Pearthree et al. (2015); see map and Plate 2 for detail of units.

Miles 0 1 2 3 4

N

Index map



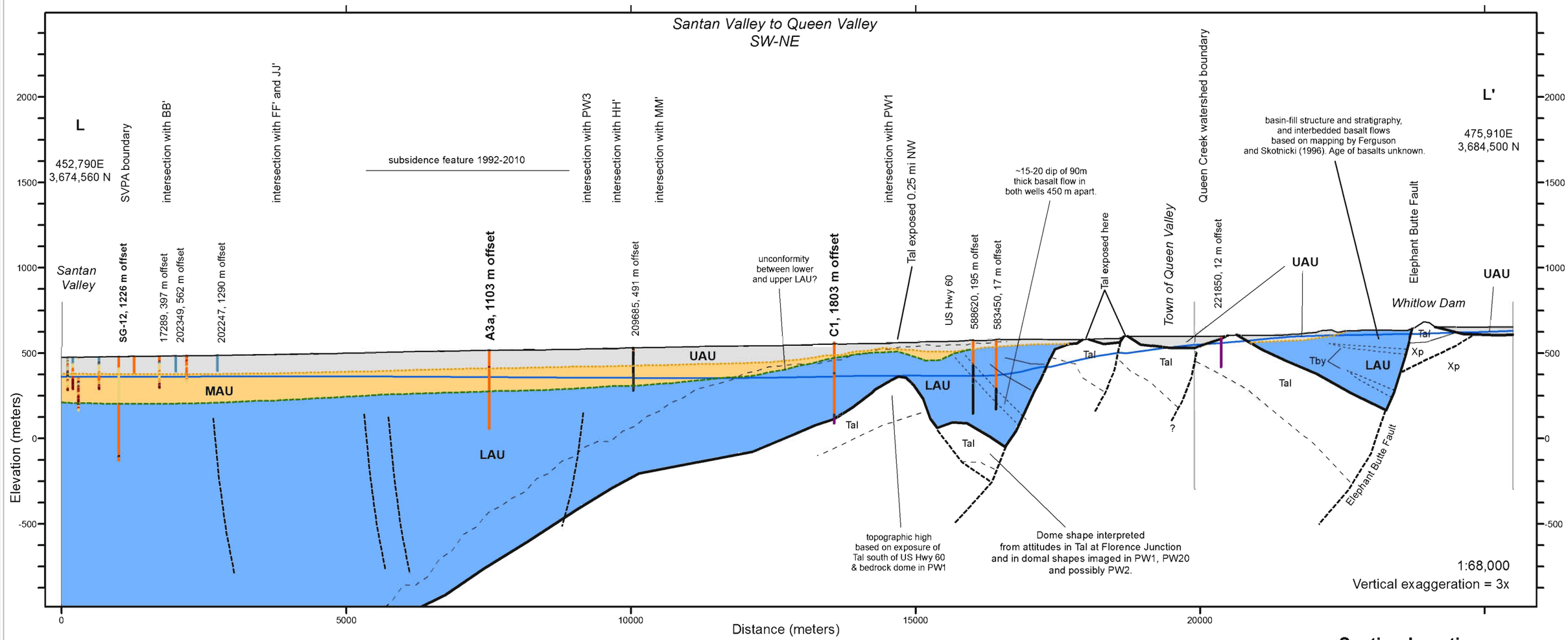
Location: C:\Data\Current Projects\SRP\projects\Figure 6 cross section locations.mxd

Last updated: 4/26/2017

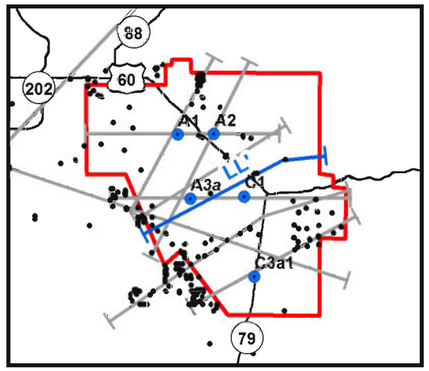
Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Superstition Vistas Planning Area

Figure 7. Hydrogeologic Cross Section L-L'



Section Location



Hydrogeologic contacts/other

- *Depth to water (2017)*
- *Bottom of UAU*
- *Bottom of MAU*
- *Depth to bedrock (2017)*
- *Depth to bedrock (2012)*

Hydrogeologic units

- *Upper Alluvial Unit*
- *Middle Alluvial Unit*
- *Lower Alluvial Unit*

Borehole lithology

- *Predominantly gravelly sediments*
- *Predominantly sand and gravel*
- *Predominantly silt and clay*
- *Predominantly clayey sediments*
- *Predominantly conglomeratic sediments*
- *Evaporite or evaporitic sediments*
- *Basalt flows or vents*
- *Felsic/intermediate volcanic rocks*
- *Crystalline bedrock (igneous or metamorphic)*
- *Unknown rock or sediment*

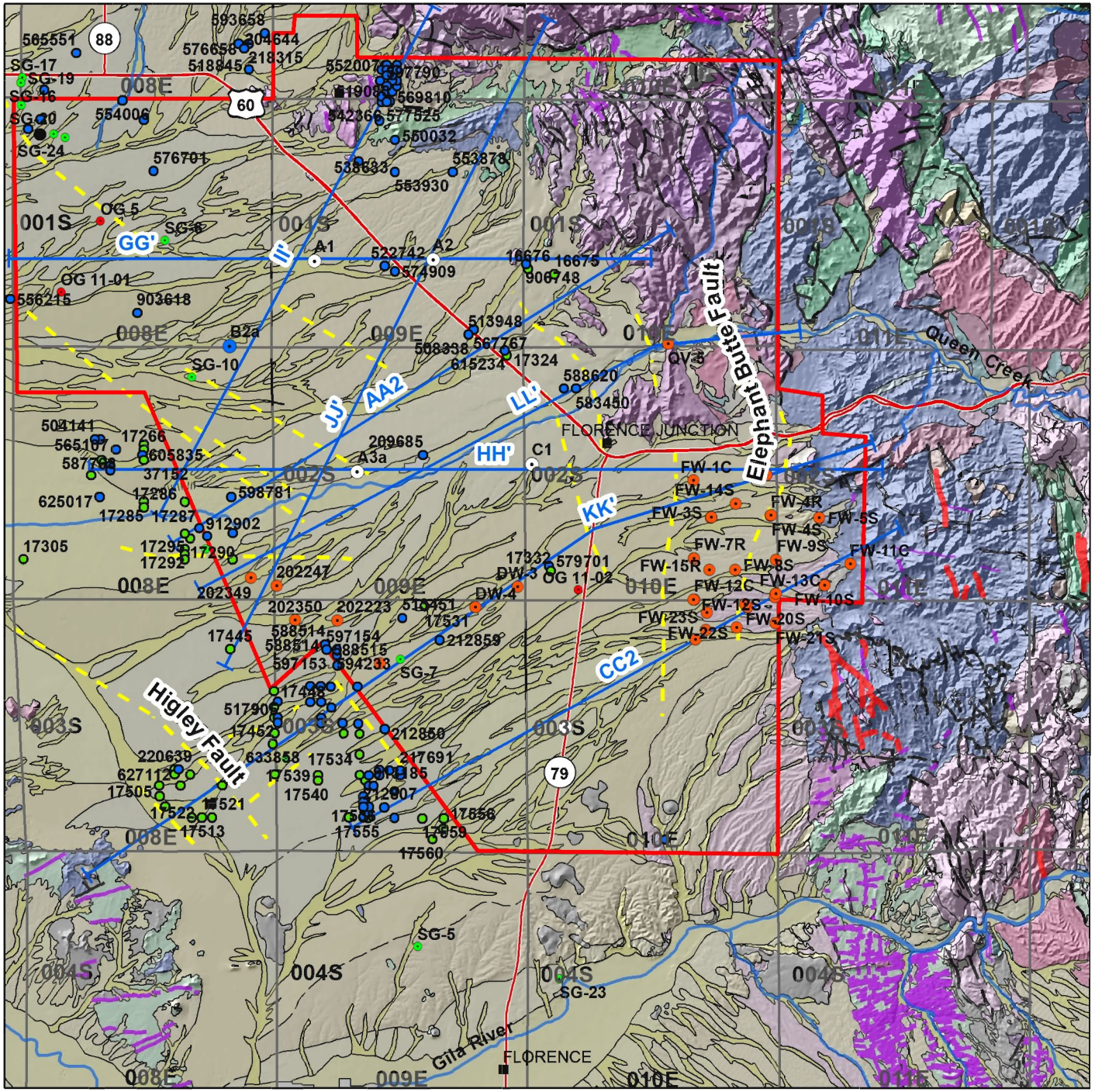


Figure 8. Geologic map and faults in SVPA.

Wells in SVPA and vicinty

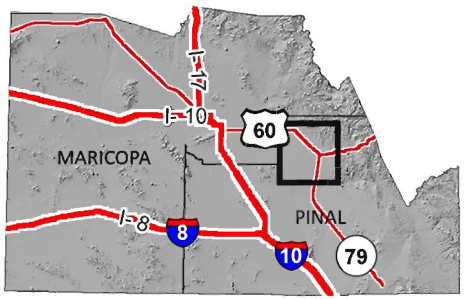
- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Geologic cross-sections (this study)*
- *Superstitions Vistas Planning Area*
- *Major drainages*
- *Township (N/S) and Range (E/W)*
- Roads - Secondary
- *Faults interpreted to cross-cut LAU stratigraphy, concealed by younger alluvium (Laney & Hahn, 1986; AZGS, 2008, Warren, 2009, Gootee, 2012 and this study)*

Geologic map compiled from Pearthree et al. (2015). See reference and Plate 2 for detail.

Miles 0 1 2 3 4

N

Index map

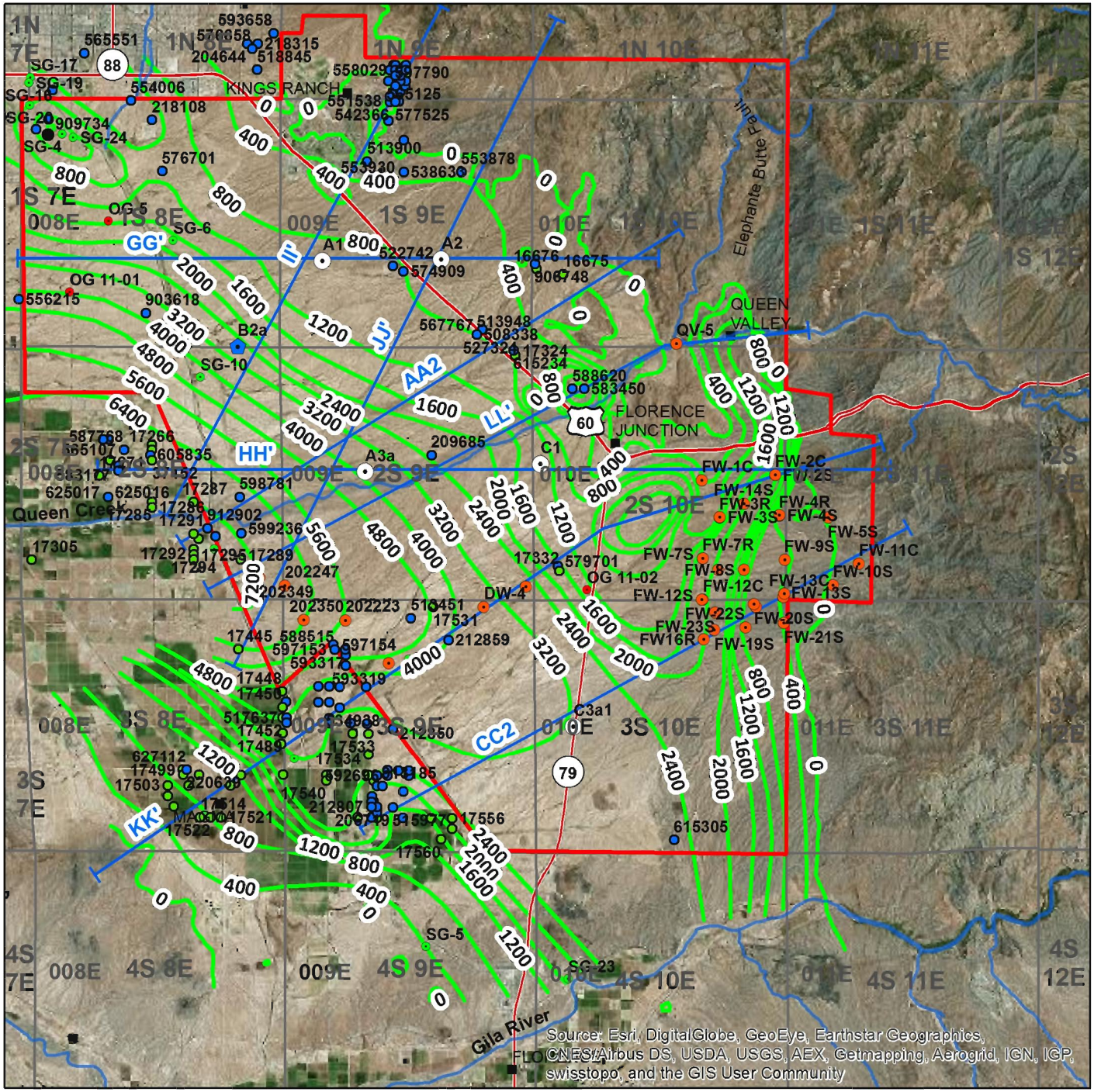


Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Location: C:\Data\Current Projects\SRP\projects\Figure 8 Geologic map and faults of SVPA.mxd

Last updated: 6/27/2017

Figure 9. Depth to base of Lower Alluvial Unit



Wells in SVPA and vicinty

- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Geologic cross-sections (this study)*
- *Superstitions Vistas Planning*
- *Major drainages*
- *Township (N/S) and Range (E/W)*
- Roads - Secondary

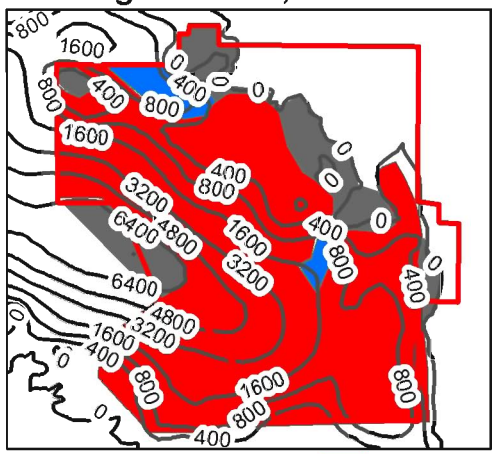
Depth to base of LAU

- *Depth to base of Lower Alluvial Unit or bedrock (ft-bls)*

0 1 2 3 4 Miles

N

Changes in DTB, 2012-2017

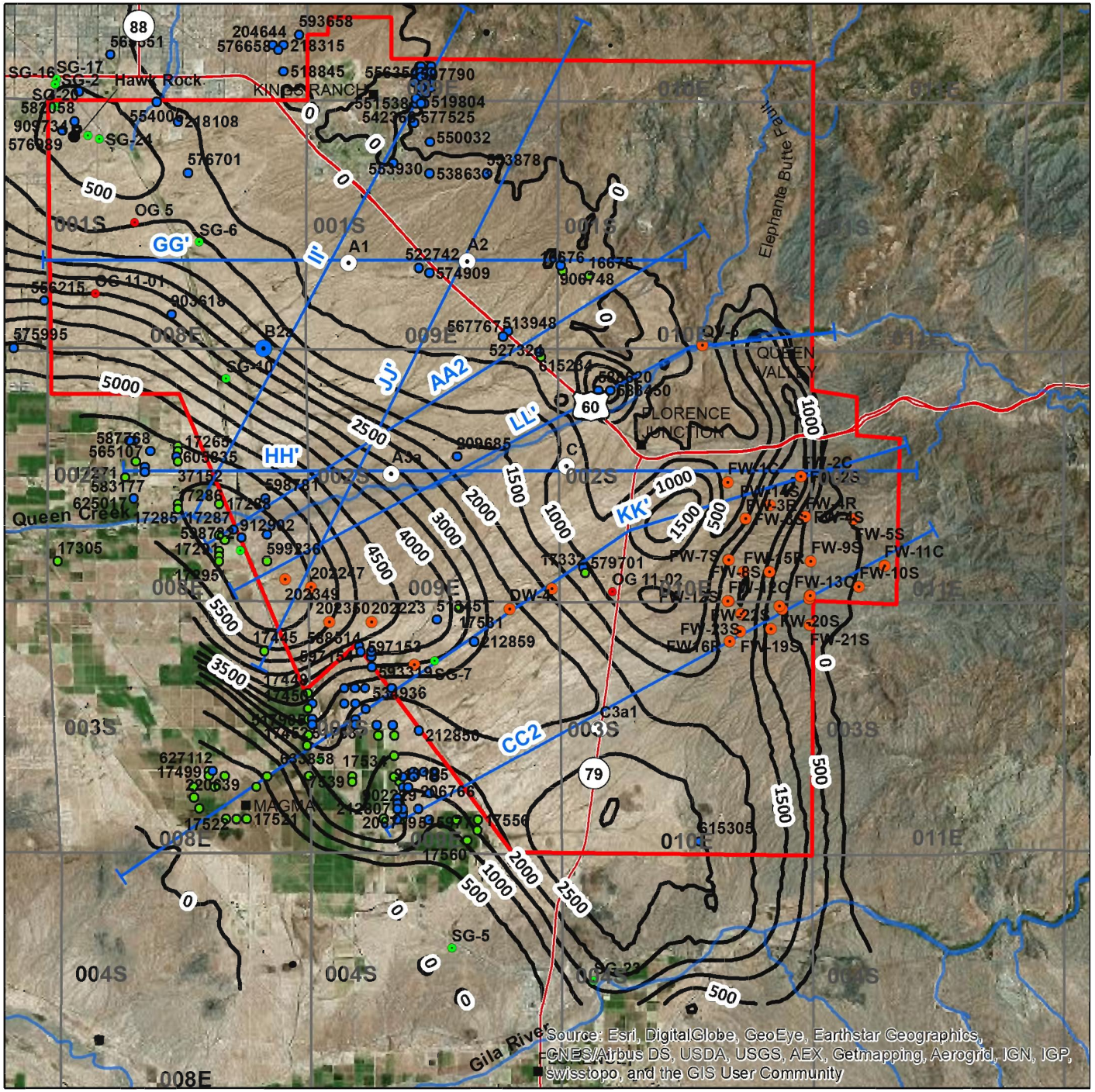


- *Depth-to-bedrock contour (ft-bls) (ADWR, 2011; AZGS, 2012)*
- Decrease DTB
- Increase DTB
- No change DTB

Location: C:\Data\Current Projects\SRP\projects\Figure 9 Depth to Base LAU.mxd

Last updated: 4/26/2017

Figure 10. Isopach map of LAU



Wells in SVPA and vicinty

- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Geologic cross-sections (this study)*
- *Superstitions Vistas Planning Area*
- *Major drainages*
- *Township (N/S) and Range (E/W)*
- Roads - Secondary

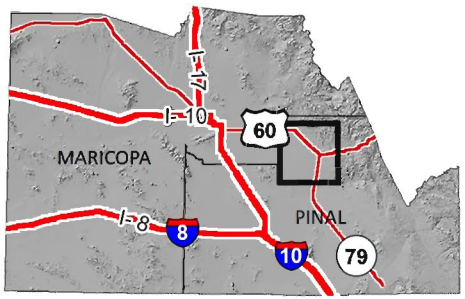
Thickness of LAU

- *Isopach (thickness) map of LAU (feet).*

N

Miles 0 1 2 3 4

Index map

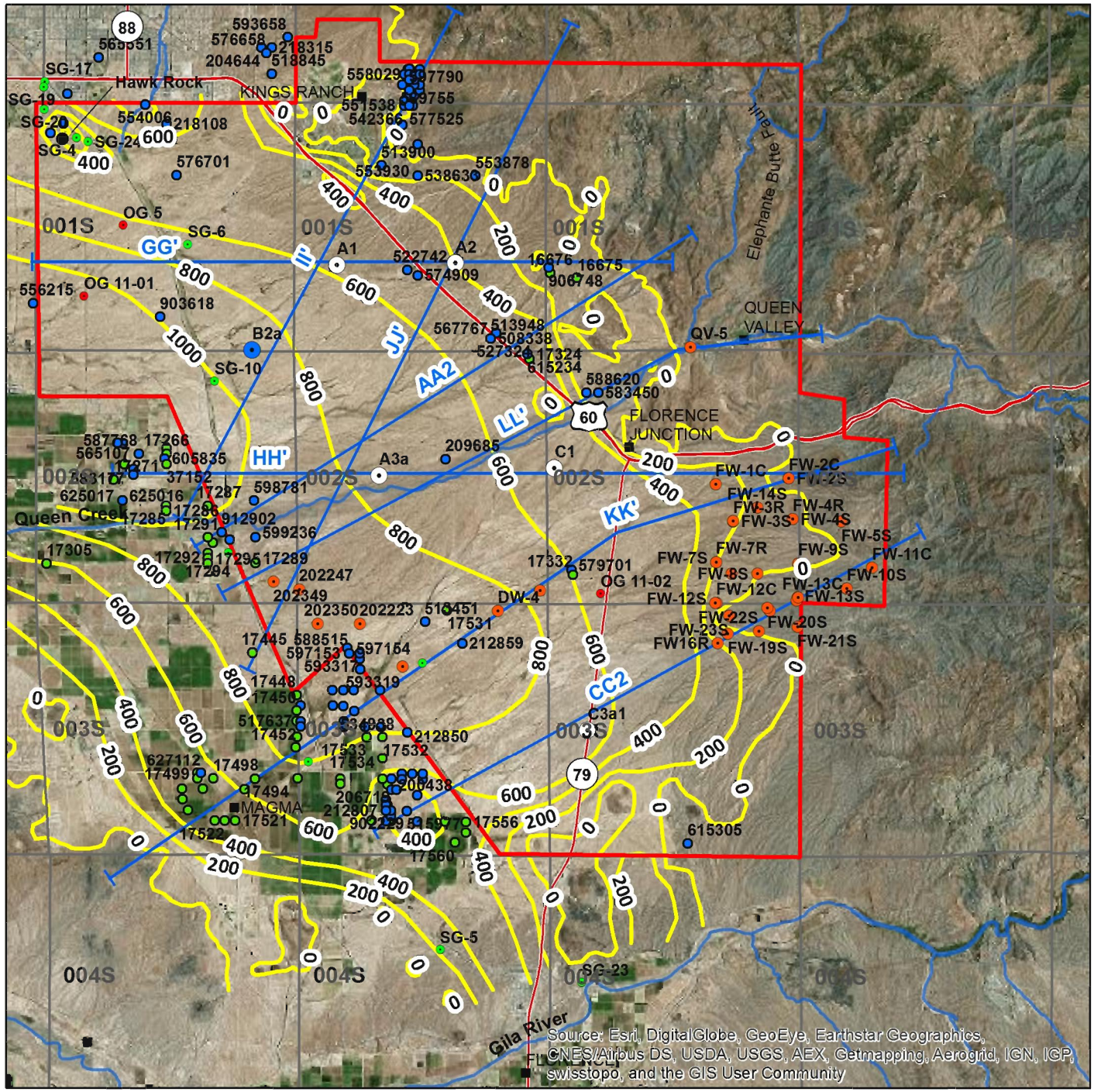


Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Location: C:\Data\Current Projects\SRP\projects\Figure 10 Isopach LAU.mxd

Last updated: 6/27/2017

Figure 11. Depth to base of Middle Alluvial Unit



Wells in SVPA and vicinty

- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Superstitions Vistas Planning Area*
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- Roads - Secondary
- *Major drainages*
- *Geologic cross-sections (this study)*

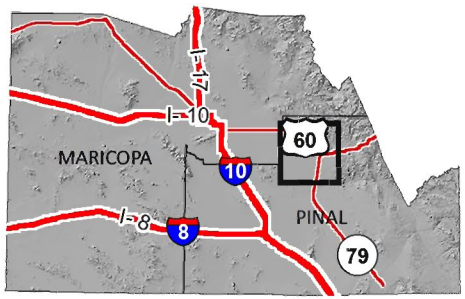
Depth to bottom MAU

- *Depth to based of Middle Alluvial Unit (ft-bls)*

N

0 1 2 3 4 Miles

Index map

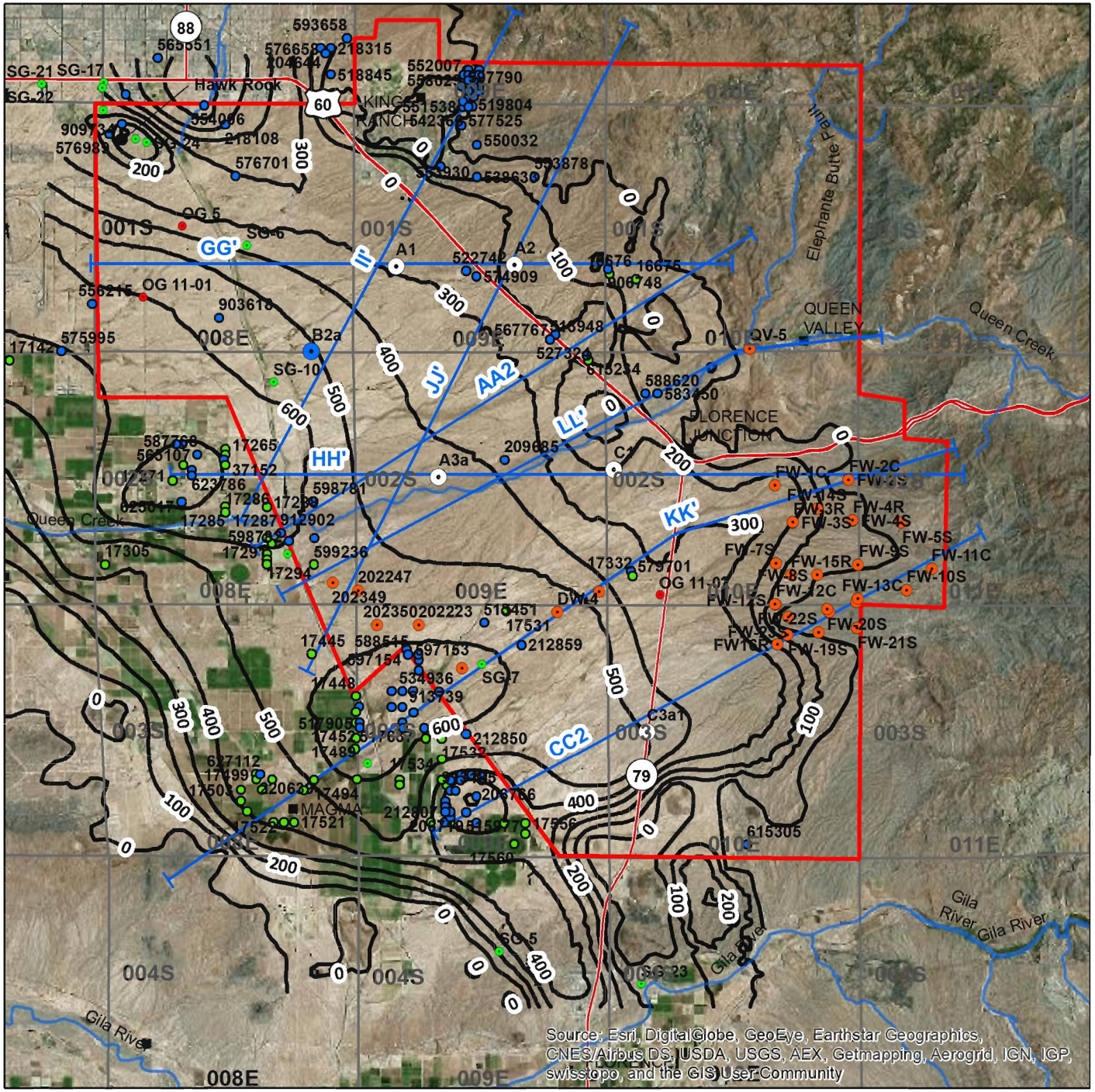


Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Location: C:\Data\Current Projects\SRP\projects\Figure 11 Depth to Base MAU.mxd

Last updated: 4/26/2017

Figure 12. Isopach map of Middle Alluvial Unit



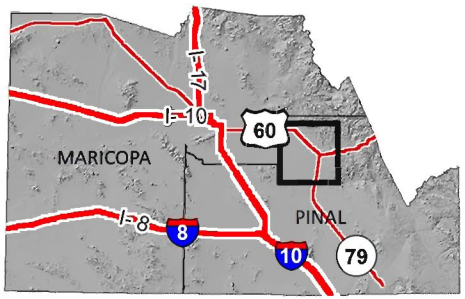
Wells in SVPA and vicinty

- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Geologic cross-sections (this study)*
- *Superstitions Vistas Planning Area*
- *Major drainages*
- *Township (N/S) and Range (E/W)*
- Roads - Secondary
- *Isopach (thickness) map of Middle Alluvial Unit (feet)*

Miles 0 1 2 3 4

N

Index map

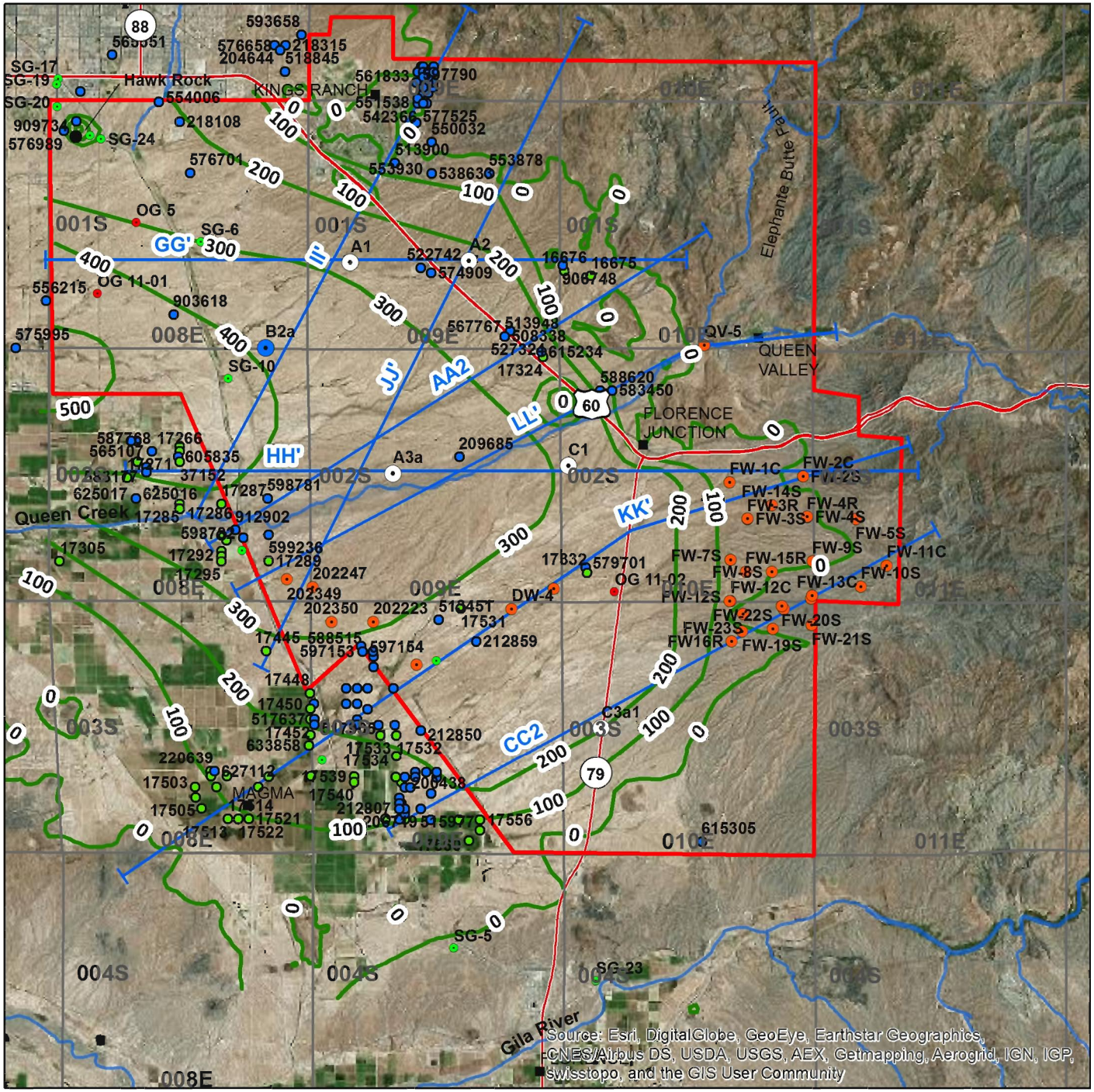


Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Location: C:\Data\Current Projects\SRP\projects\Figure 12 Isopach MAU.mxd

Last updated: 6/27/2017

Figure 13. Depth to Base of Upper Alluvial Unit



Wells in SVPA and vicinty

- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Superstitions Vistas Planning*
- *Township (N/S) and Range (E/W)*
- Roads - Secondary
- *Major drainages*
- *Geologic cross-sections (this study)*

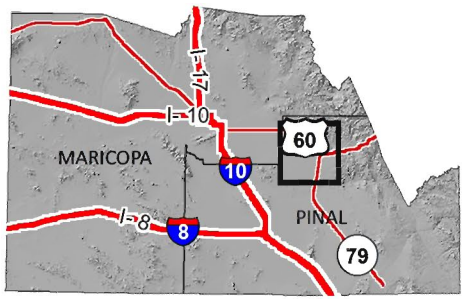
Depth to Bottom UAU

- *Depth to base of Upper Alluvial Unit (ft-bls)*

0 1 2 3 4 Miles

N

Index map

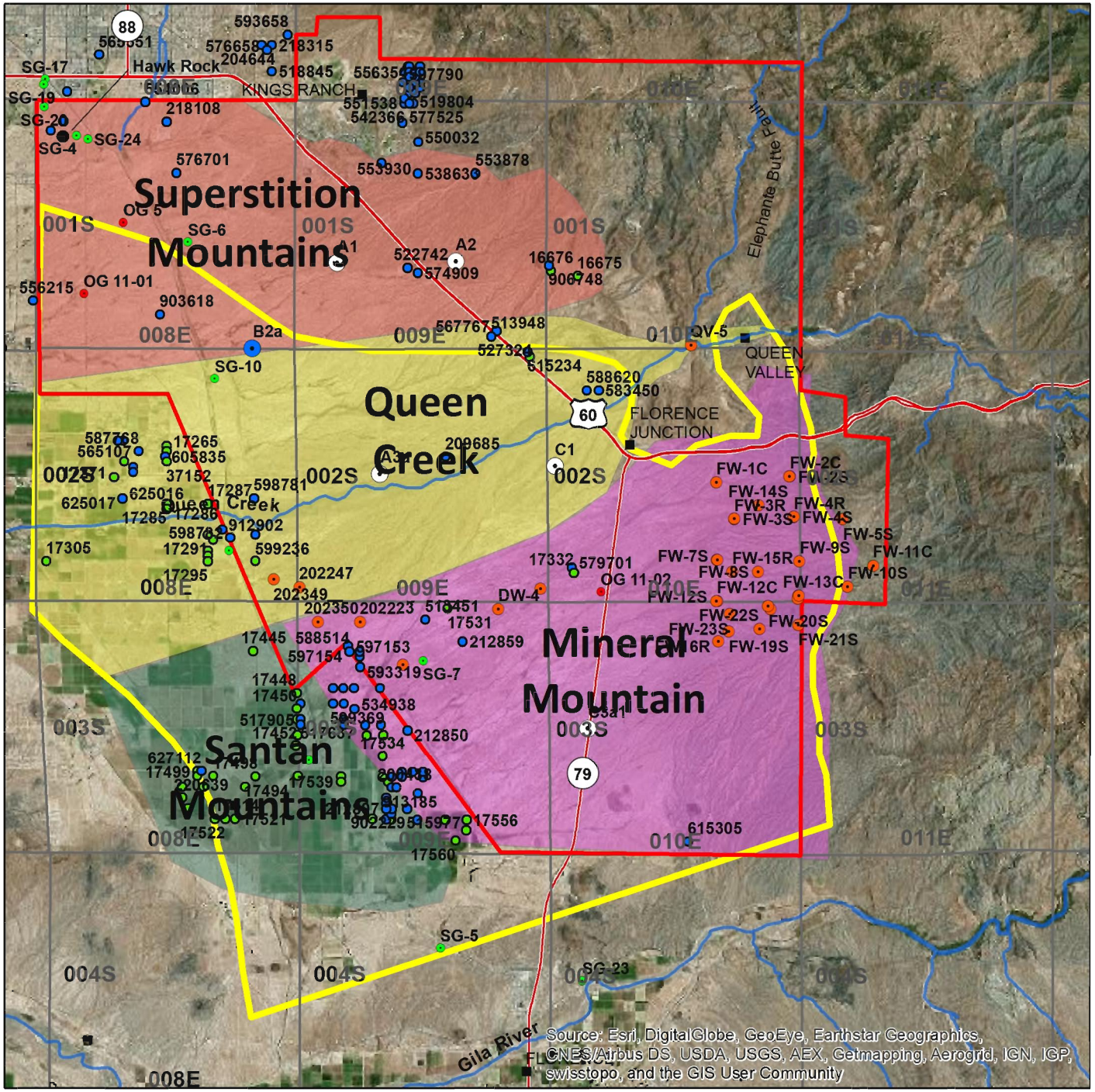


Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Location: C:\Data\Current Projects\SRP\projects\Figure 13 Depth to Base UAU.mxd

Last updated: 4/26/2017

Figure 14. Facies Map and Extent of Basalts



Wells in SVPA and vicinty

- Borings
- Test Well
- ADWR 55-wells (6-digit ID)
- ADWR 35-wells (5-digit ID)
- Resolution Copper wells
- Oil and Gas wells
- Salt-Gila wells
- *Superstitions Vistas Planning Area*
- *Major drainages*
- *Township (N/S) and Range (E/W)*
- Roads - Secondary

Extent of basalt in LAU

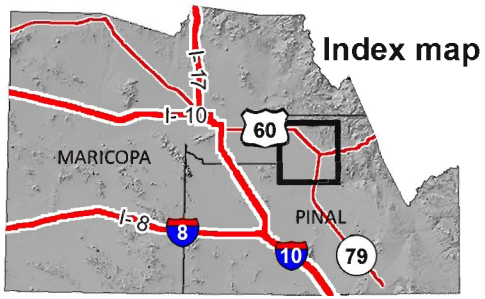
- *Extent of interbedded basalt and conglomerate in LAU.*

Sedimentary facies in UAU/MAU

- Superstition Mountains
- Queen Creek
- Mineral Mountain
- Santan Mountains

N

Miles 0 1 2 3 4



Superstition Vistas Planning Area
Phase II Water Resource Investigation, April 2017

Location: C:\Data\Current Projects\SRP\projects\Figure 14 Facies in SVPA.mxd

Last updated: 6/27/2017

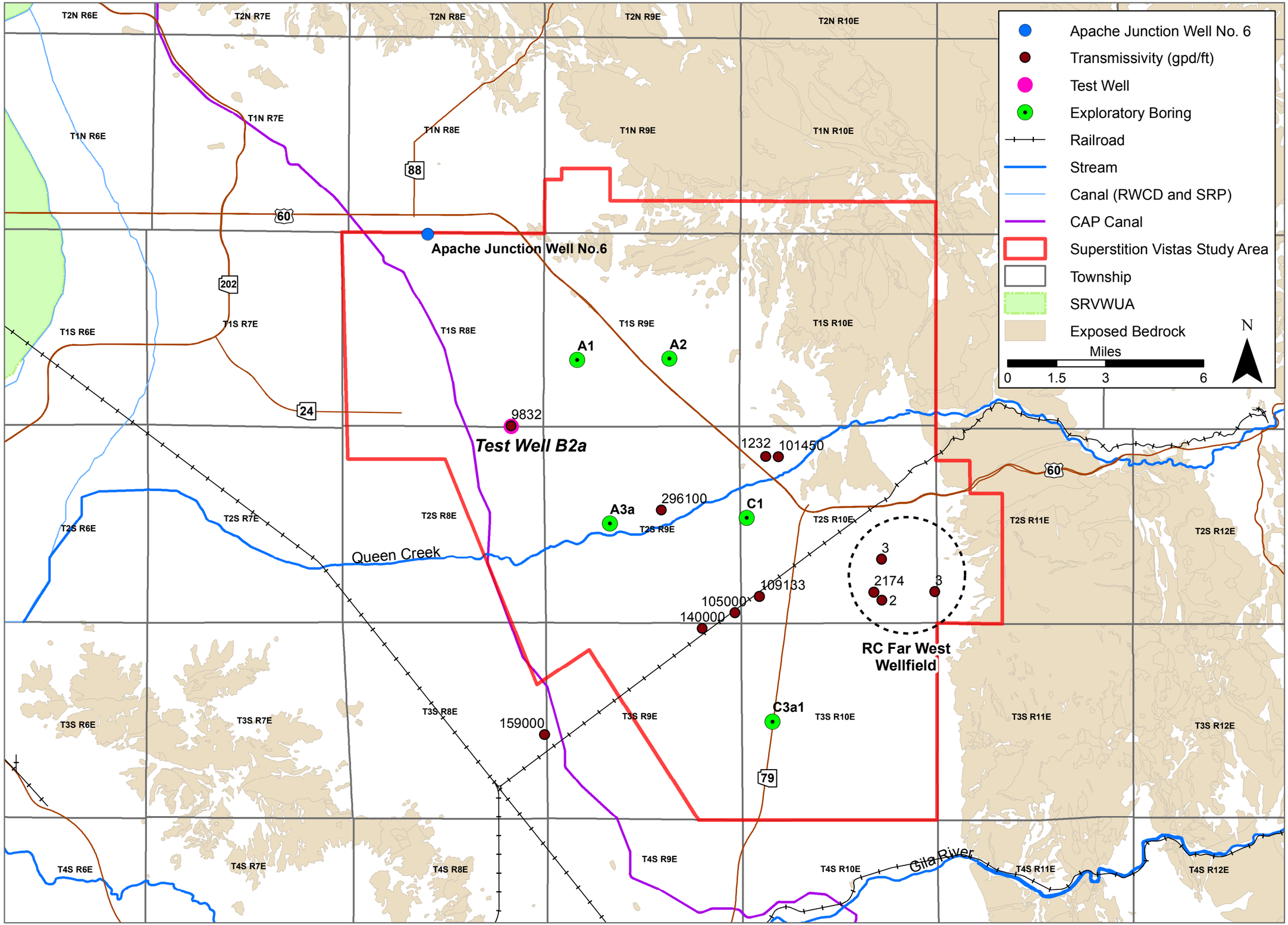
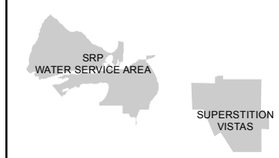


Figure 15
Transmissivity in the Superstition Vistas Area

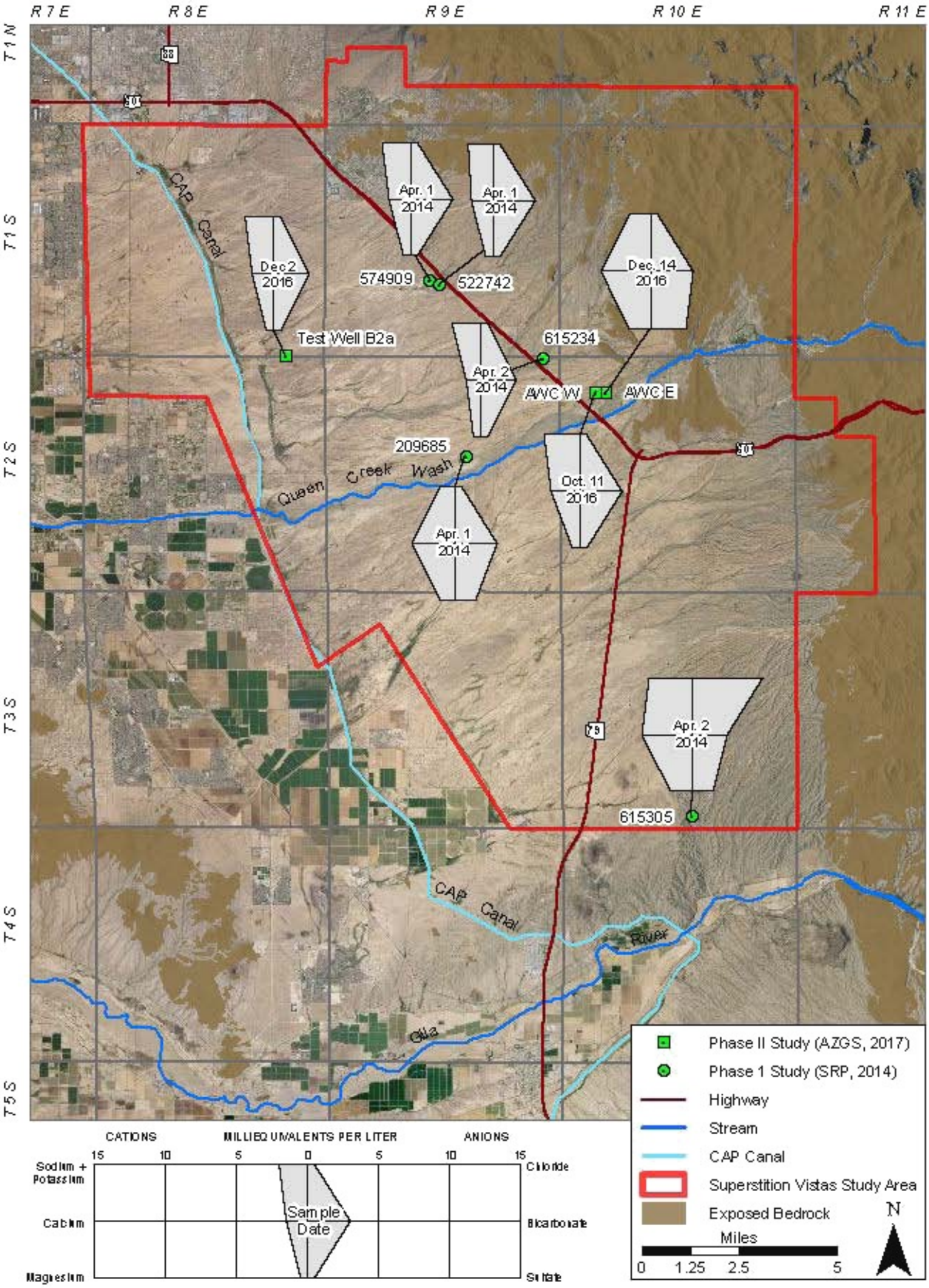
Project Vicinity

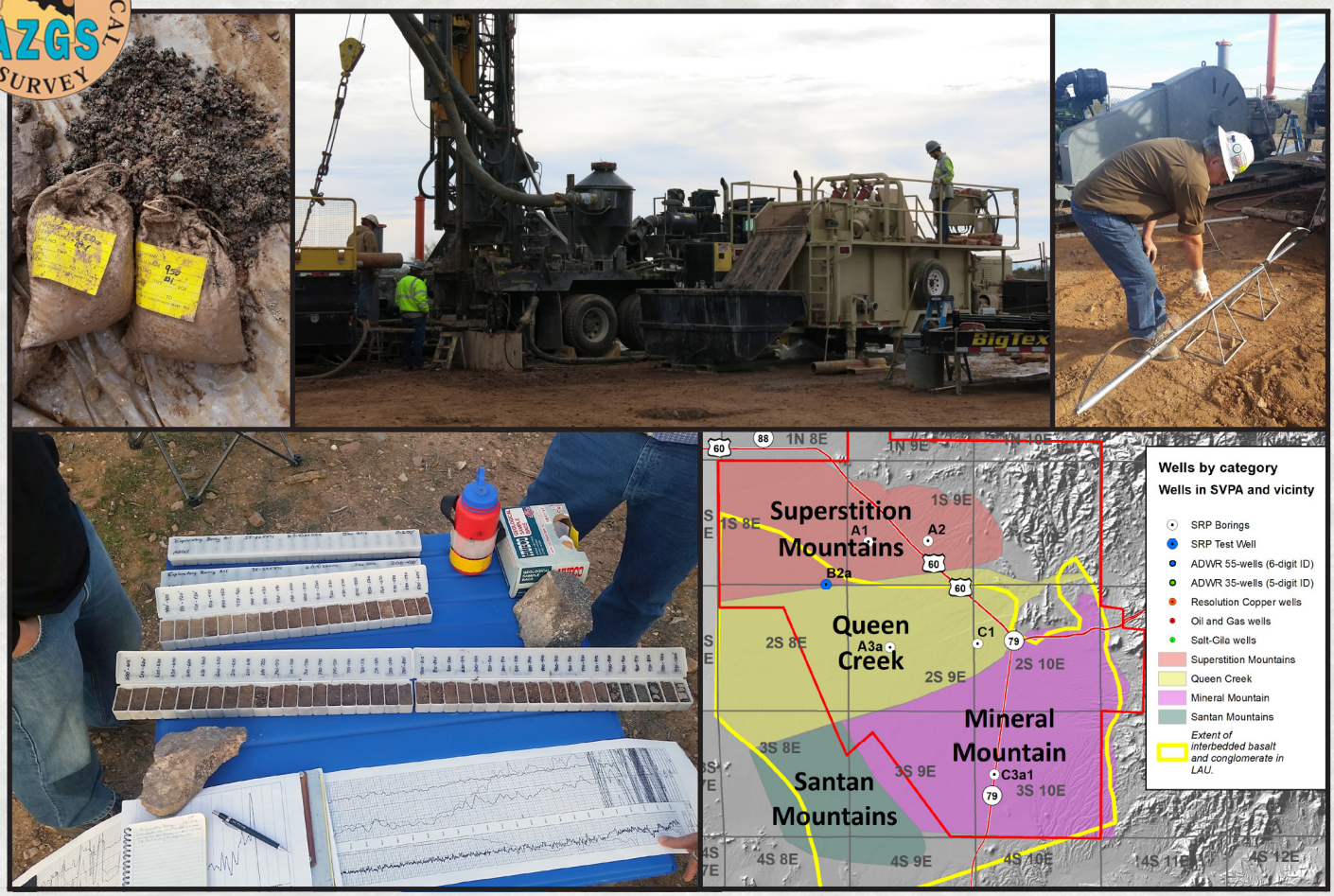


Superstition Vistas
Arizona

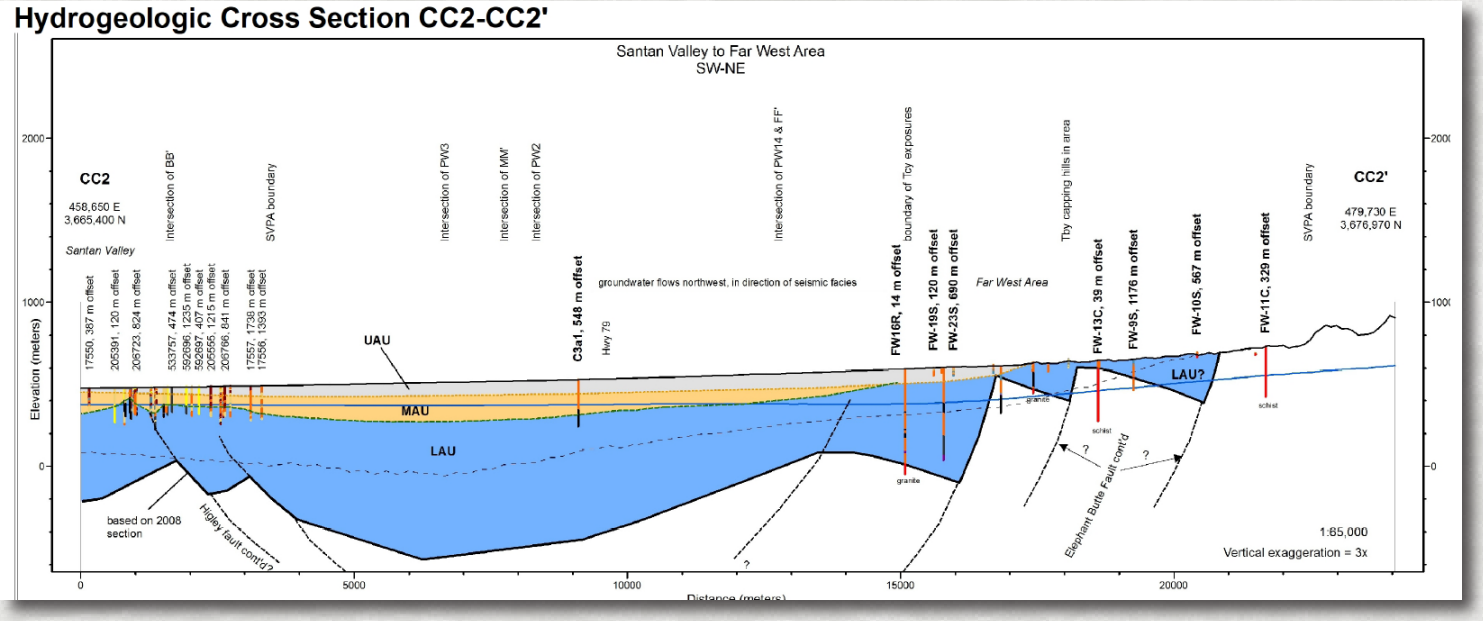
Carto: transmissivity_ssv.mxd
6/22/2017

Figure 16 - Well Water Chemistry, Superstition Vistas





Photos by Brian Gootee



AZGS Special paper 11 Subsurface Hydrogeologic Investigation of the Superstition Vistas Planning Area, Maricopa and Pinal Counties, Arizona

UA Science