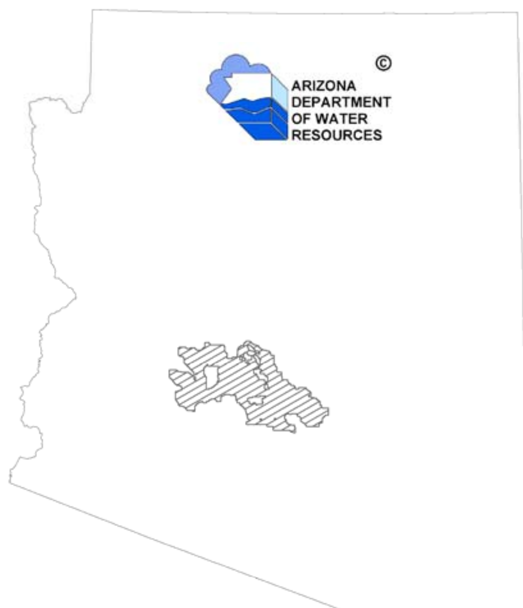
ARIZONA DEPARTMENT OF WATER RESOURCES

GEOLOGICAL UPDATE FOR THE COMBINED SRV AND LOWER HASSAYAMPA REGIONAL GROUNDWATER FLOW MODEL AREAS IN THE PHOENIX AMA



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MODELING REPORT NO. 23

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LIST OF ACRONYMS

ADWR	Arizona Department of Water Resources
AMA	Active Management Area
ESRV	East Salt River Valley
HBU	Hydrologic Bedrock Unit
LAU	Lower Alluvial Unit
MAU	Middle Alluvial Unit
SRV	Salt River Valley
UAU	Upper Alluvial Unit
WSRV	West Salt River Valley

ABSTRACT

The investigation of the geology in a model area is an important step in the development of any groundwater model because it is the basis for defining the geologic framework of the model and parameters such as hydraulic conductivity, storage and transmissivity.

The model geology presented in the Regional Groundwater Flow Model of the Salt River Valley, Phoenix Active Management Area, Model Update and Calibration Report (Freihoefer et. al., 2009) included the geology for the Lake Pleasant area which had been added following the publication of the Salt River Valley Geology Update Provisional Report (Dubas and Davis, 2006). Since that time some areas within the Salt River Valley Regional Groundwater Model domain were reevaluated and the Lower Hassayampa model geology from Brown and Caldwell (2006) was merged with the Salt River Valley model geology. The merged Salt River Valley and Lower Hassayampa model will be referenced as the Phoenix Regional Groundwater Model.

The Lower Hassayampa sub-basin geology was based on the geology presented by Brown and Caldwell in their Lower Hassayampa Sub-Basin Hydrogeologic Study report (2006). However, the Brown and Caldwell interpretations were modified where new information was available or where their interpretation did not match with the hydrogeologic unit definitions and interpretive rules from Dubas and Davis (2006). During the reinterpretation of the Lower Hassayampa geology and the joining of the Lower Hassayampa geology to the Salt River Valley regional groundwater model geology, 455 well logs were evaluated by the Arizona Department of Water Resources for the presence of an upper alluvial unit, middle alluvial unit, and lower alluvial unit. The review resulted in changes in the following areas: Surprise, northwest of the White Tank Mountains, between the Belmont Mountains and Saddle Mountain, south of the White Tank Mountains, and the narrow area between the Belmont Mountains and the White Tank Mountains.

The recent acquisition of geologic data provided by the City of Phoenix and the City of Scottsdale in the vicinity of a thick clay unit and deep basin between the McDowell Mountains and the Union Hills resulted in a more thorough understanding of

the geologic processes in that area. A total of 66 logs were reviewed for the analysis, resulting in a reduction of the thickness of the middle alluvial unit from the previous interpretation.

Although some uncertainty was reduced due to the revisions specified in this report, the geology for the majority of the model area was not revised and therefore the comparative level of uncertainty in these areas has not changed.

1.0 Introduction

The geology interpretation in this report is the result of the joining of the geologic interpretations published in Modeling Report No. 19 (Freihoefer et. al., 2009) with the interpretations used in the Lower Hassayampa Sub-Basin Hydrologic Study conducted by Brown and Caldwell (2006) and the incorporation of new data obtained after the publication of the provisional report (Dubas and Davis, 2006). The Lower Hassayampa model geology was reevaluated to ensure the representation followed the same interpretation procedures used in Modeling Report No. 16 (Dubas and Davis, 2006). The purpose of this report is to document the data collection activities and findings of the hydrogeologic framework of the study area to be used in the development of a new Phoenix Active Management Area groundwater model. The geology presented in this report may be modified (as needed) during the model calibration process and the final version will be included in the Phoenix Regional Groundwater Flow Model report which will document the development and calibration of the new groundwater flow model.

2.0 General Regional Setting

The Phoenix Active Management Area (AMA) is located in central Arizona, and is further divided into seven groundwater sub-basins; East Salt River Valley (ESRV), West Salt River Valley (WSRV), Lower Hassayampa, Rainbow Valley, Fountain Hills, Lake Pleasant, and Carefree (Corkhill et. al., 1993). The Phoenix AMA regional groundwater flow model domain covers the ESRV, WSRV, and the Lower Hassayampa sub-basins (**Figure 1**).

The Phoenix AMA is located within the Basin and Range Physiographic Province of Arizona, which was formed during the Cenozoic. During the Oligocene Epoch a period of intense tectonic activity began. This period of intense tectonic activity has been called the “Mid-Tertiary Orogeny” (Nations and Stump, 1996). During this orogeny, the landscape changed from one of a flat lying relatively stable surface, to that of a tectonically active area characterized by basaltic volcanism, crustal melting, low-angle gravity-induced faulting, the formation of metamorphic core complexes, and the deposition of thick sequences of sediments in basins. Crustal extension caused a series of steeply-dipping normal faults. The subsiding fault-blocks formed grabens (or deep basins) and the stable blocks formed horsts (or mountain ranges) (Nations and Stump, 1996).

Metamorphic core complexes including South Mountain south of Phoenix and the White Tank Mountains northwest of Goodyear (**Figure 2**) exhibit a northeast orientation, unlike the fault block mountains which have a more northerly orientation. These mountain ranges are believed to be caused by thermal upwellings (Nations and Stump, 1996). Predictably the metamorphic core complexes impact the lithology in their vicinity, especially when compared to the areas around mountains formed by crustal extension.

2.1 Geologic Overview

Four major hydrogeologic units were recognized in the Regional Groundwater Flow Model of the Salt River Valley, Phoenix Active Management Area Model Update and Calibration (Freihoefer et. al., 2009) report and were also used in this study. These units include the Upper Alluvial Unit (UAU), the Middle Alluvial Unit (MAU), the Lower Alluvial Unit (LAU), and the Hydrologic Bedrock Unit (HBU).

2.2 Description of Hydrogeologic Units

The definitions of the UAU, MAU, and LAU used in this study were based on descriptions provided in the Phase One report for the Salt River Valley Regional Groundwater Flow Model (Corkhill et. al., 1993). The descriptions are generalized here, but more detailed information on how these units were defined can be found in the Phase One report. The units are described in order from land surface to the top of bedrock.

2.2.1 Upper Alluvial Unit (UAU)

The UAU overlies the MAU and consists mainly of gravel, sand, and silt. The composition of the UAU is dominated by gravel and sand near the present-day Salt and Gila rivers, near the former course of the Salt River east and south of South Mountain, and near the margins of the alluvial basins. In other areas, the unit is typically dominated by sand and gravel.

2.2.2 Middle Alluvial Unit (MAU)

The MAU overlies the LAU and consists mainly of clay, silt, mudstone, and gypsiferous mudstone with some interbedded sand and gravel. Near the margins of the alluvial basins the MAU consists mainly of sand and gravel and is difficult or impossible to distinguish from the other units.

2.2.3 Lower Alluvial Unit (LAU)

The LAU overlies or is in fault contact with the hydrologic bedrock unit and the "red unit" (Corkhill et al, 1993). The LAU consists mainly of conglomerate and gravel near the basin margins, grading into mudstone, gypsiferous and anhydritic mudstone and anhydrite in the central areas of the basin. Alternating layers of decomposed volcanics and alluvial fill material comprise the LAU in portions of the northeastern and western study area.

For a complete summary of the hydrogeologic setting in the Salt River Valley (SRV) model area and the Lower Hassayampa model area refer to Corkhill et. al. (1993) and Brown and Caldwell (2006).

2.3 Modifications to the Geologic Interpretation

The model geology presented in the Regional Groundwater Flow Model of the Salt River Valley, Phoenix Active Management Area, Model Update and Calibration Report (Freihoefer et. al., 2009) included the geology for the Lake Pleasant area which was added following the publication of the Salt River Valley Geology Update Provisional Report (Dubas and Davis, 2006). The geology for the Lake Pleasant area was modified from geology provided to us by Clear Creek Associates for a groundwater model they had done that covered the Lake Pleasant area. Since that time some areas within the Salt River Valley Regional Groundwater Model domain were reevaluated and the Lower Hassayampa model geology from Brown and Caldwell (2006) was merged with the Salt River Valley model geology to create the geology for the Phoenix Regional Groundwater Model.

In order to merge the Lower Hassayampa and the Lake Pleasant model geology with the Salt River Valley model geology the datasets had to be compared. Of particular interest was if the geology established by Brown and Caldwell and Clear Creek Associates followed the same rules that had been established in Dubas and Davis (2006) for the SRV update. For example, the start of the MAU was defined in Dubas and Davis (2006) as the point at which at least 60 feet of continuous sediments contained at least 40% silt and clay. In addition, in Dubas and Davis (2006) the transition zones into and out of the MAU were added to the MAU and not the UAU or LAU. The final consideration was if available data supported the Brown and Caldwell and Clear Creek Associates geologic interpretations.

2.3.1 Lower Hassayampa Sub-Basin

The Lower Hassayampa sub-basin geology was based on the geology presented by Brown and Caldwell in their Lower Hassayampa Sub-Basin Hydrogeologic Study report (2006). However, the Brown and Caldwell interpretations were modified where new information was available or where their interpretation did not agree with the hydrogeologic unit definitions and interpretive rules from Dubas and Davis (2006).

Further analysis was also conducted in the areas where the Lower Hassayampa model geology overlapped the SRV model geology (**Figure 2**). Drilling data obtained since the publication of the SRV model geology report and the Lower Hassayampa model report in both the Surprise and Buckeye areas enabled better definition of the MAU. **Figure 3** compares the locations of logs analyzed by Brown and Caldwell and those analyzed during the 2009 Arizona Department of Water Resources (ADWR) review.

2.3.1.1 Palo Verde Clay

During the geology review conducted for the 2006 Dubas and Davis report, a transition zone was noted in the WSRV and consisted of a coarser fine-grained transition into the fine-grained MAU. This coarser fine-grained transition was included in the MAU in that study. The Lower Hassayampa geology presented by Brown and Caldwell indicated a coarser fine-grained transition was encountered at the bottom of the Palo Verde Clay (MAU) and included in the LAU. Since the transition zone above the MAU in the WSRV was assigned to the MAU in the Dubas and Davis (2006) review, the transition zone which had been included in the LAU by Brown and Caldwell was moved to the MAU.

The extent of the Palo Verde Clay was reexamined due to new data in the area but there was insufficient data to accurately define the extent of the Palo Verde Clay. The thickness of the MAU in the area between Saddle Mountain, the Gila Bend Mountains, and the Buckeye Hills are educated estimates only. More data would be needed in this area to determine the extent of the Palo Verde Clay unit. For example, **Figure 4** shows there is very little data available in the deepest part of the Palo Verde Clay. The thickest MAU was 1,122 feet, but there was no data surrounding that point to estimate the thickest area of the MAU. Further towards the northwest a log showed a MAU thickness of 965 feet, but the log was not deep enough to verify the end of the MAU had been reached. At the bottom of the fine grained layer sand was present, which could be part of the transition into the LAU. If that is the case the MAU could be thicker in that location. Data was also lacking to the northeast and the southwest.

2.3.1.2 Buckeye Area

The Buckeye area in the geology review for the 2006 Dubas and Davis report was based on limited data and very few logs beyond the model boundary west of Buckeye were reviewed. Since a lot more work had been done in this area since the collection of geology information stopped prior to the publication of the 2006 report, a lot of time was spent in this particular area to estimate where the fine-grained MAU ended towards the edges of the model area. However, when the Brown and Caldwell geology was merged with the SRV geology it was determined that their geology was a lot more accurate when it came to the Palo Verde Clay which had been cut off closer to the edge of the western model boundary west of Buckeye in the SRV geology update. Therefore, the Brown and Caldwell geology was used and modified with the information obtained from the newly available logs.

2.3.1.3 Northern Lower Hassayampa Sub-Basin / Northern West Salt River Valley Sub-Basin

A thorough review was conducted in the area between the Belmont and Vulture Mountains and north of the White Tank Mountains, which included the City of Surprise. Every available log was reviewed in the area and as a result that section was changed more than any area reviewed in the Lower Hassayampa sub-basin. In some cases the MAU proposed by Brown and Caldwell proved to be too thick and in some areas the MAU was too thin.

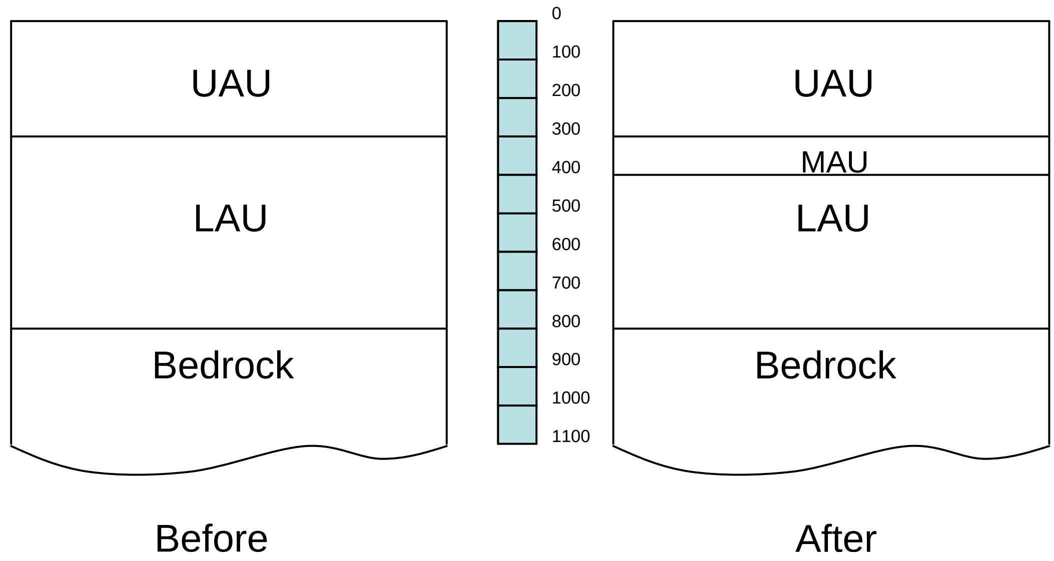
2.3.1.4 Depth to Bedrock in the Lower Hassayampa Sub-Basin

The location of bedrock in most areas of the Lower Hassayampa sub-basin was not reevaluated because Brown and Caldwell had hired an independent consultant to review available geophysical studies (including a geophysical study completed by the ADWR geophysical survey team) and depth to bedrock data from wells in the area. The interpretations provided by Brown and Caldwell's independent consultant were considered reasonable and generally representative of the depth to bedrock in the area and very few changes were made. However, the depth to bedrock contours provided by the independent consultant in a basin between the Belmont Mountains and the Saddle Mountains indicated a much steeper depth to bedrock gradient towards the basin edges than was indicated in the geophysical survey completed by ADWR and no information was presented to explain the change. The depth to bedrock representation from the independent consultant used in this study was therefore changed in this area to be more consistent with the interpretations provided by the survey team.

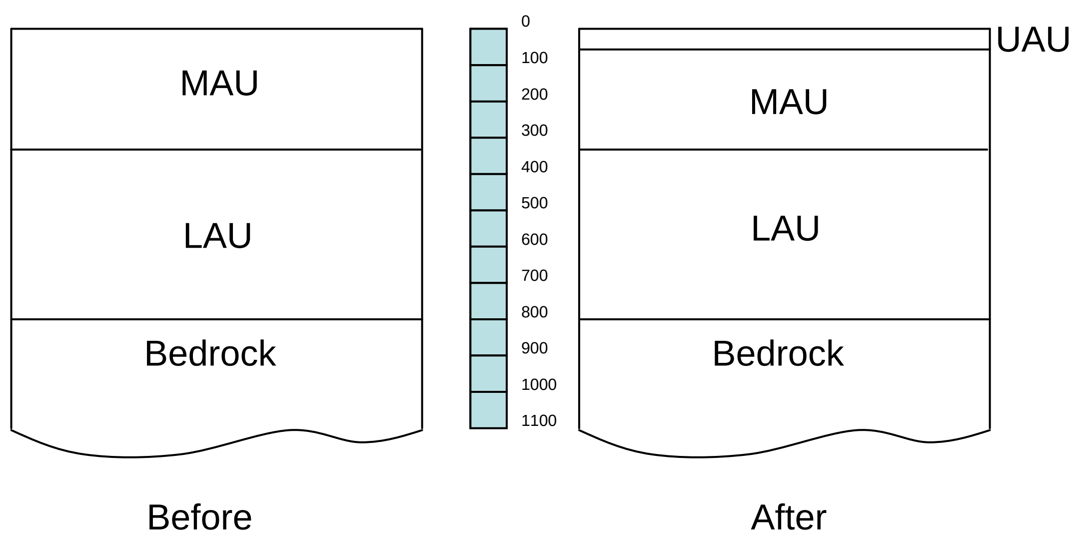
2.3.1.5 Basin Wide Generalizations

At the end of the Lower Hassayampa geology review several generalizations were applied to the geology that was merged with the WSRV geology to create the Phoenix model geology.

- The LAU (Layer 3) had to have a thickness of at least 100 feet.
- If there was no MAU (Layer 2), then a standard thickness of 99 feet was applied to Layer 2 of the model for that cell. A thickness of 99 feet was then subtracted from Layer 3. An example is given below. In the cells where no MAU exists, both Layer 2 and Layer 3 will be given the same hydrologic parameters that are associated with the LAU.

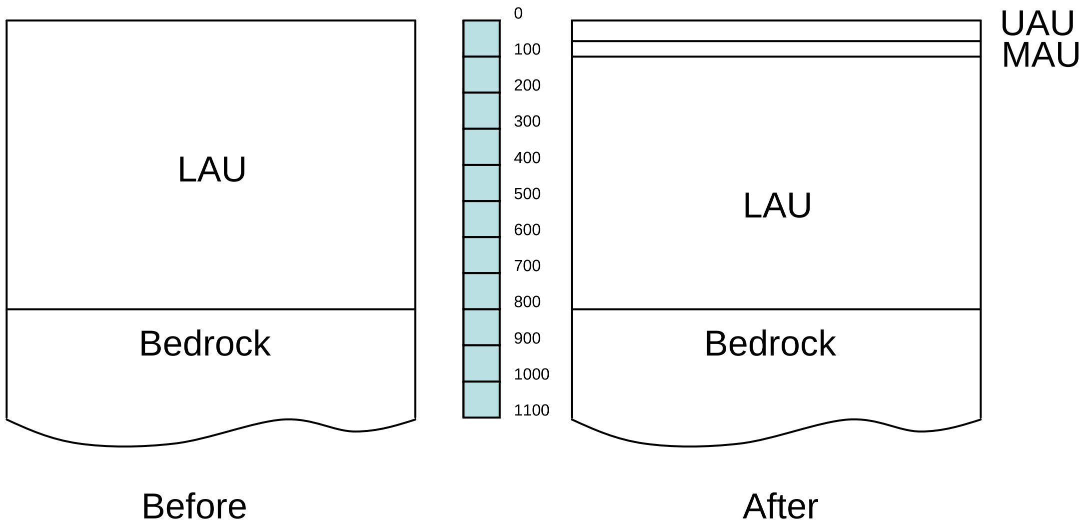


- Where there was no UAU (Layer 1) a standard thickness of 50 feet was applied to Layer 1 of the model for that cell. A thickness of 50 feet was then subtracted from Layer 2. An example is given below. In the cells where no UAU exits, both Layer 1 and Layer 2 will be given the same hydrologic parameters that are associated with the MAU.



- The exception to the above rule occurred when there was no UAU (Layer 1) or MAU (Layer 2) and only sediments characteristic of the LAU (Layer 3) were encountered. In this case a standard thickness of 50 feet was applied to the UAU (Layer 1), a standard thickness of 49 feet was applied to the MAU (Layer 2), and

99 feet was then subtracted from the LAU (Layer 3). In other words, 99 feet was applied to the MAU (Layer 2) but 50 feet of that was taken for the UAU (Layer 1) which left 49 feet for Layer 2. In these cells Layer 1 and Layer 2 will be given the same hydrologic parameters that are associated with the LAU (Layer 3) in those cells. An example is given below.



2.3.2 Lake Pleasant

Between the publication of the Salt River Valley Model Geology Update report (Dubas and Davis, 2006) and the Model Update and Calibration report (Freihoefer et. al., 2009) the Lake Pleasant sub-basin was added to the ADWR SRV model area. The Lake Pleasant geologic interpretations were developed using a combination of data supplied by Clear Creek Associates from a groundwater model which was ultimately included in a report submitted to the City of Phoenix (Carollo Engineers et. al., 2009), lithologic information from nearby wells, and a geophysical study submitted by Clear Creek Associates to ADWR. The geologic interpretation was also modified during the calibration process to help water flow through the system and to ensure each layer had a thickness of at least 100 feet.

2.3.3 Pinal AMA

Concurrent to the calibration of the 1983 to 2006 SRV model and the joining of the Lower Hassayampa geology to the SRV geology, work has been ongoing to update the Pinal AMA Regional Groundwater model which overlaps with portions of the SRV model domain in the southern part of the model area (**Figure 5**). The Pinal model updates have been used to reevaluate the geologic interpretations, mainly in the Gila River Indian Community and northeast of Florence. The geology update is documented in Modeling Report No. 20 (Dubas and Liu, 2010). Modifications to the geology in this overlap area have continued during the calibration of the Pinal AMA transient model, however, the geology data reposted in this study is current as of the publication of this report.

During the geology update for the Pinal model the total sedimentary thickness was reduced throughout much of the Gila River Indian Community. This decrease occurred because the thickness of the MAU was reduced throughout much of the Reservation and the UAU was reduced between the Santan and Sacaton Mountains.

2.3.4 City of Peoria

A consultants' report reviewed for the updated SRV geology published in 2006 (Dubas and Davis, 2006) indicated the presence of a 200 feet thick MAU at a depth of approximately 500 feet below land surface in an area of Peoria south of the Hieroglyphic Mountains. However, a 200 foot thickness of fine-grained MAU, isolated from the more contiguous body of fine-grained sediment located toward the WSRV basin centers seemed improbable. Considerable time was spent reviewing this area, resulting in an alternate interpretation.

Another consultants' report for a well located north of the Hieroglyphic Mountains contained a description of a welded tuff layer above the rhyolite bedrock. That study, which also encompassed the area south of the Hieroglyphic Mountains, indicated that this 200 feet thick clay mentioned in the consultants' report was likely a welded tuff. Therefore, ADWR's interpretations in this area were modified to eliminate the fine-grained zone of the MAU just south of the Hieroglyphic Mountains.

2.3.5 City of Phoenix / City of Scottsdale

During a search of aquifer test data in the Phoenix and Scottsdale area more geology information was submitted by the City of Phoenix and the City of Scottsdale which aided in the reevaluation of this area (**Figure 6**).

The material described in the logs within Township 5N and Range 4E and in the northwest corner of Township 4N and Range 4E was indicative of a thick alluvial fan. The descriptions consisted of mostly silt, sand and gravel and little if any fine-grained material. Therefore Layer 2 in the model has been assigned in this area the properties of a coarse-grained material. Inter-fingering of clay is present in Township 5N and Range 3E and Township 4N and 3E.

Several of the logs reviewed previously in the area between the Union Hills and the McDowell Mountains in Phoenix and Scottsdale indicated the presence of a clay unit at a depth starting around 1400 feet below land surface. However, a log in Township 4N and Range 4E indicates the presence of a diabase and weathered granite at around 1440 feet below land surface, which is the interval that was being described as "clay" in other logs within the same area. Based on this new information it was assumed that this "clay" was not actually clay and the MAU was truncated to a depth of approximately 800 feet below land surface.

2.4 Geologic Cross-Section Maps

The cross-sections in **Figures 7** through **Figure 29** were produced using interpreted and smoothed geologic contact depths taken from model cell centers (nodes) and therefore may not be representational of the described geologic contact depths encountered at any particular well. The "per-node" geology represents an approximation based on all the logs reviewed in the model area.

2.4.1 Lower Hassayampa Sub-Basin / SRV Sub-Basin Join Area

Cross-section A-A’ (**Figure 7**) and cross-section B-B’ (**Figure 8**) in the Lower Hassayampa sub-basin indicate the MAU is not very thick in that region, but that the LAU has a substantial thickness. Two areas within the SRV model domain that underwent further analysis when the Lower Hassayampa geology was merged with the SRV geology are represented in cross-section C-C’ (**Figure 9**) and cross-section D-D’ (**Figure 10**). More recent data within both areas permitted better interpretation. The Palo Verde Clay unit (MAU) is shown in cross-section C-C’ (**Figure 9**) and cross-section S-S’ (**Figure 11**) as evident by the thickening of the MAU near the location of Buckeye on the map. At the north end of the Lower Hassayampa Basin a thick clay unit along with a deep basin is shown in cross-section D-D’ (**Figure 10**). Cross-section M-M’ represents the thick LAU to the west, with a thinning of the units at the Hassayampa River, and then a thickening of the MAU and LAU towards the east (**Figure 12**).

2.4.2 City of Phoenix / City of Scottsdale / Paradise Valley Area Reevaluation

The area of Phoenix and Scottsdale north of Paradise Valley between the Union Hills, the Phoenix Mountains, and the McDowell Mountains that was reexamined by ADWR during this review are depicted in cross-section N-N’ (**Figure 13**), cross-section O-O’ (**Figure 14**) and cross-section P-P’ (**Figure 15**). These cross-sections along with cross-section Rb-Rb’ (**Figure 16**) depict the changes in the geologic units north to south.

2.4.3 Phoenix Model and Pinal AMA Model Shared Model Cells

The geology in Pinal County covered by both the Phoenix model and the Pinal model are represented by cross-section V-V’ (**Figure 17**), cross-section G-G’ (**Figure**

18), Cross-section H-H’ (**Figure 19**), cross-section I-I’ (**Figure 20**), cross-section T-T’ (**Figure 21**), and cross-section U-U’ (**Figure 22**).

2.4.4 Lake Pleasant Model Area

The Lake Pleasant area is represented by cross-section K-K’ (**Figure 23**), cross-section L-L’ (**Figure 24**), and cross-section F-F’ (**Figure 25**). The cross-sections indicate a thicker LAU west of the Union Hills.

2.4.5 Constricted Underflow Areas

Within some portions of the model area the groundwater flows through narrow gaps between bedrock outcrops. In these constricted areas groundwater flow converges and is sometimes forced to the surface to become baseflow (such as in the channel of the Gila River, in the gap between South Mountain and the Sierra Estrella Mountains [**Figure 17**]). Since hydraulic gradients and groundwater flow through constricted areas can be difficult to simulate, special attention was taken to reevaluate the available geologic data. Constricted areas within the Phoenix model domain that were reevaluated are shown in cross-section L-L’ (**Figure 24**), cross-section Q-Q’ (**Figure 26**), cross-section C-C’ (**Figure 9**), cross-section V-V’ (**Figure 17**) and cross-section U-U’ (**Figure 22**).

2.4.6 Thinning of the MAU Closer to the Mountains

The transition from a thin MAU towards the mountains and a thick MAU in the centers of the sub-basins are represented by cross-section E-E’ (**Figure 27**), cross-section I-I’ (**Figure 20**), cross-section J-J’ (**Figure 28**), cross-section Ra-Ra’ (**Figure 29**), cross-section S-S’ (**Figure 11**) and cross-section T-T’ (**Figure 21**). It should be noted that hydraulic properties of the MAU vary, with hydraulic conductivity and storativity often increasing where the unit thins.

2.5 Uncertainty Associated with Geology Interpretation

Although a substantial amount of new data were obtained during the 2009/2010 data review in the Lower Hassayampa sub-basin and Phoenix/Scottsdale areas of the model, the majority of the model domain geology was not reevaluated. Geologic data deficient areas indicated on **Figure 2.5** in Modeling Report No. 19 (Freihoefer et. al., 2009) are still deficient. However, due to the review of logs submitted since the finalization of the geology for Modeling Report No. 19, the area between the Hieroglyphic Mountains and the White Tank Mountains and the area adjacent to the McDowell Mountains in Scottsdale are less data deficient and have better geologic characterization.

Figure 30, **Figure 31**, and **Figure 32** show the locations of logs used for the estimates of the UAU, MAU, and LAU bottom depths. From the distribution of well logs the areas where limited data were available are readily apparent.

2.5.1 Indian Reservations

Approximately 6% of the Phoenix regional groundwater flow model area is covered by Indian Reservations **(Figure 30)**. Approximately 52 percent of the Salt River Pima-Maricopa Indian Community is within the active model domain and is approximately 1.3% of the total domain area. Close to 99% of the Gila River Pima-Maricopa Indian Community is located within the active model domain and is 4.9% of the total domain area.

2.5.2 Lake Pleasant Area

With the exception of the Anthem community, very little development has occurred in this section of the model. This area has not been reevaluated since the completion of the 2006 geologic analysis by Dubas and Davis.

2.5.3 Model Boundaries

The outer boundary of the model domain (in particular areas close to bedrock) typically has fewer logs available than the main portions of the basins. Logs that are available for these areas normally do not indicate the presence of a fine-grained unit (the MAU), therefore making the UAU difficult to distinguish from the LAU. Along the hardrock areas the depth to basement can change greatly over a relatively short distance.

2.5.4 Basin Centers

Well data are lacking within the deepest parts of the ESRV, the WSRV, and the Lower Hassayampa sub-basins on the thickness of the MAU and for the depth to bedrock. Published estimates of the depth to bedrock from the Arizona Geological Survey and geophysical data collected by ADWR staff have been used in several areas of the model where deep well data are not available.

2.5.5 Quality of Source Data

The geology review conducted to join the Lower Hassayampa geology to the SRV geology as well as the reinterpretation of data in the Phoenix / Scottsdale and Peoria areas was dependant on the quality of the data reviewed. During this reevaluation 455 well logs were reviewed in the Lower Hassayampa sub-basin and Lower Hassayampa/SRV merge areas, and 66 logs were reviewed in the Phoenix/Scottsdale area north of Paradise Valley and between Union Hills and the McDowell Mountains. As with the geology review for the SRV 1983 to 2006 groundwater model, each log reviewed was evaluated for quality. Factors used to establish the quality of a log include the following:

- Documented sample frequency – a log with one description for a 1,200 feet well was considered to be of lower quality than one with more numerous intervals described by the driller or geologist for the same depth well;

- Sample description – a log with the description “rocks” was regarded as poor quality, while a description which includes size and coarseness of grains; percentages of fine versus coarse grained material as well as the types of materials encountered was generally considered of good quality. Other descriptions which could give the log a “poor” quality would be limestone, shells, and sandstone which are typically not found in this area;

- Log suite agreement – if the driller log, geologist log, particle size log and/or geophysical log for a particular well showed lithologic agreement between the different logs the quality increased, whereas if the lithology in the log suite did not agree, the quality decreased;

According to the criteria established for the SRV geology (Dubas and Davis, 2006) driller logs are generally not considered to be better than “fair” in quality because sample descriptions are very general and if no other types of logs are available there is nothing to confirm the lithologic interpretation.

3.0 Limitations

The geologic interpretations presented in this report are regional in scope and may not be suitable for site-specific applications. Cell-size limitations, the lack of localized data, and the regional scale of the analysis make it difficult to accurately represent the geologic complexities and details of all areas within the model domain. It is recommended that the geology presented in this report and the Phoenix groundwater flow model which includes the Lower Hassayampa sub-basin be amended with site specific geology information, if available, for any more localized hydrologic applications of the model. For example, a localized study in a heavily faulted area would be generalized in this representation of the geology because in a regional scale model localized faulting may be irrelevant. It should also be noted the model cell size may be inappropriate for highly "local" applications of the Phoenix model. In addition, a comparison of local geology data close to the edges of the model domain may not be comparable because thicknesses of units were increased or decreased based on the regional scale of the Phoenix model.

4.0 References

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Figure 1

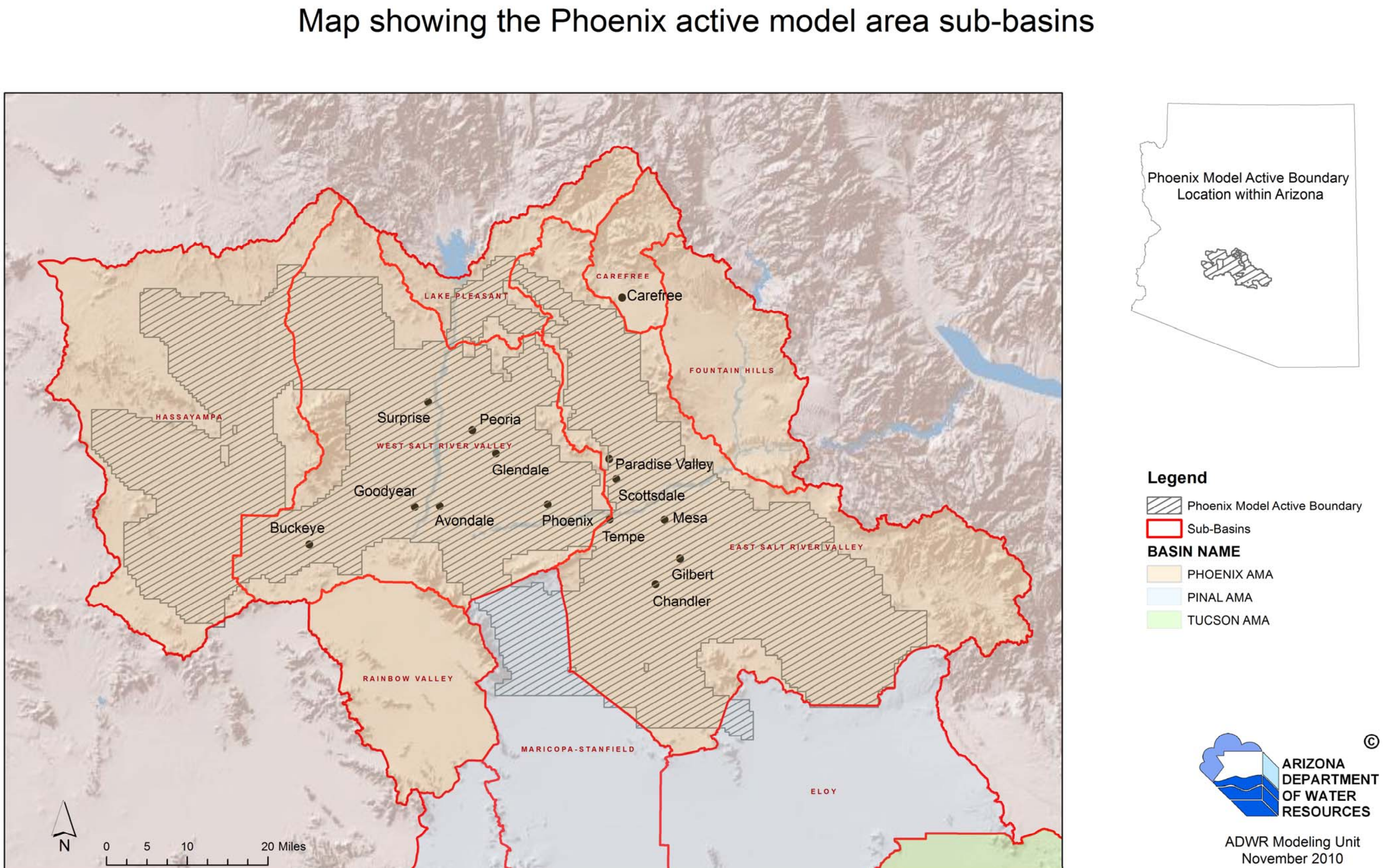
Map showing the Phoenix active model area sub-basins
HASSAYAMPA
LAKE PLEASANT
CAREFREE
Carefree
FOUNTAIN HILLS
Surprise
Peoria
WEST SALT RIVER VALLEY
Glendale
Paradise Valley
Goodyear
Scottsdale
Avondale
Phoenix
Mesa
Buckeye
Tempe
EAST SALT RIVER VALLEY
Gilbert
Chandler
RAINBOW VALLEY
MARICOPA-STANFIELD
ELOY
N
0 5 10 20 Miles
Phoenix Model Active Boundary Location within Arizona
Legend
Phoenix Model Active Boundary
Sub-Basins
BASIN NAME
PHOENIX AMA
PINAL AMA
TUCSON AMA
ARIZONA DEPARTMENT OF WATER RESOURCES
ADWR Modeling Unit
November 2010

Figure 2

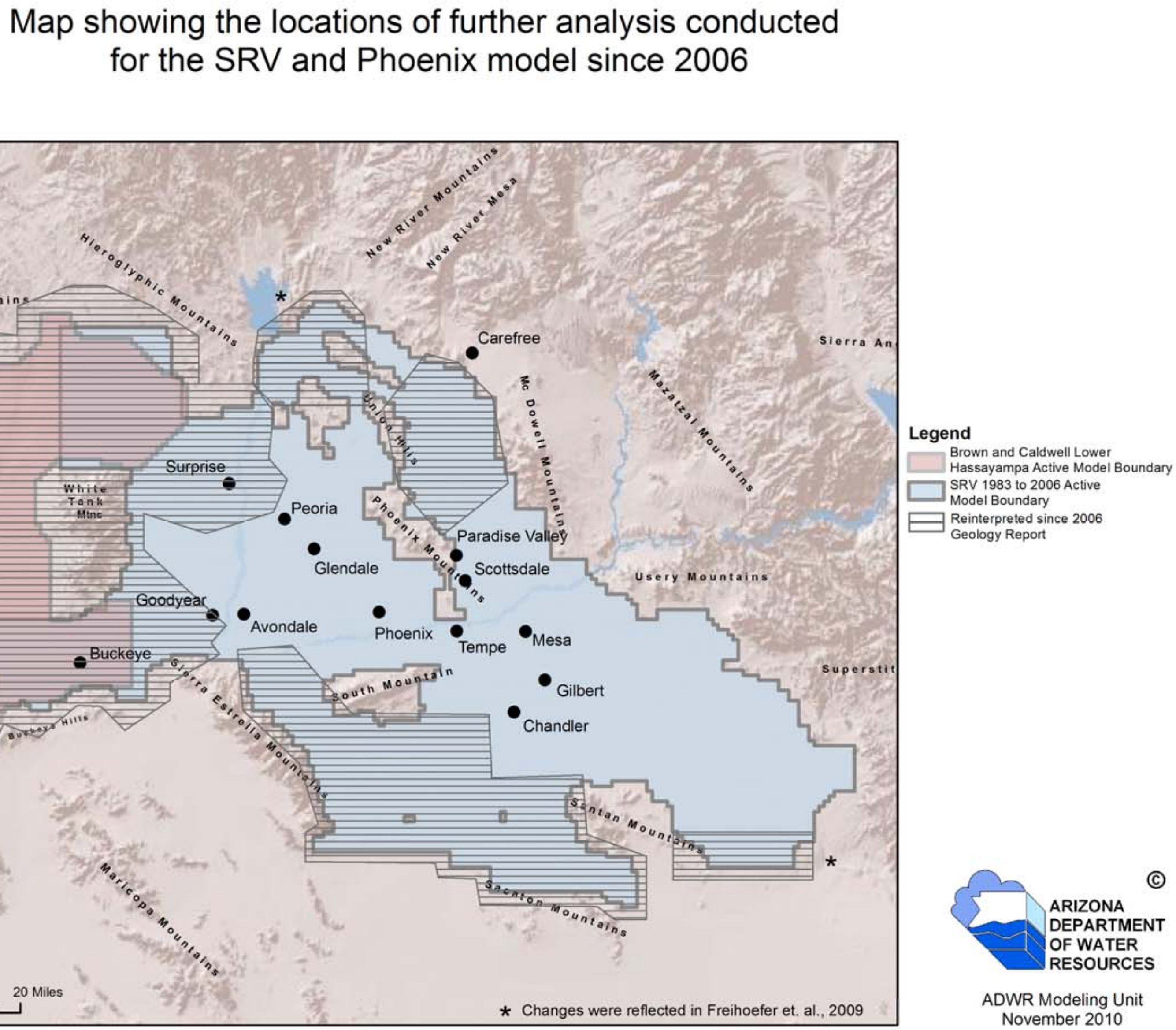
Map showing the locations of further analysis conducted
for the SRV and Phoenix model since 2006
Legend
Brown and Caldwell Lower Hassayampa Active Model Boundary
SRV 1983 to 2006 Active Model Boundary
Reinterpreted since 2006 Geology Report
Vulture Mountains
Hieroglyphic Mountains
New River Mountains
New River Mesa
Carefree
Sierra An
Mc Dowell Mountains
Mazatzal Mountains
Union Hills
Belmont Mountains
White Tank Mtns
Surprise
Peoria
Phoenix Mountains
Paradise Valley
Glendale
Scottsdale
Usery Mountains
Saddle Mountain
Goodyear
Avondale
Phoenix
Tempe
Mesa
Buckeye
Sierra Estrella Mountains
South Mountain
Superstit
Gilbert
Chandler
Buckeye Hills
Gila Bend Mountains
Santan Mountains
Sacaton Mountains
Maricopa Mountains
N
0 5 10 20 Miles
* Changes were reflected in Freihoefer et. al., 2009
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Figure 3

Map showing wells with logs available that were reviewed by ADWR and Brown and Caldwell in the Lower Hassayampa sub-basin area

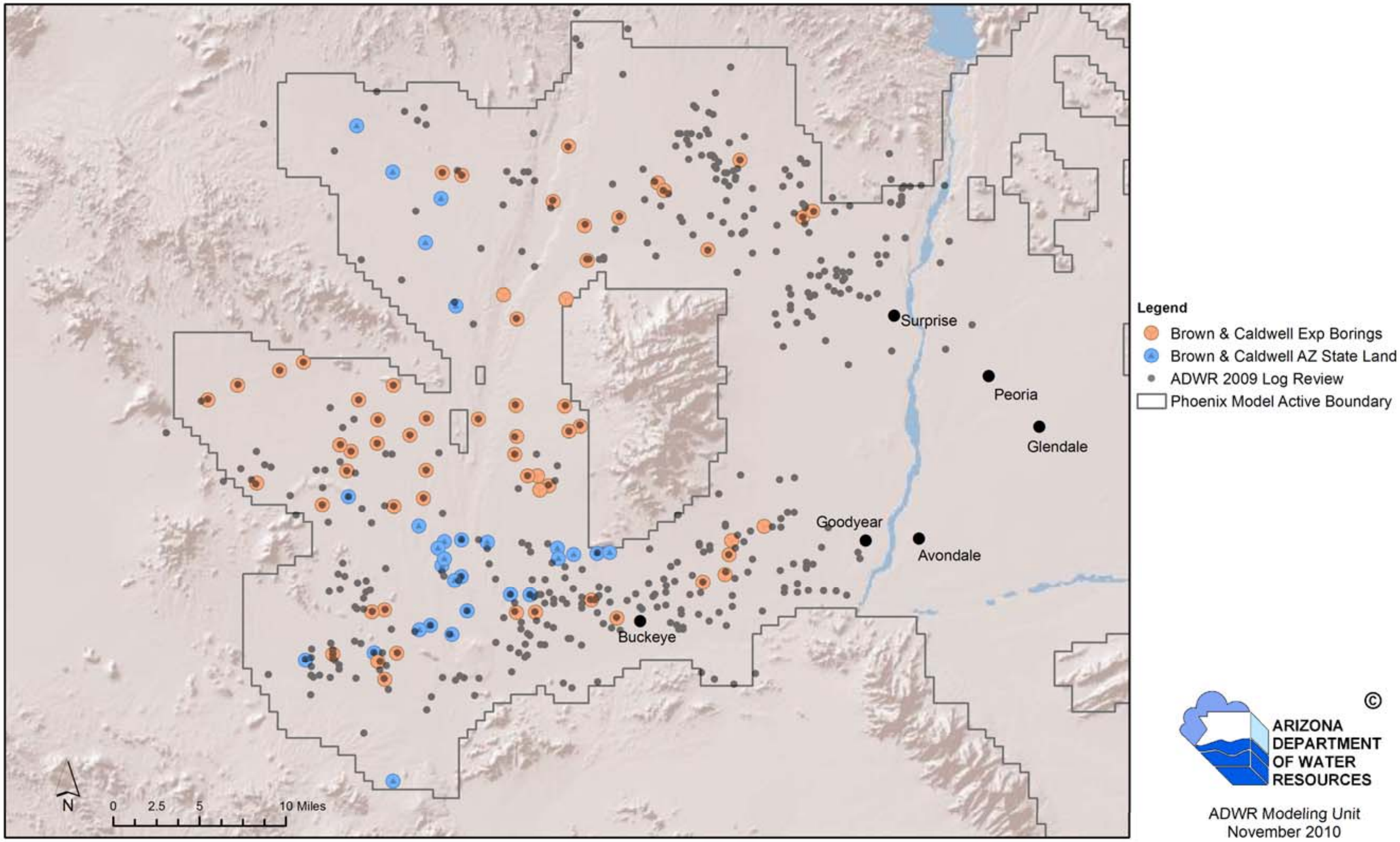

Figure 4

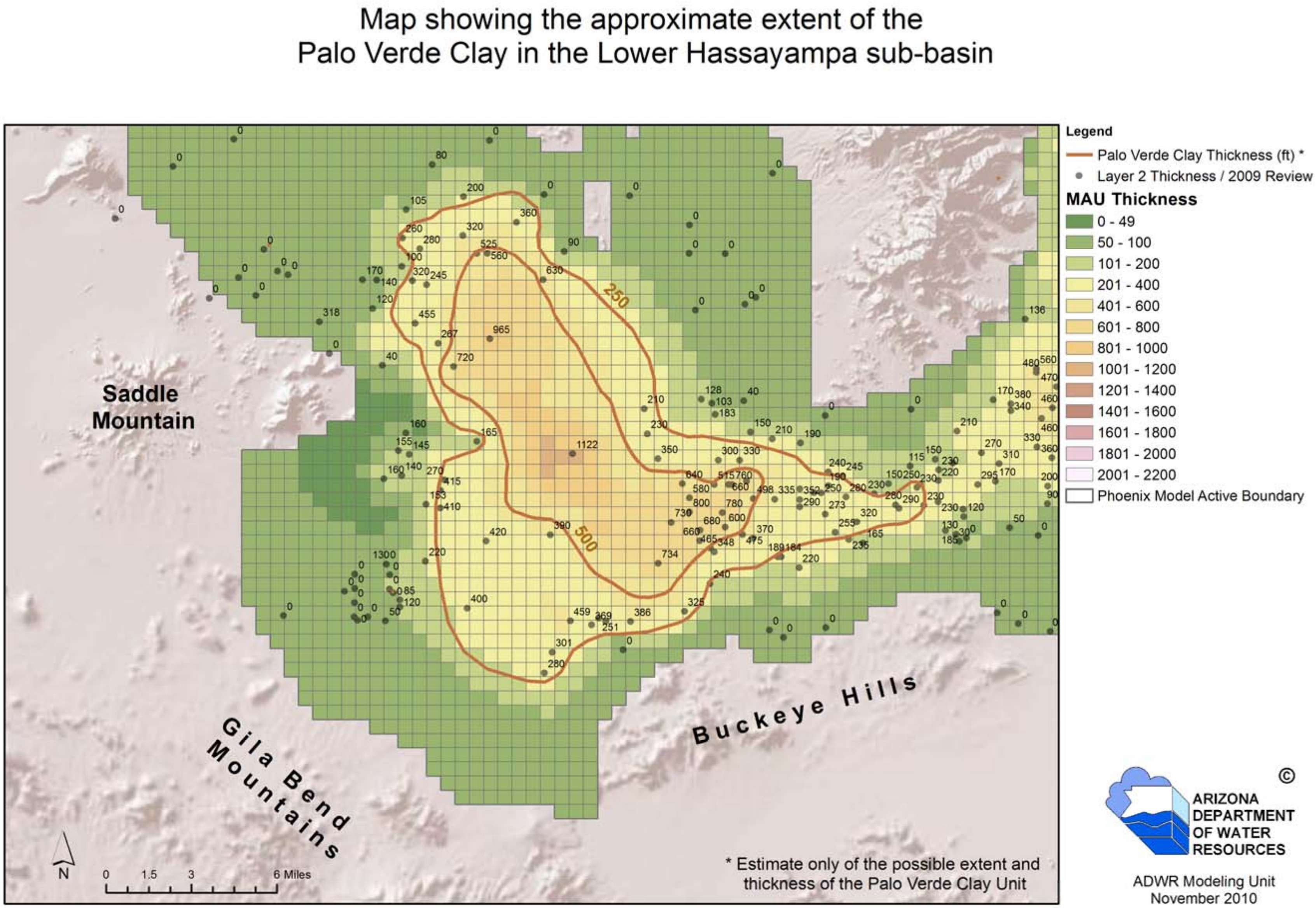
Map showing the approximate extent of the
Palo Verde Clay in the Lower Hassayampa sub-basin
Legend
Palo Verde Clay Thickness (ft) *
Layer 2 Thickness / 2009 Review
MAU Thickness
0 - 49
50 - 100
101 - 200
201 - 400
401 - 600
601 - 800
801 - 1000
1001 - 1200
1201 - 1400
1401 - 1600
1601 - 1800
1801 - 2000
2001 - 2200
Phoenix Model Active Boundary
Saddle Mountain
Gila Bend Mountains
Buckeye Hills
250
500
N
0 1.5 3 6 Miles
* Estimate only of the possible extent and thickness of the Palo Verde Clay Unit
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Figure 5

Map showing model cells within the Phoenix model active grid that are shared by the updated Pinal model active grid

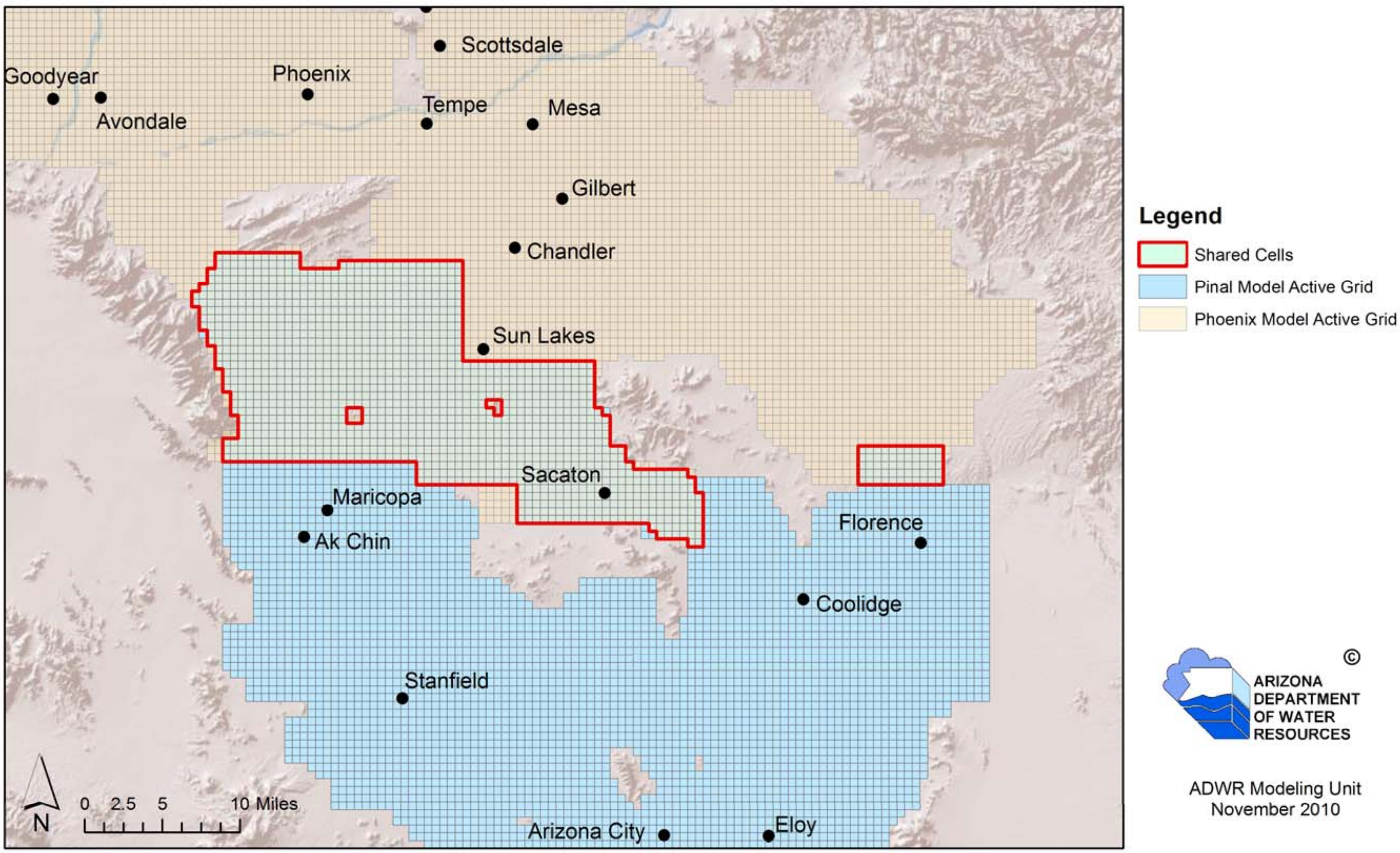


Figure 6

Map showing the location of wells with logs that were reevaluated in the Phoenix / Scottsdale area

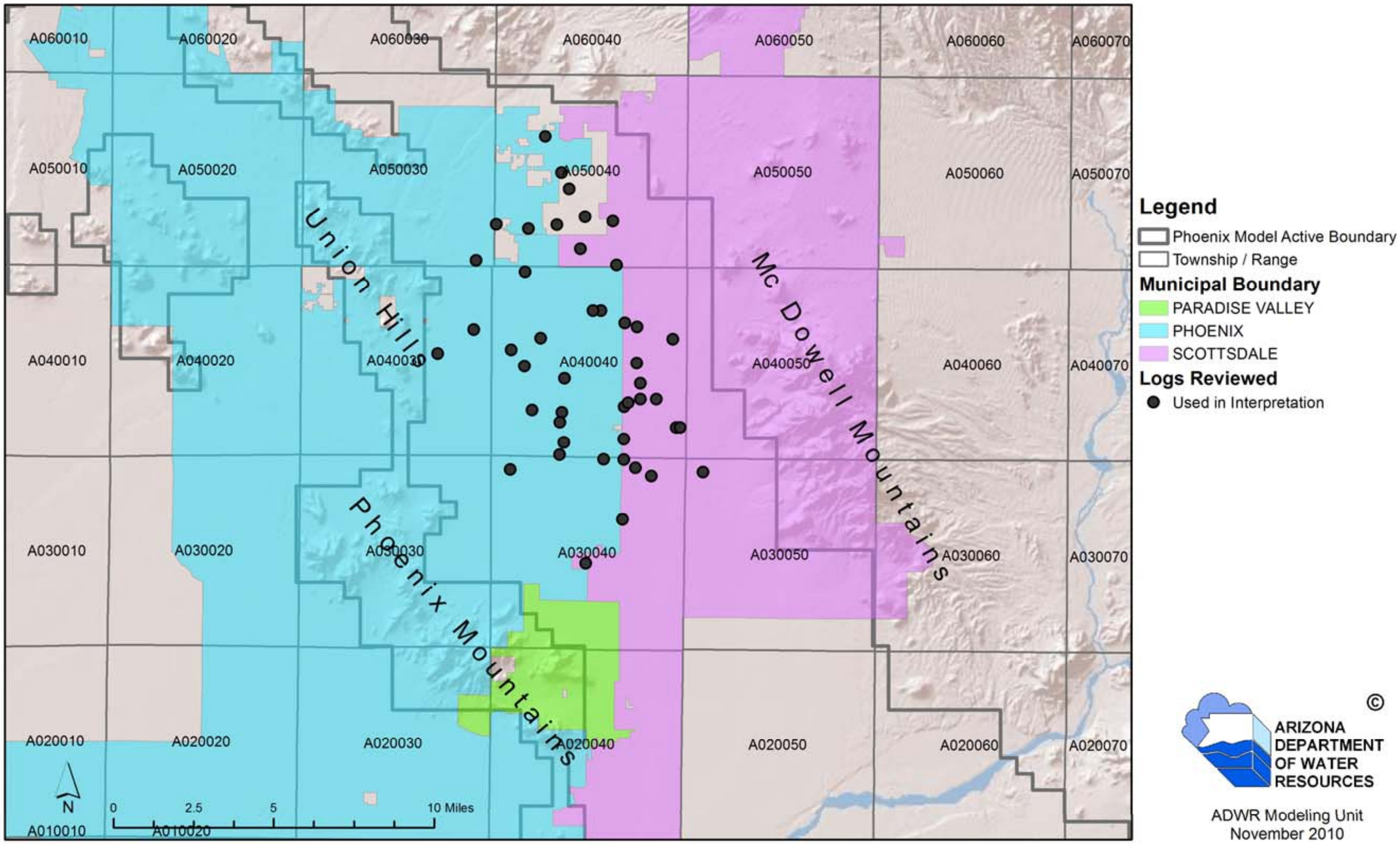
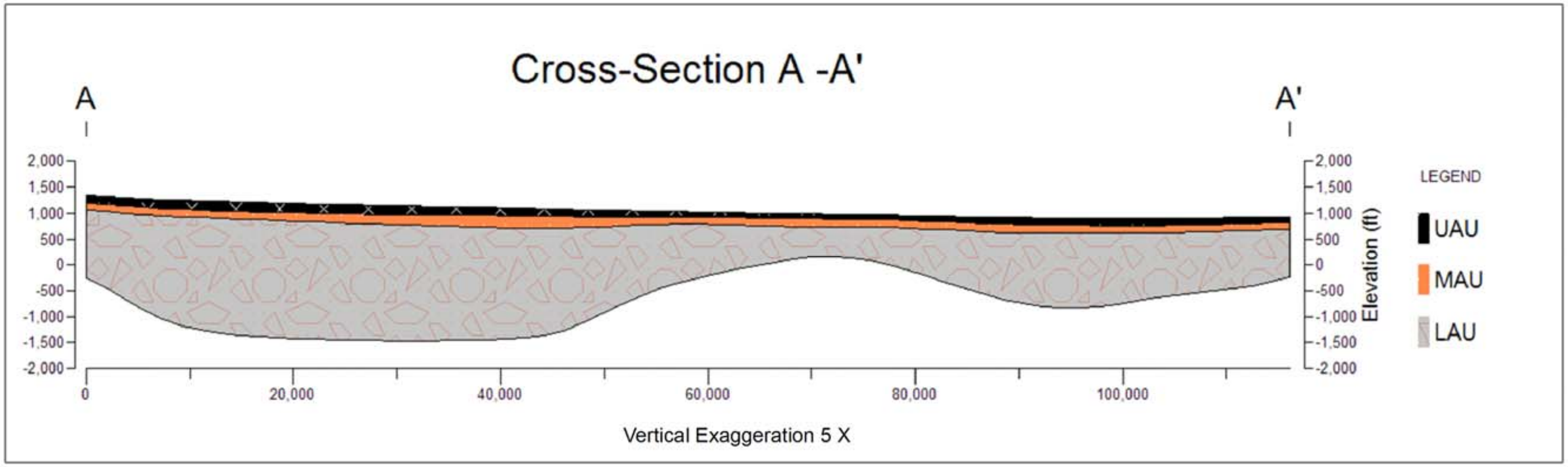
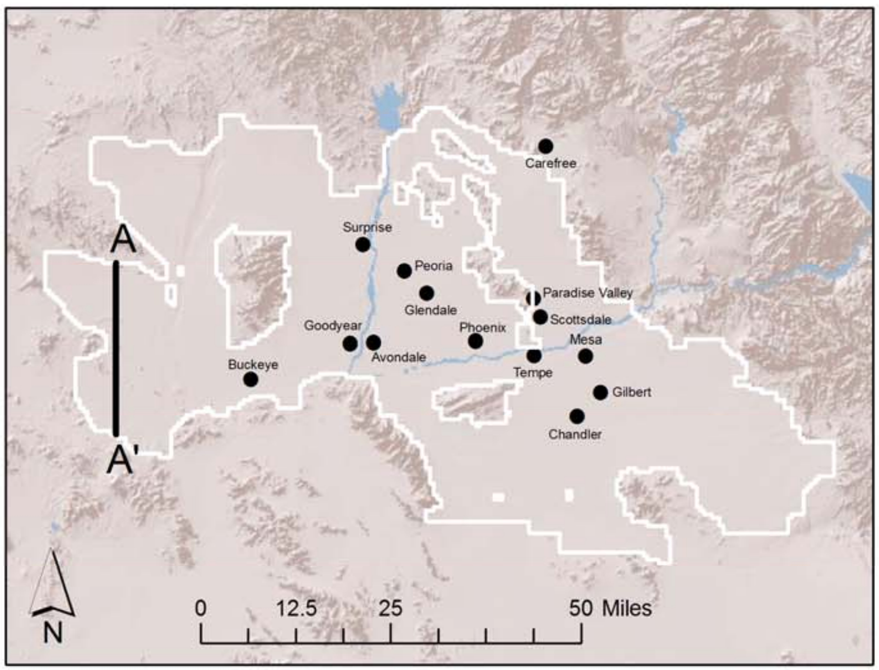


Figure 7



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section A-A'

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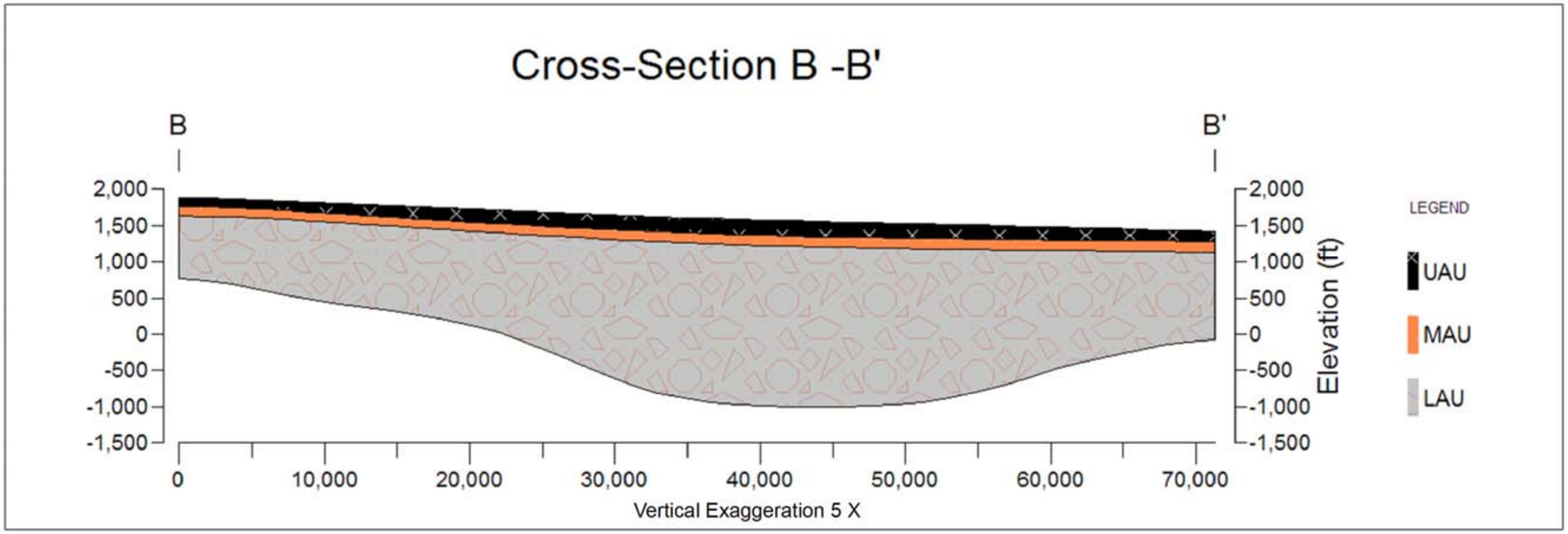
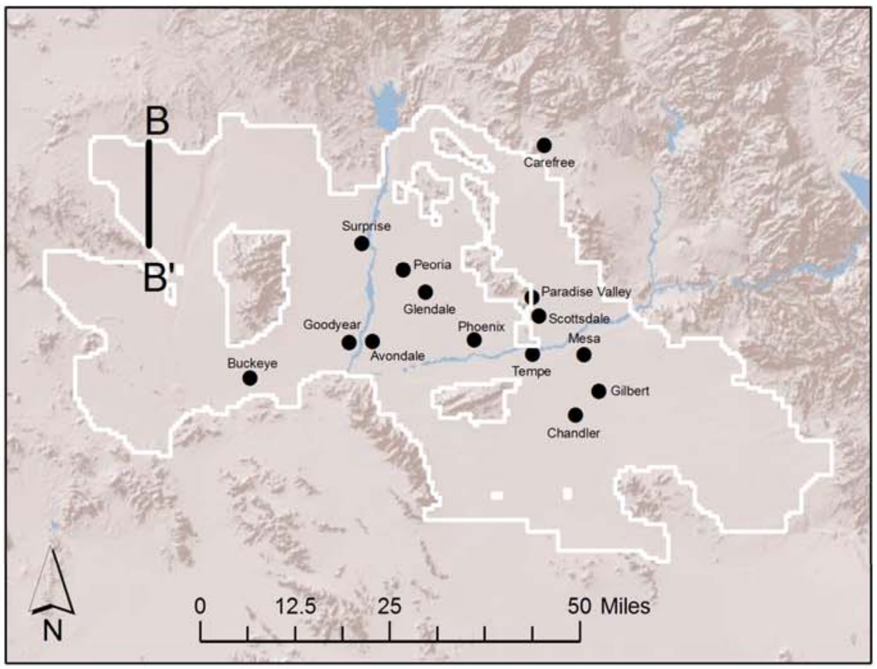
Figure 8



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section B-B'

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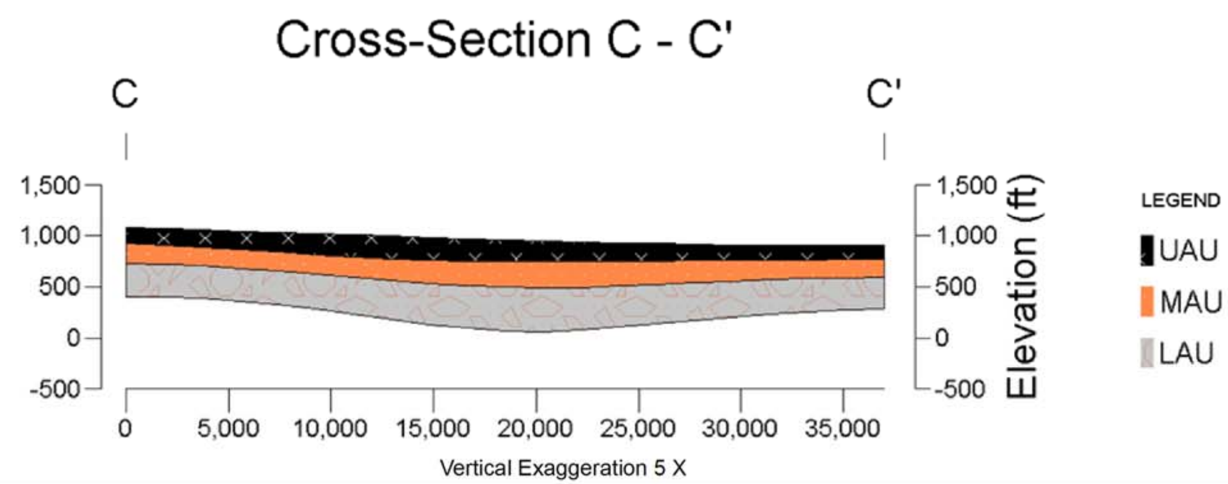
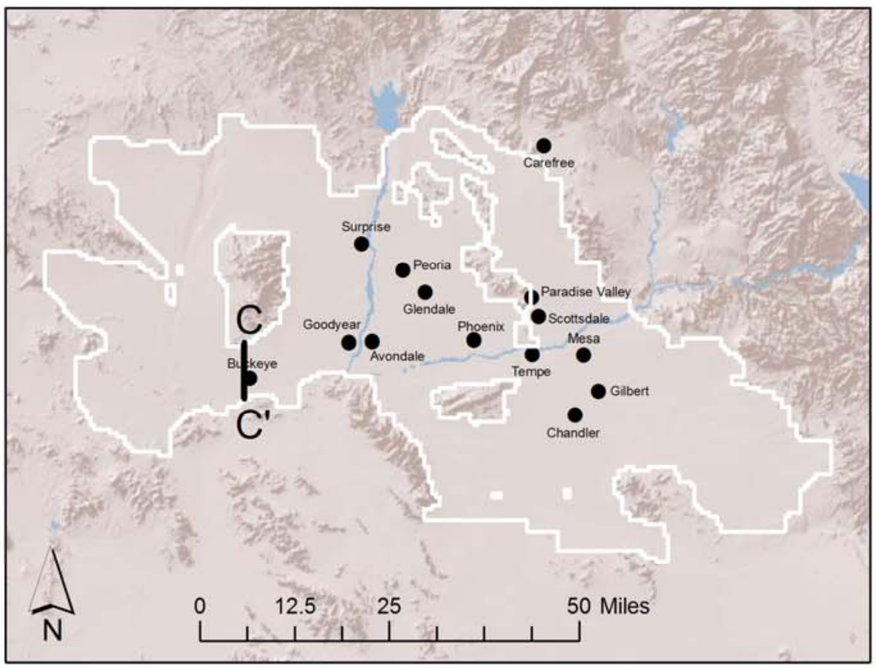
Figure 9



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet
above mean sea level



Map showing the cross-section
and location map for
cross-section C-C'

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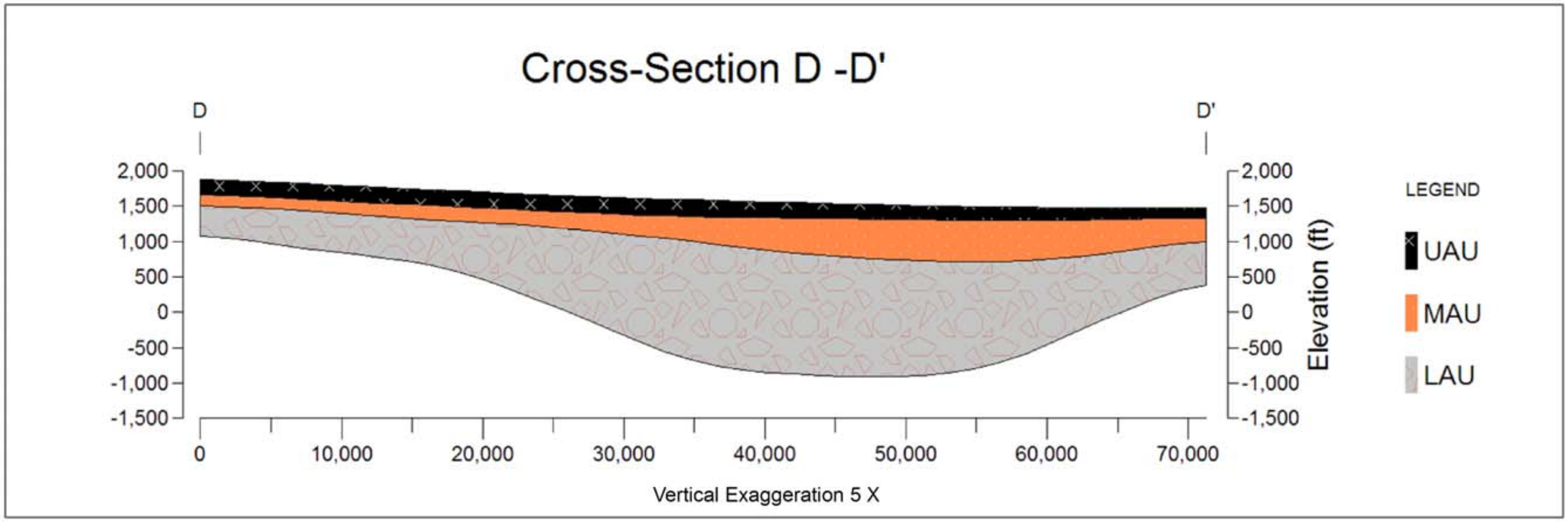
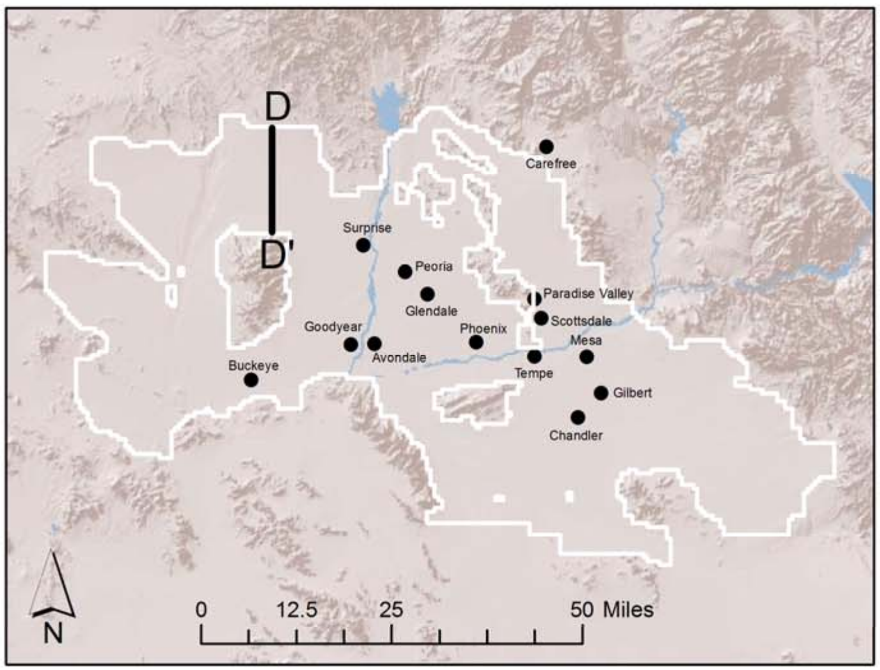
Figure 10



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet
above mean sea level



Map showing the cross-section
and location map for
cross-section D-D'

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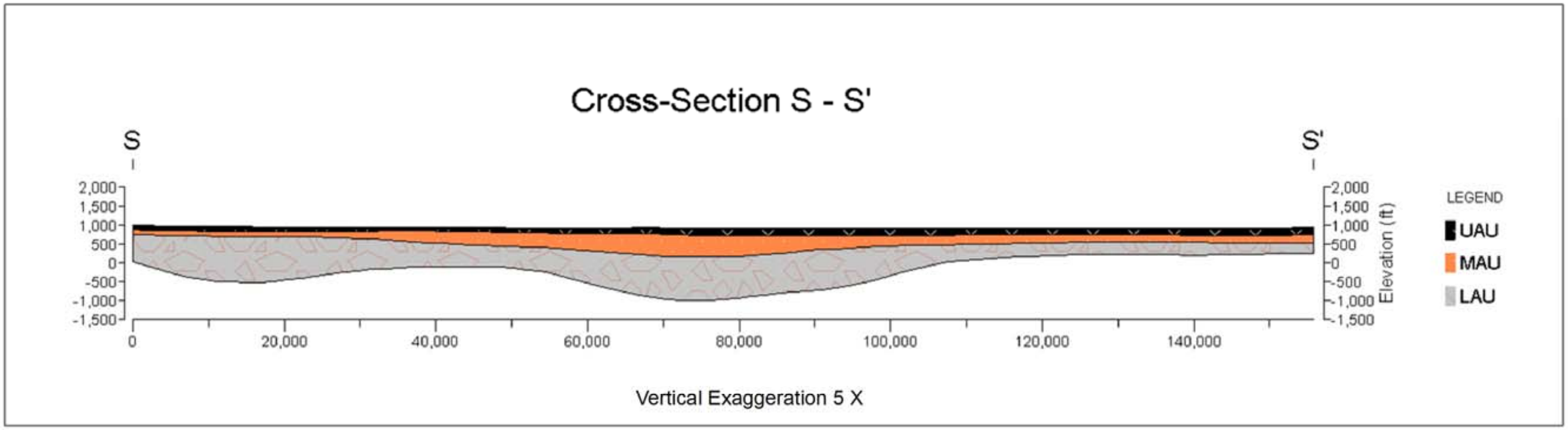
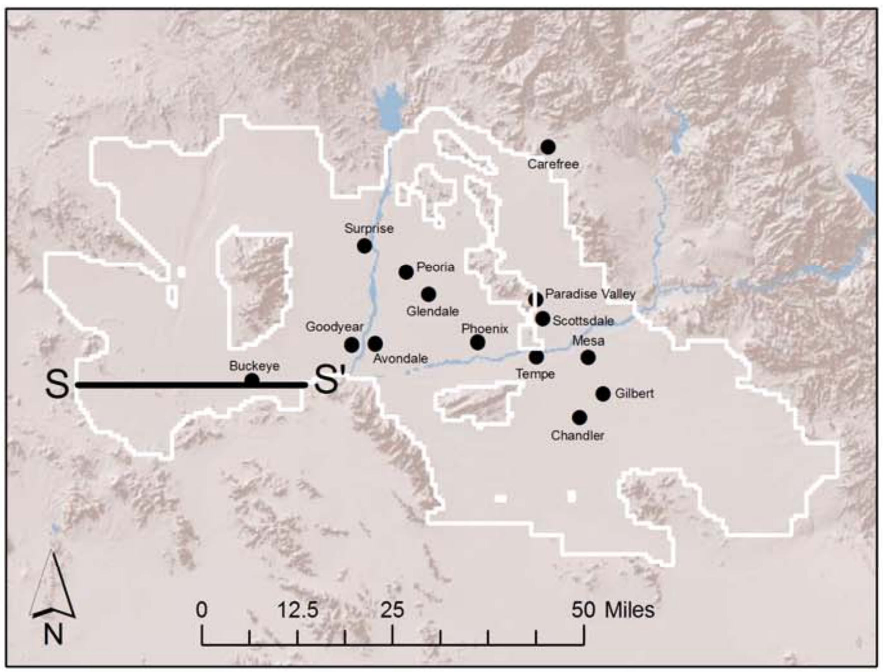
Figure 11



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section S-S'

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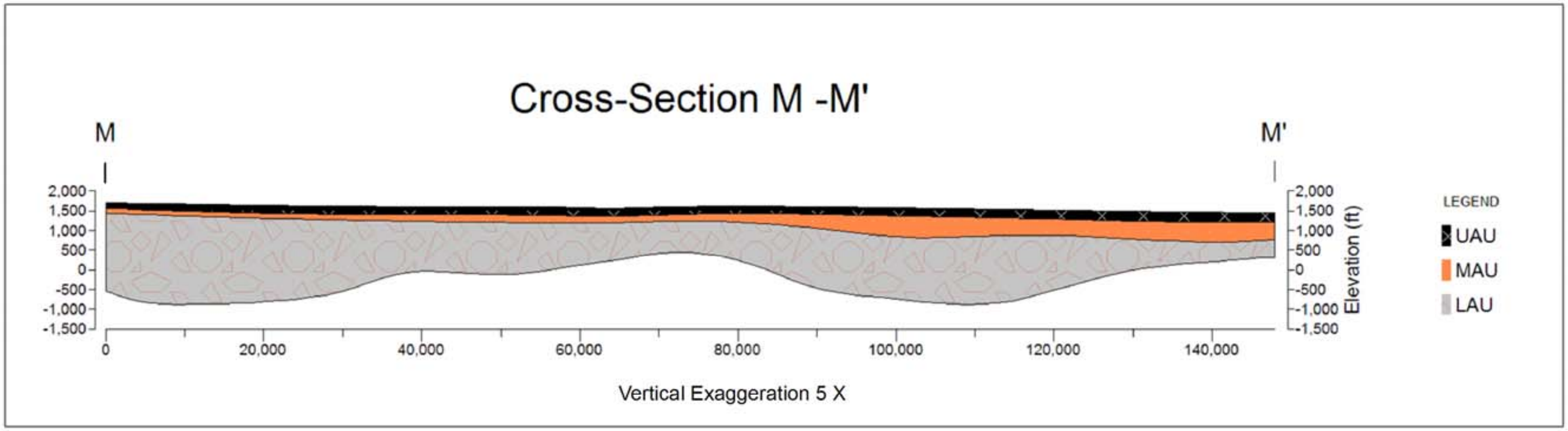
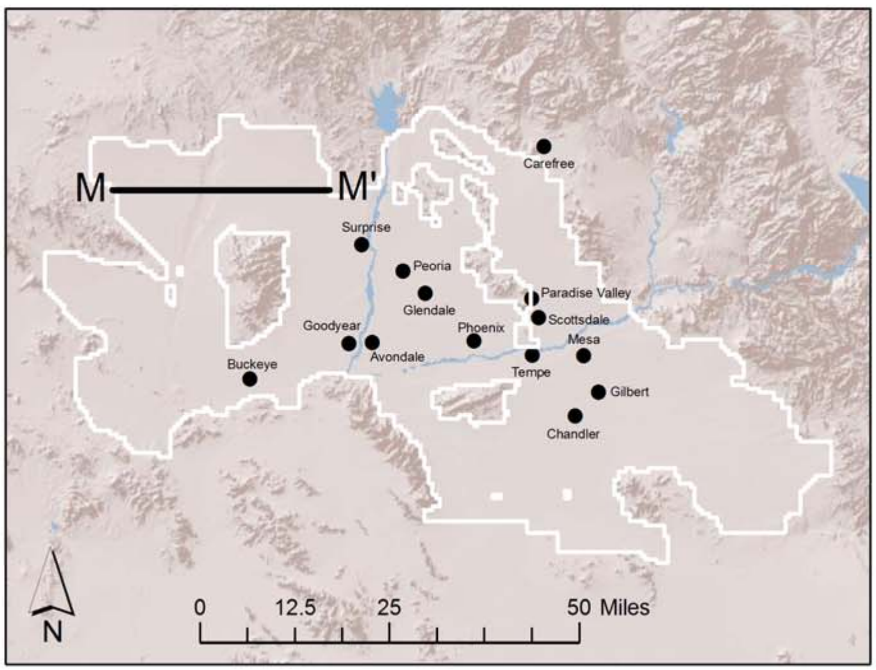
Figure 12



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section M-M'

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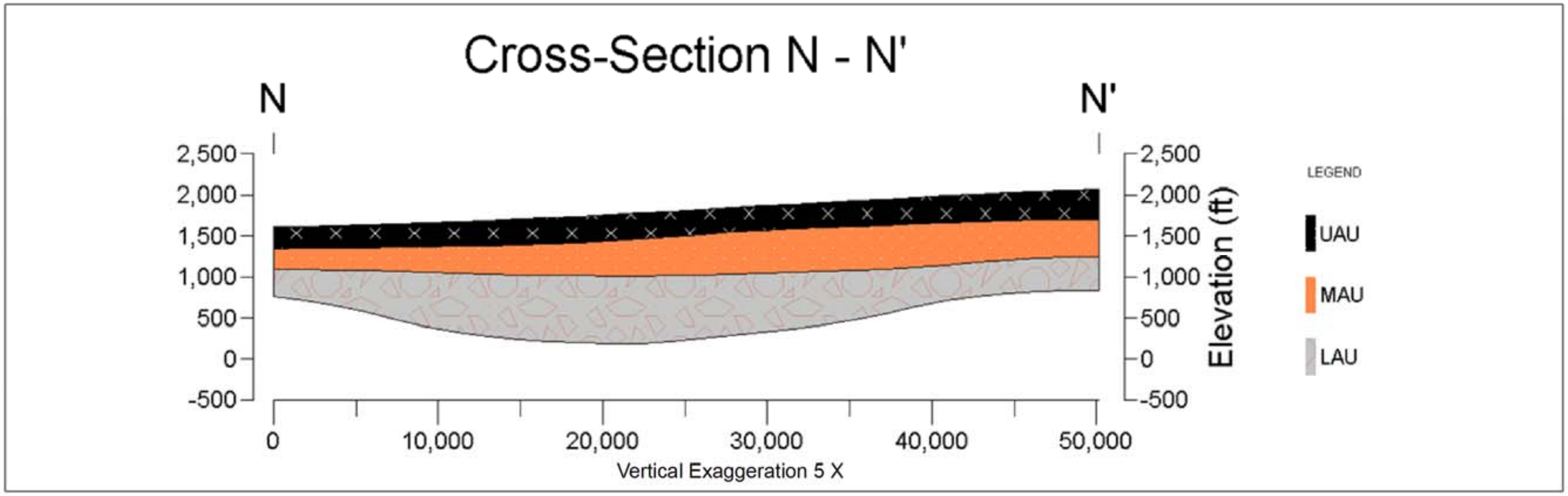
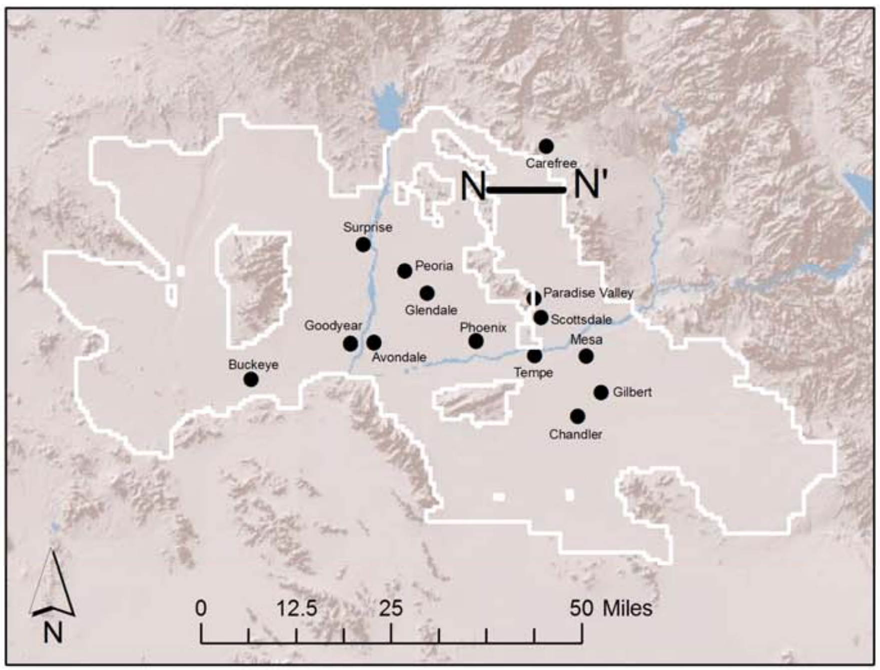
Figure 13



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet
above mean sea level



Map showing the cross-section and location map for cross-section N-N'

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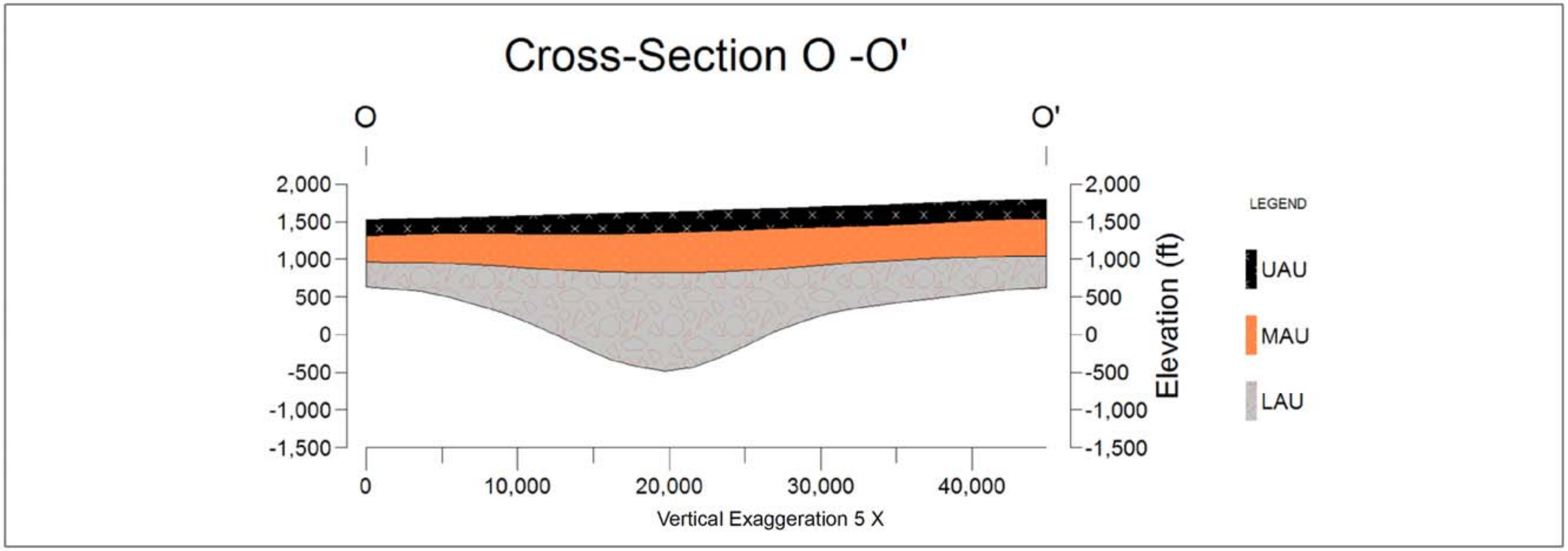
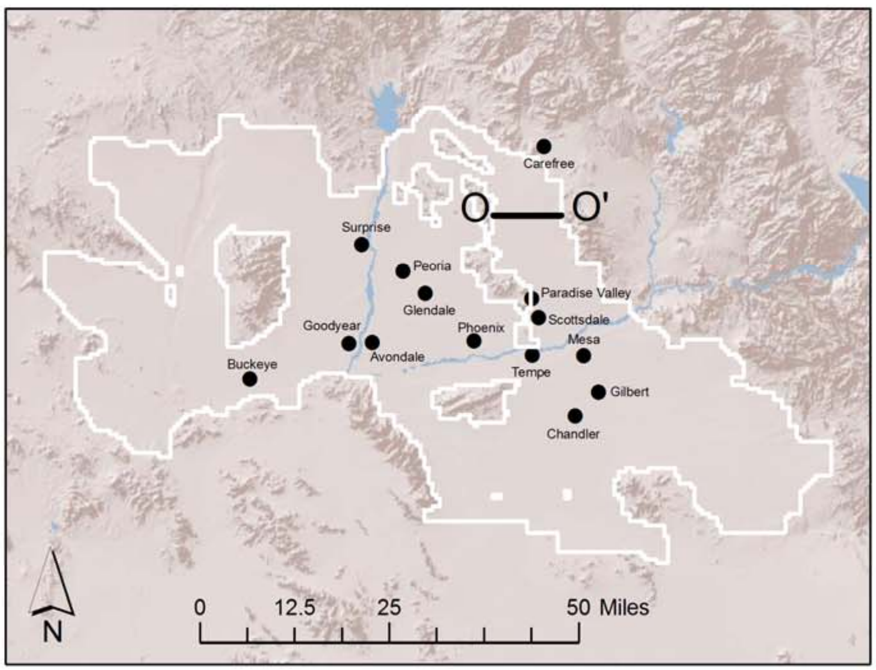
Figure 14





X-Axis - Distance in Feet

Y-Axis - Elevation in Feet
above mean sea level

Map showing the cross-section
and location map for
cross-section O-O'

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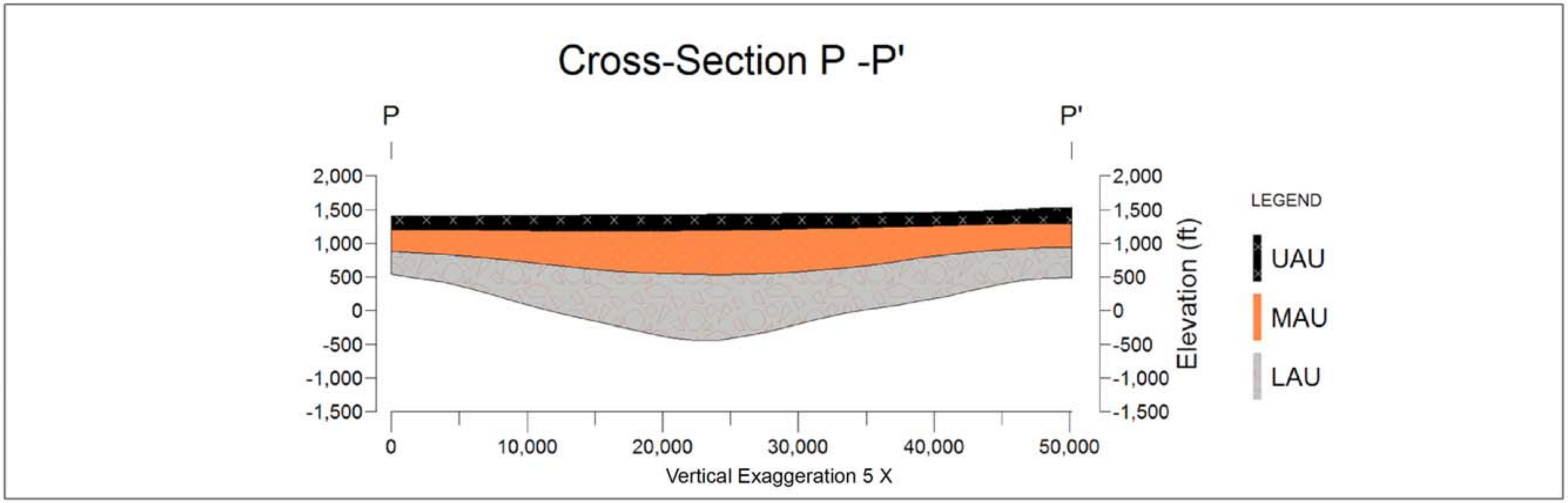
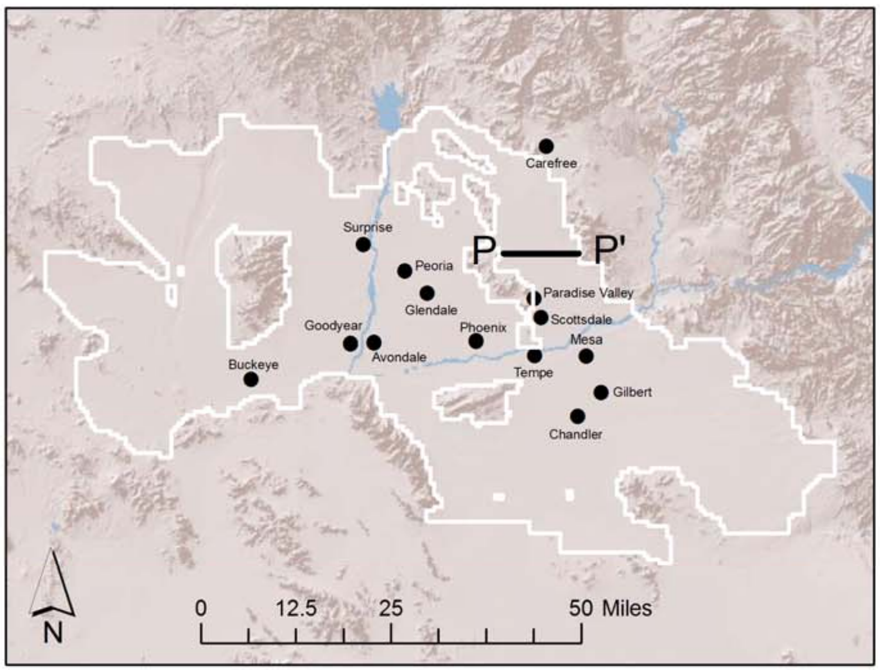
Figure 15



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet
above mean sea level



Map showing the cross-section
and location map for
cross-section P-P'

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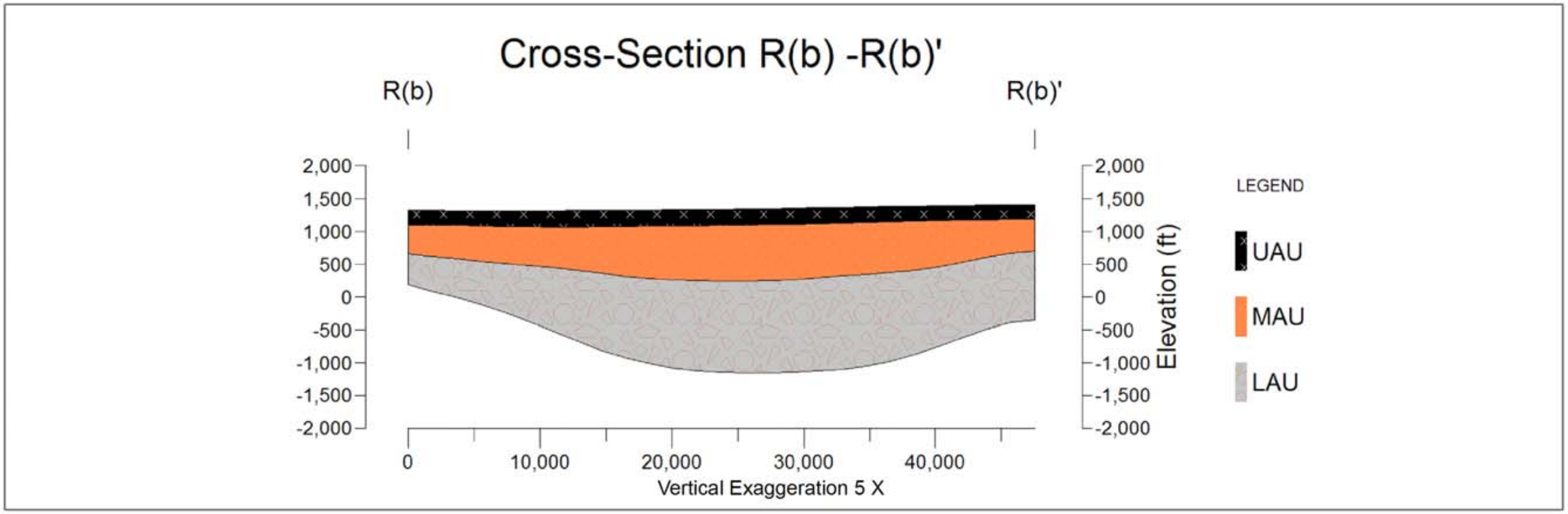
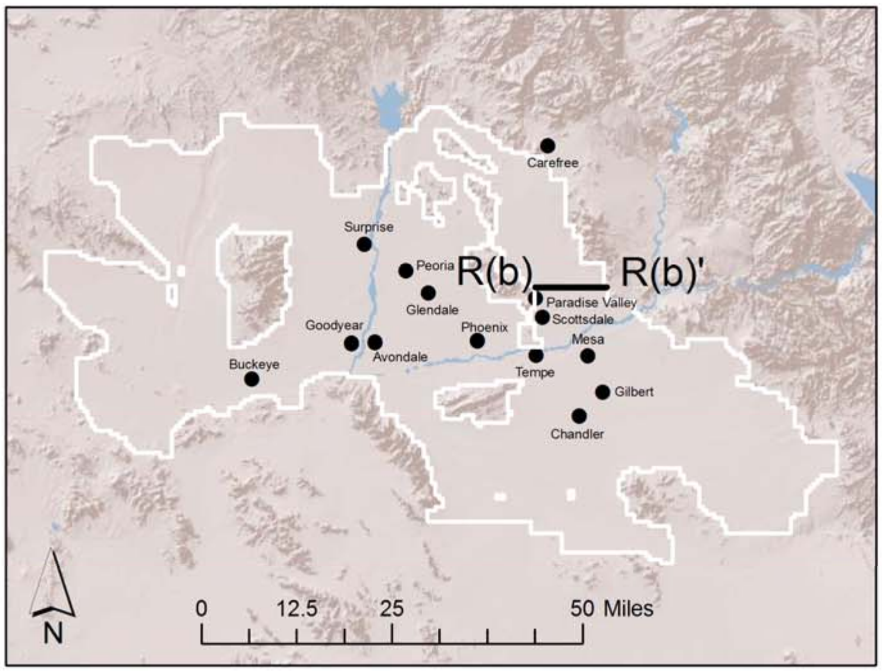
Figure 16



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section R(b)-R(b)'

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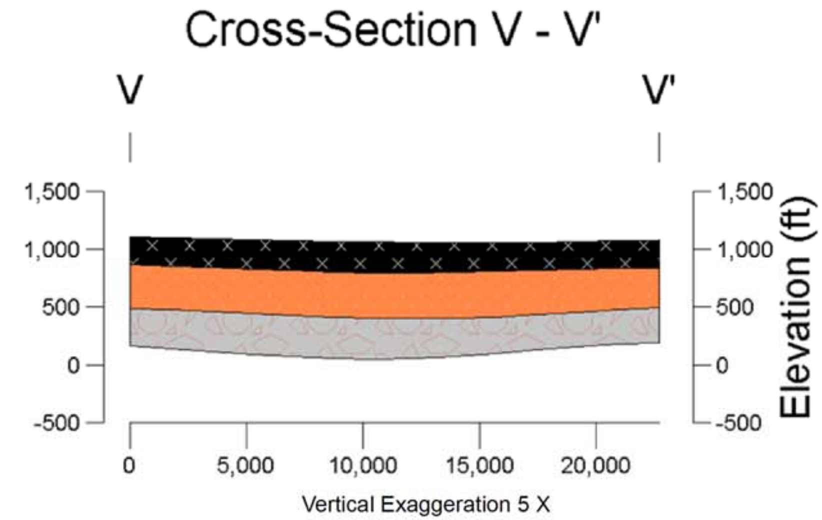
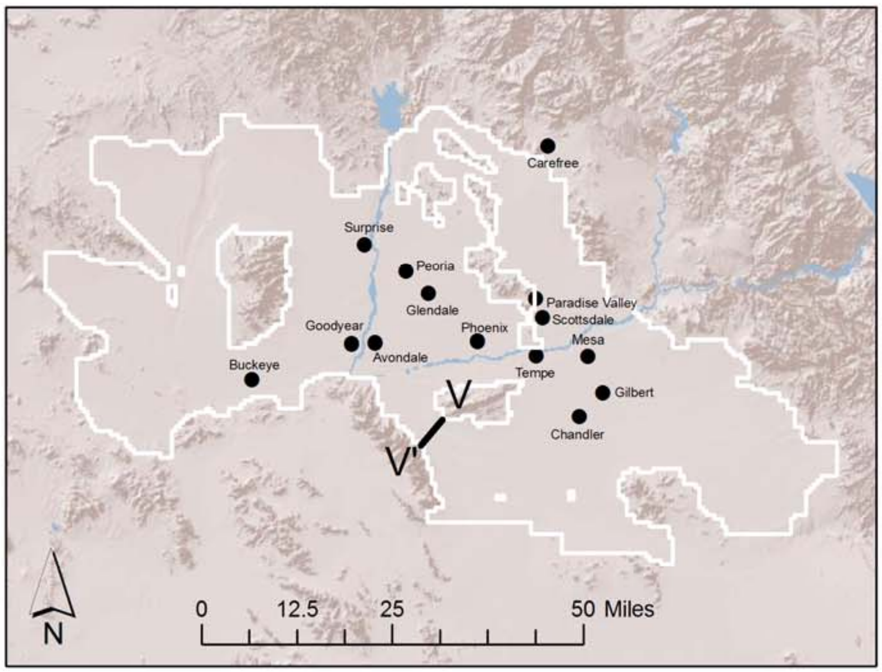
Figure 17



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section V-V'

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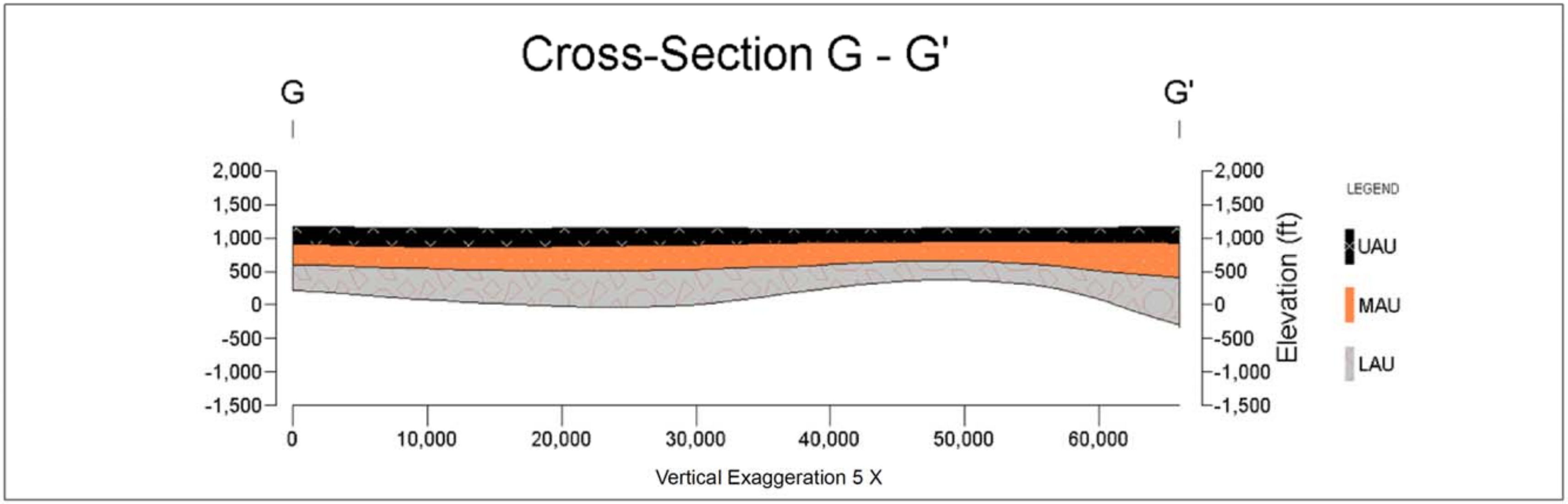
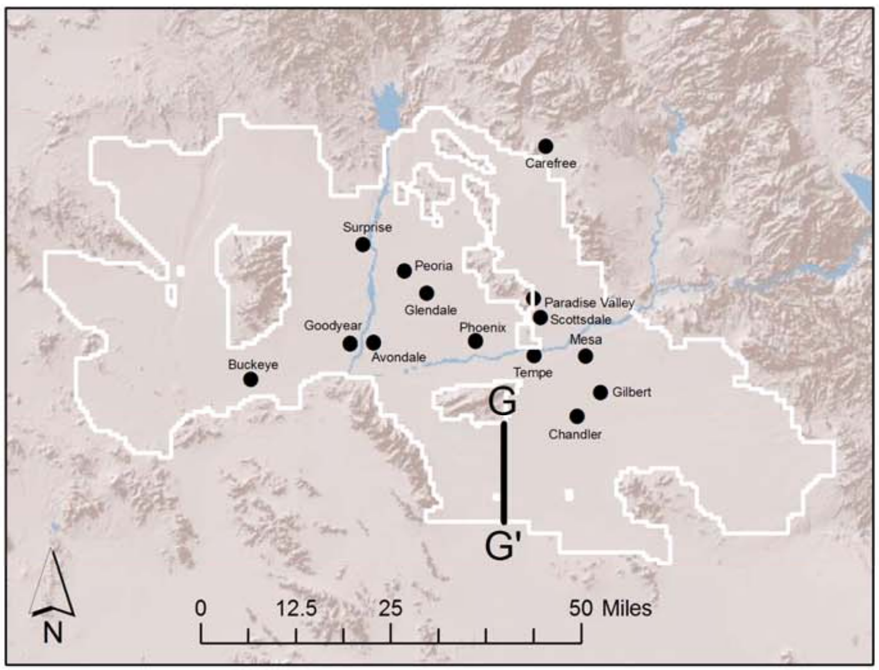
Figure 18



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet
above mean sea level



Map showing the cross-section
and location map for
cross-section G-G'

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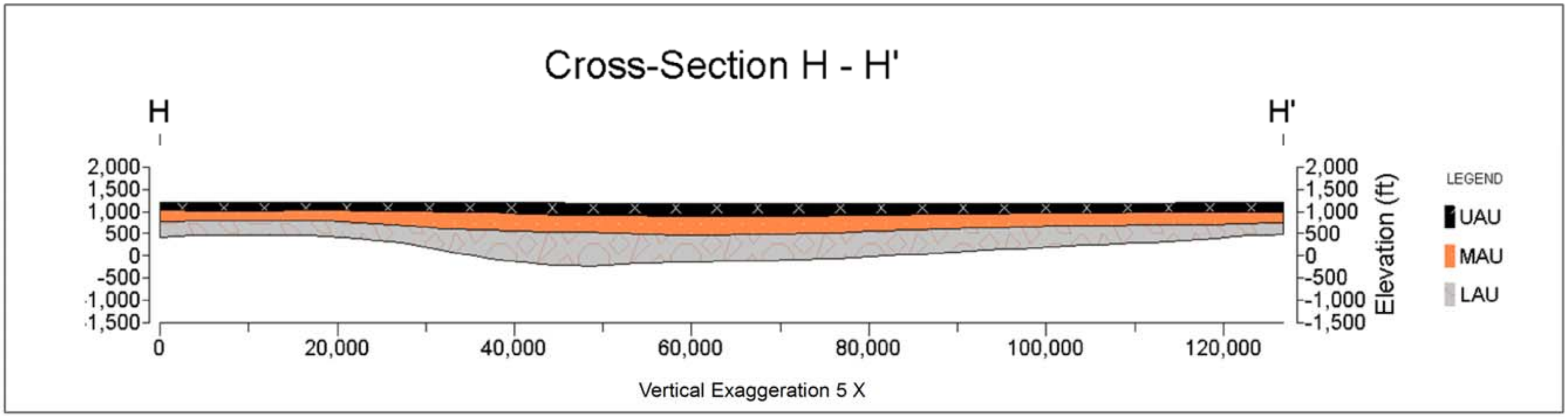
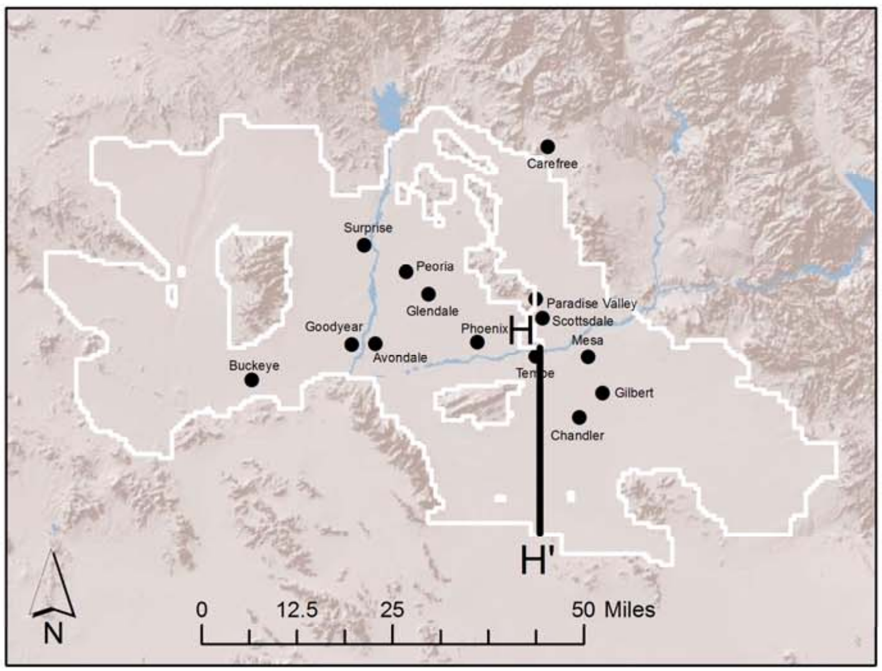
Figure 19



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet
above mean sea level



Map showing the cross-section and location map for cross-section H-H'

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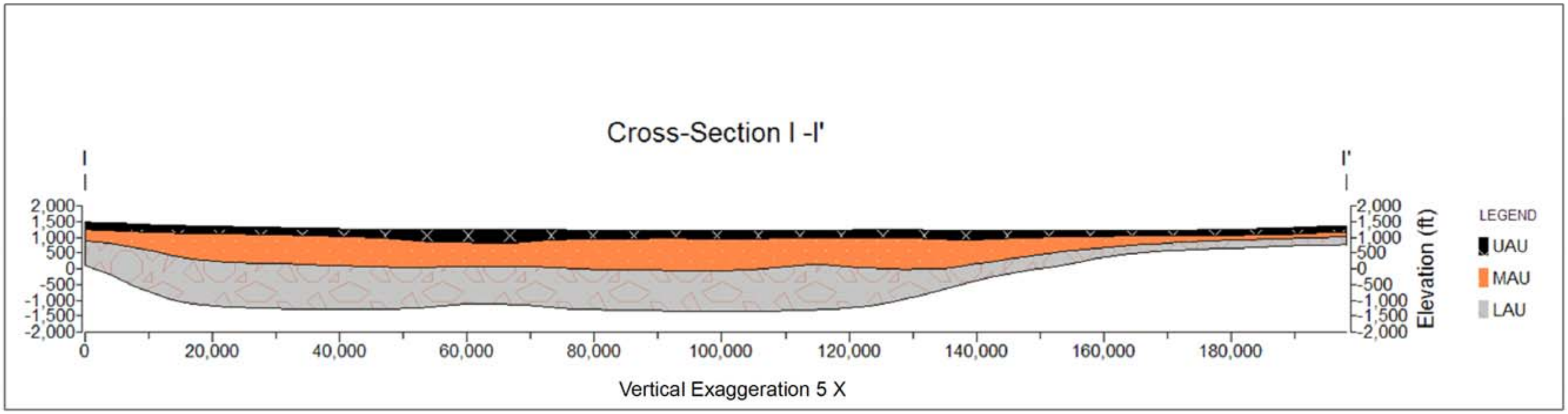
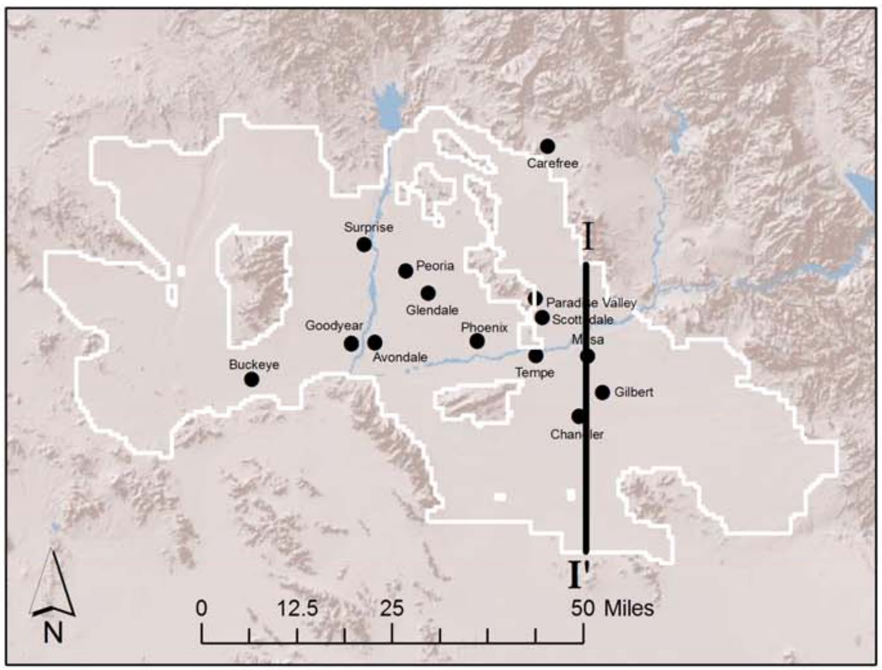
Figure 20



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section I-I'

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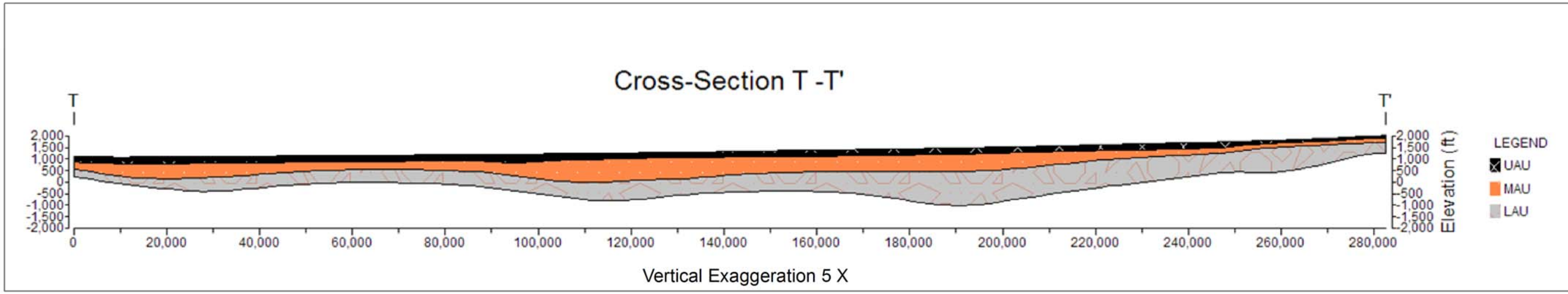
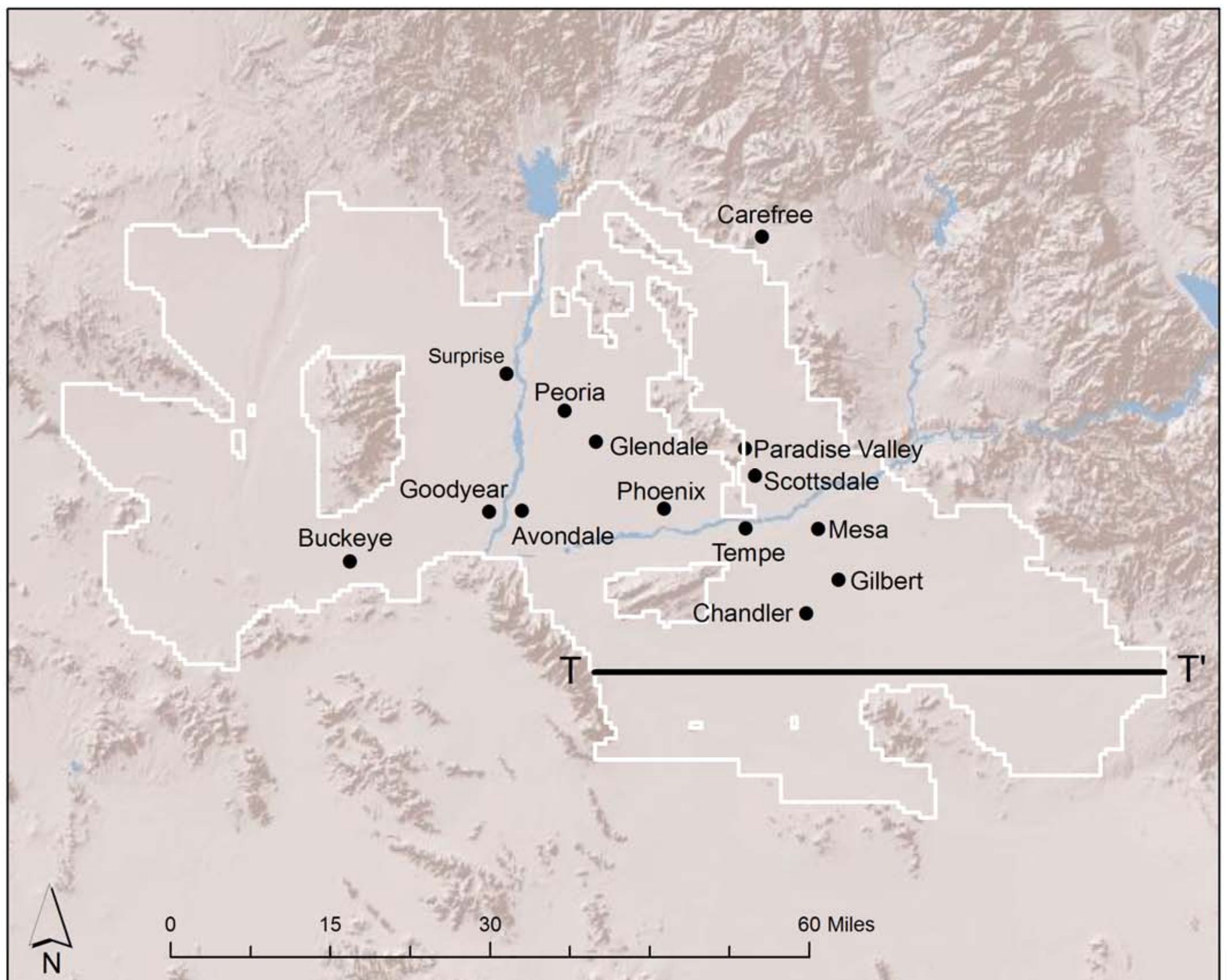
Figure 21



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section T-T'

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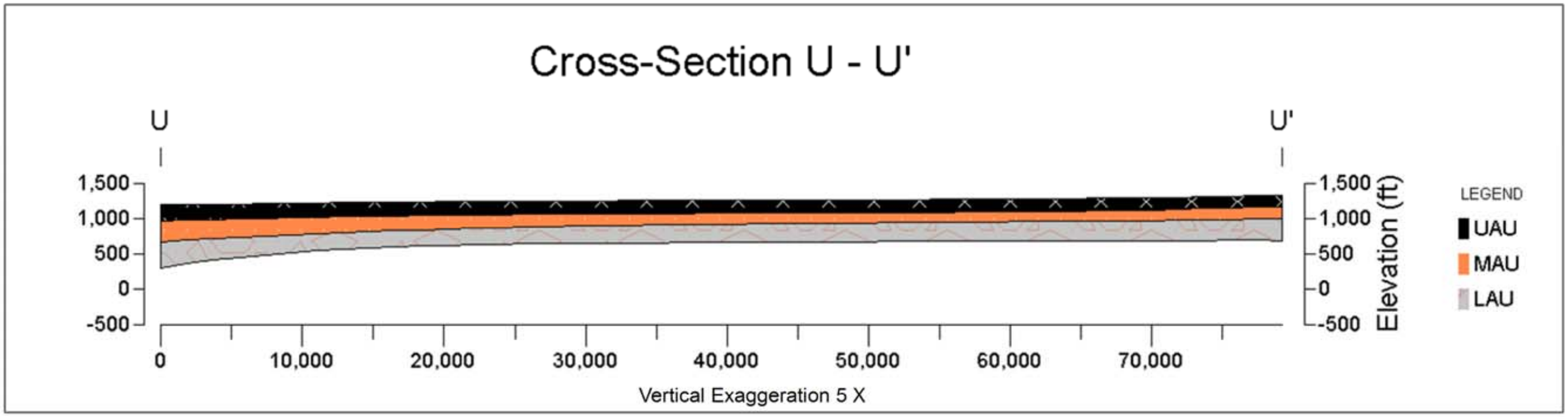
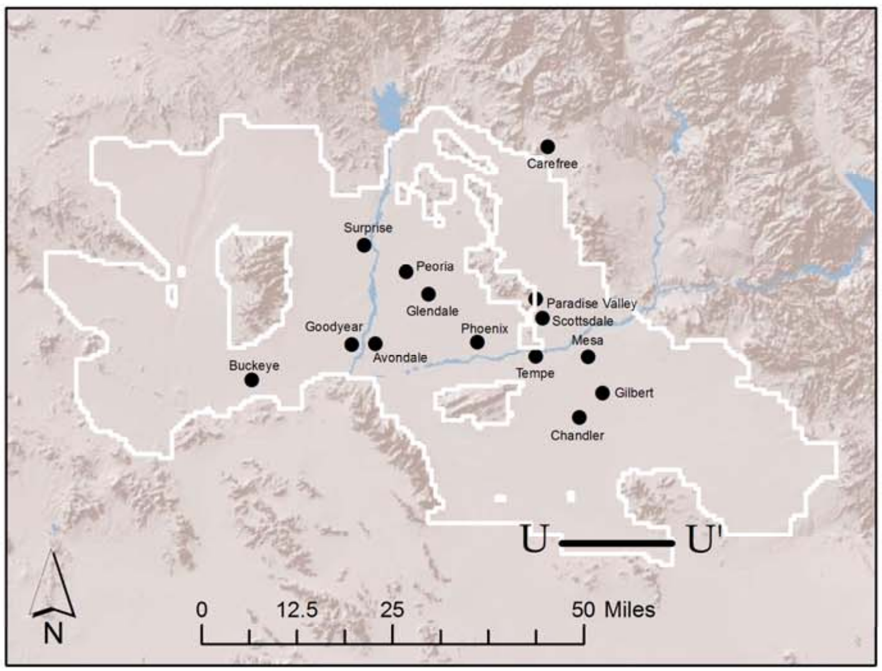
Figure 22



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet
above mean sea level



Map showing the cross-section and location map for cross-section U-U'

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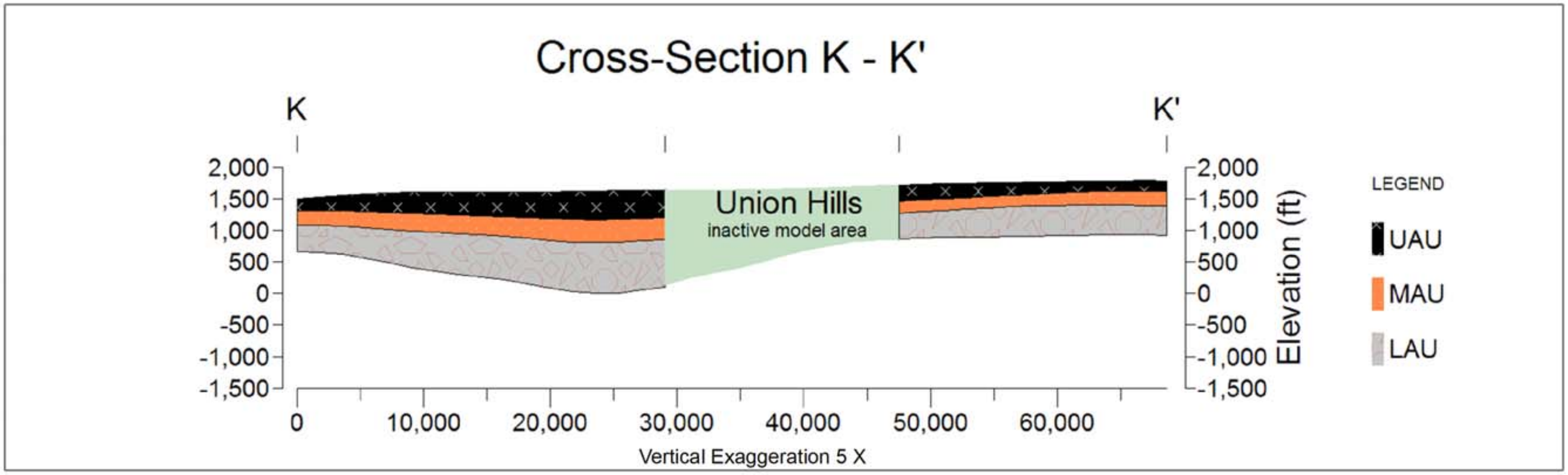
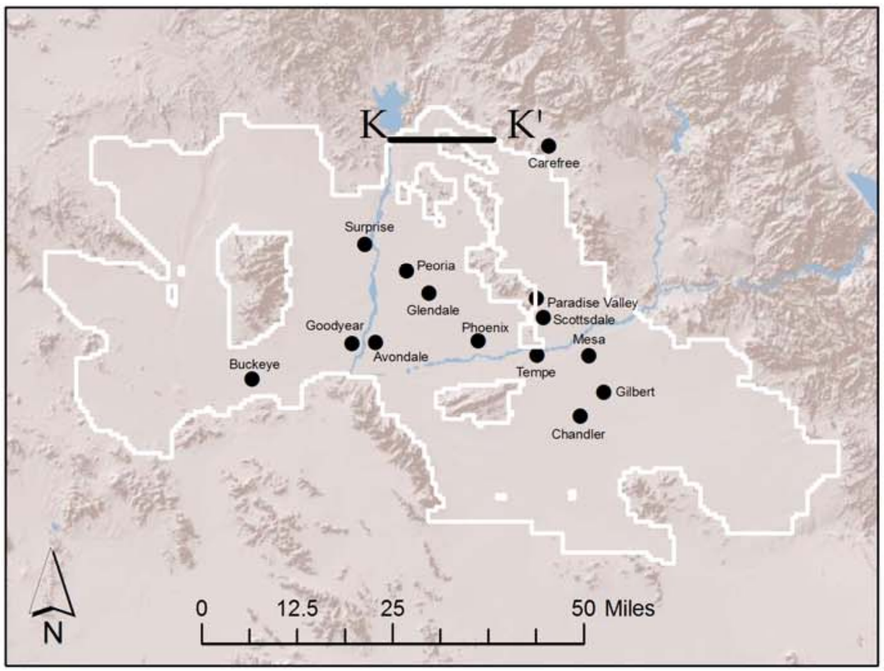
Figure 23



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section K-K'

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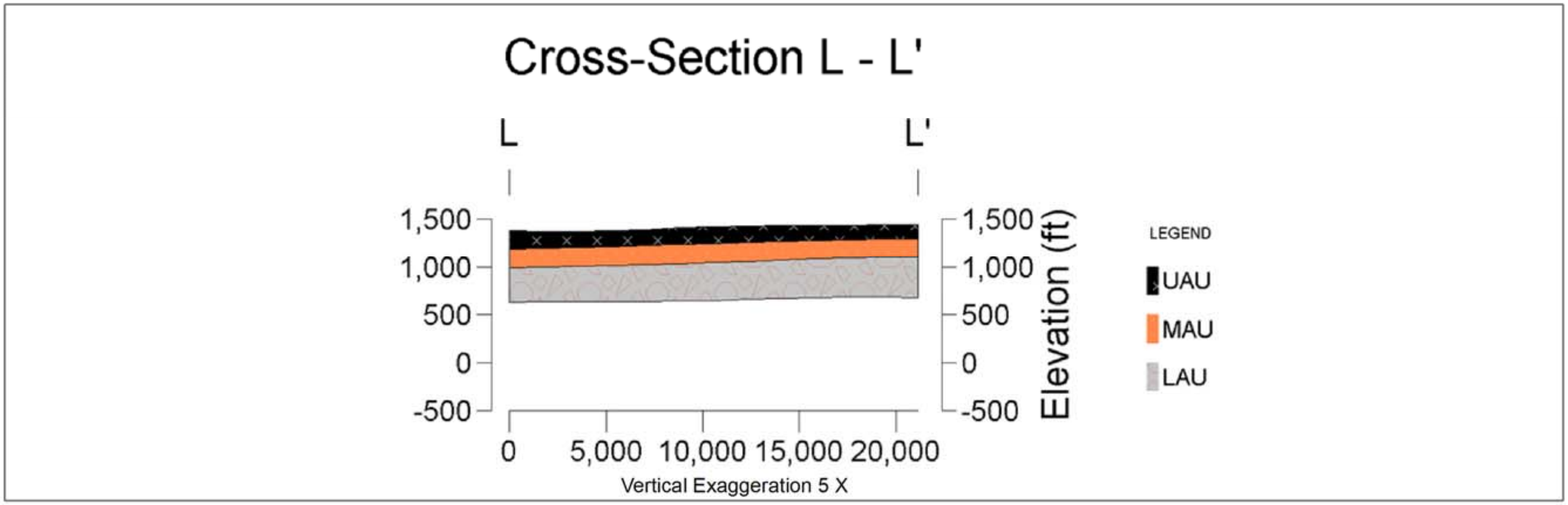
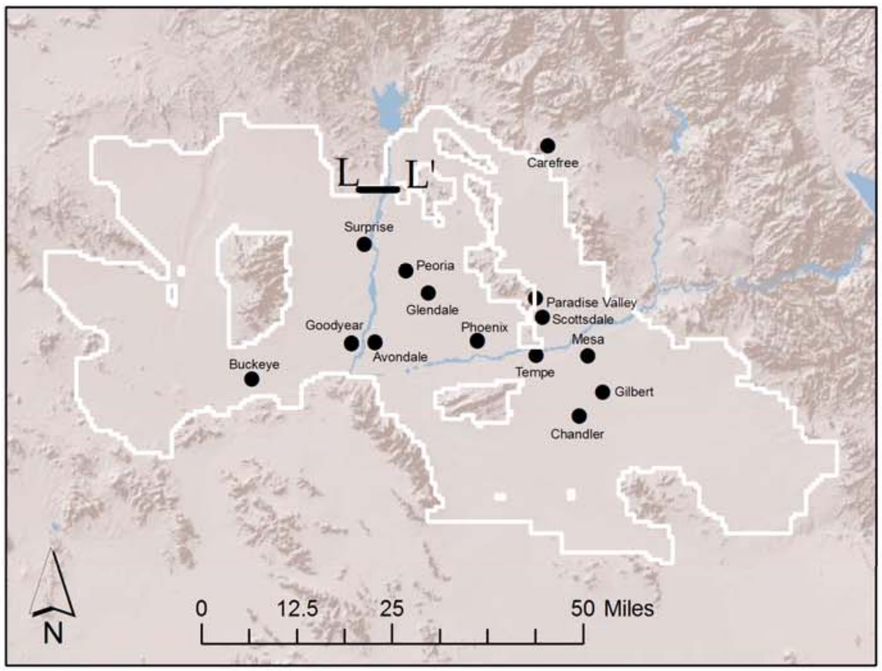
Figure 24



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet
above mean sea level



Map showing the cross-section
and location map for
cross-section L-L'

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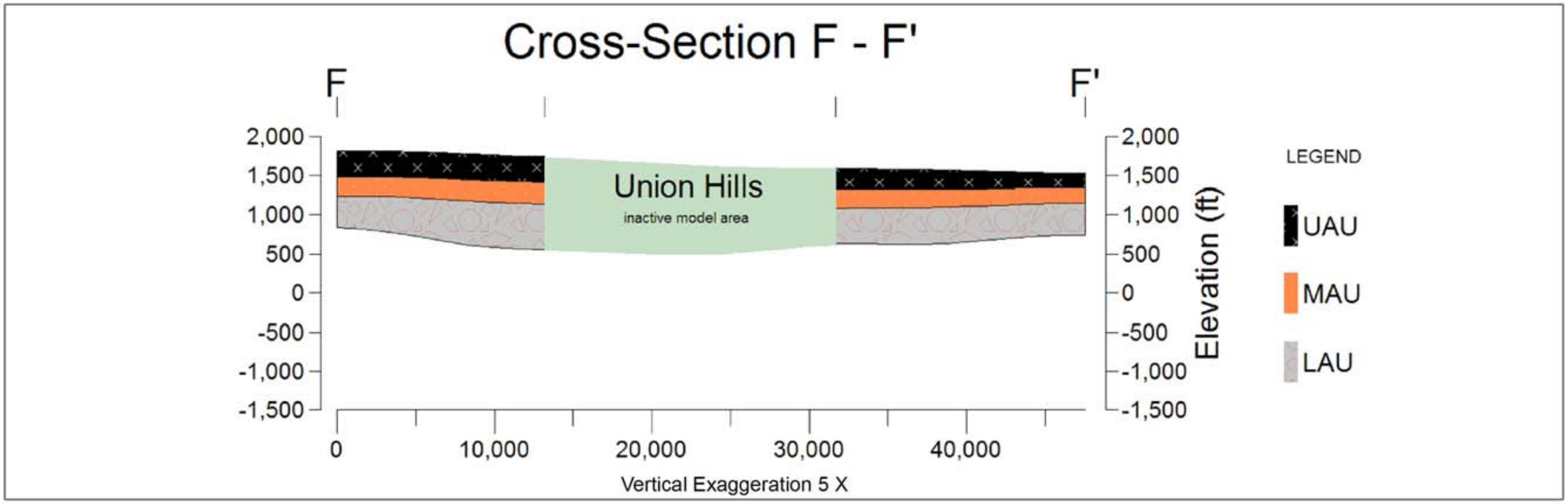
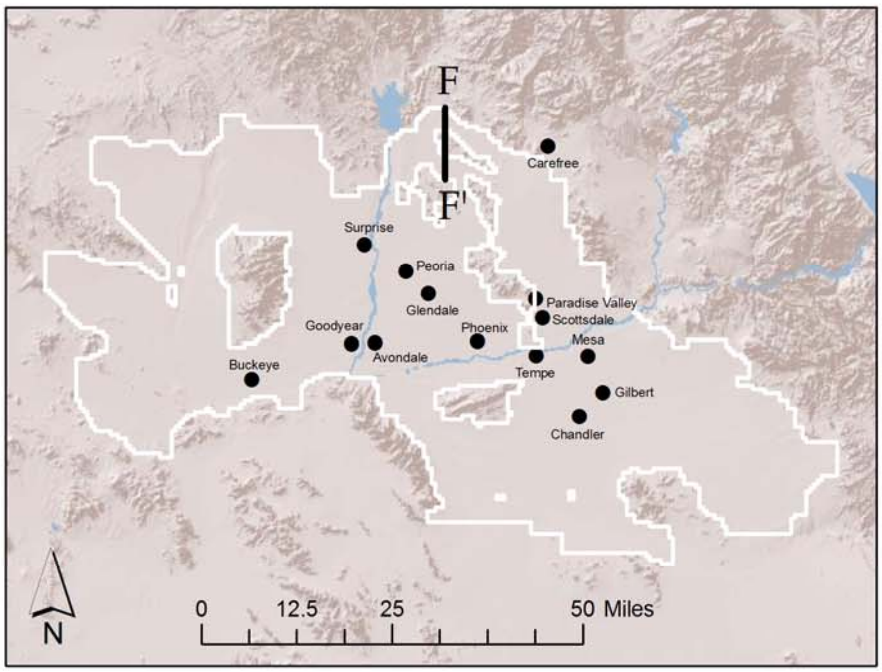
Figure 25



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section F-F'

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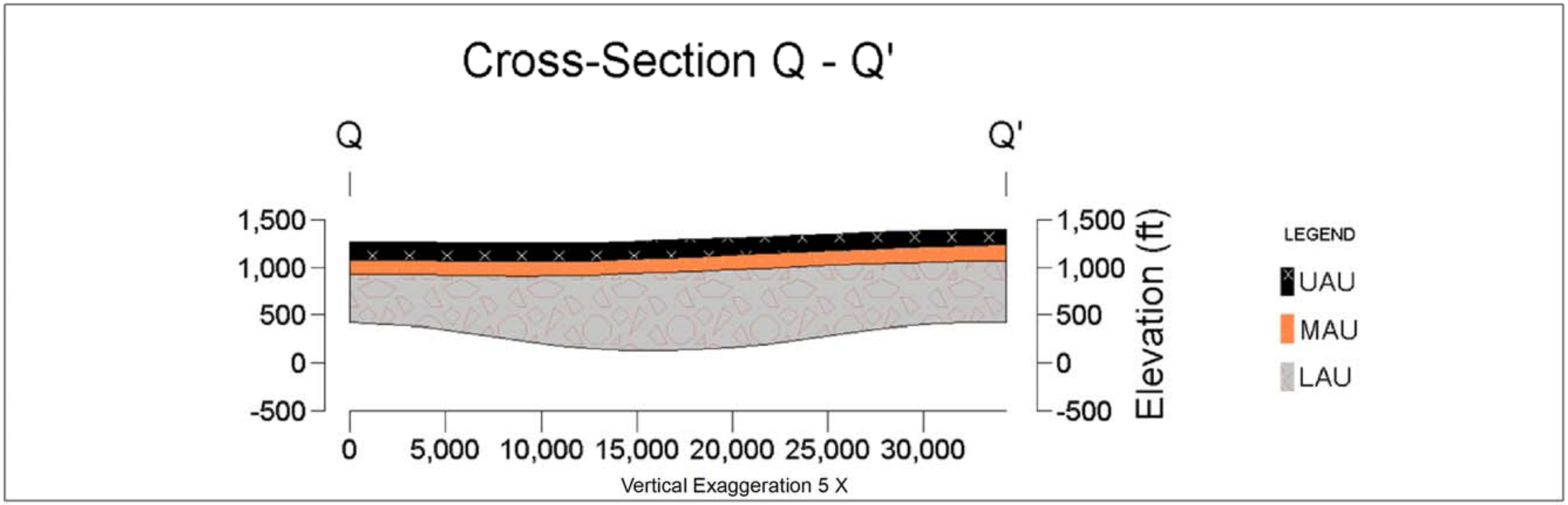
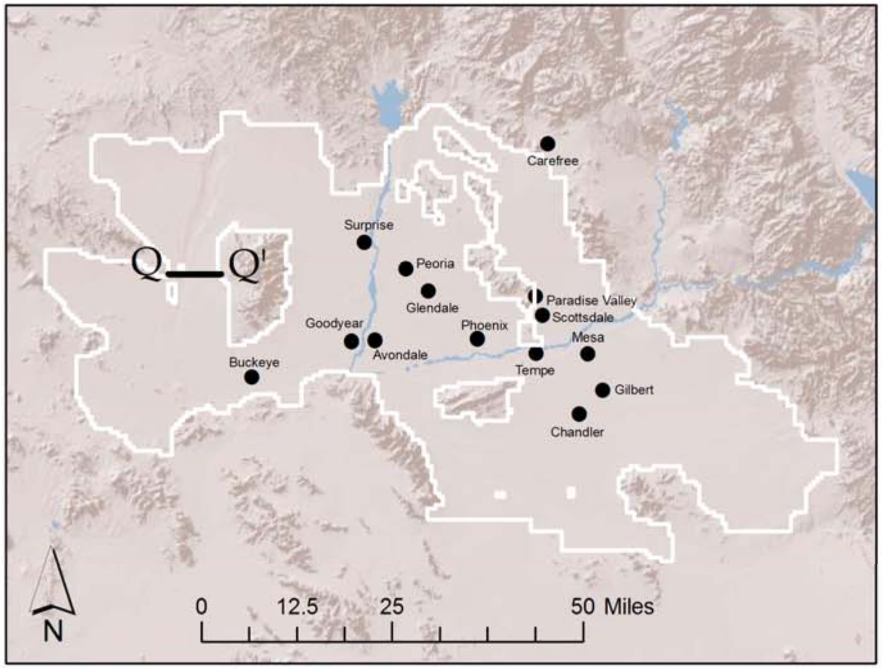
Figure 26



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section Q-Q'

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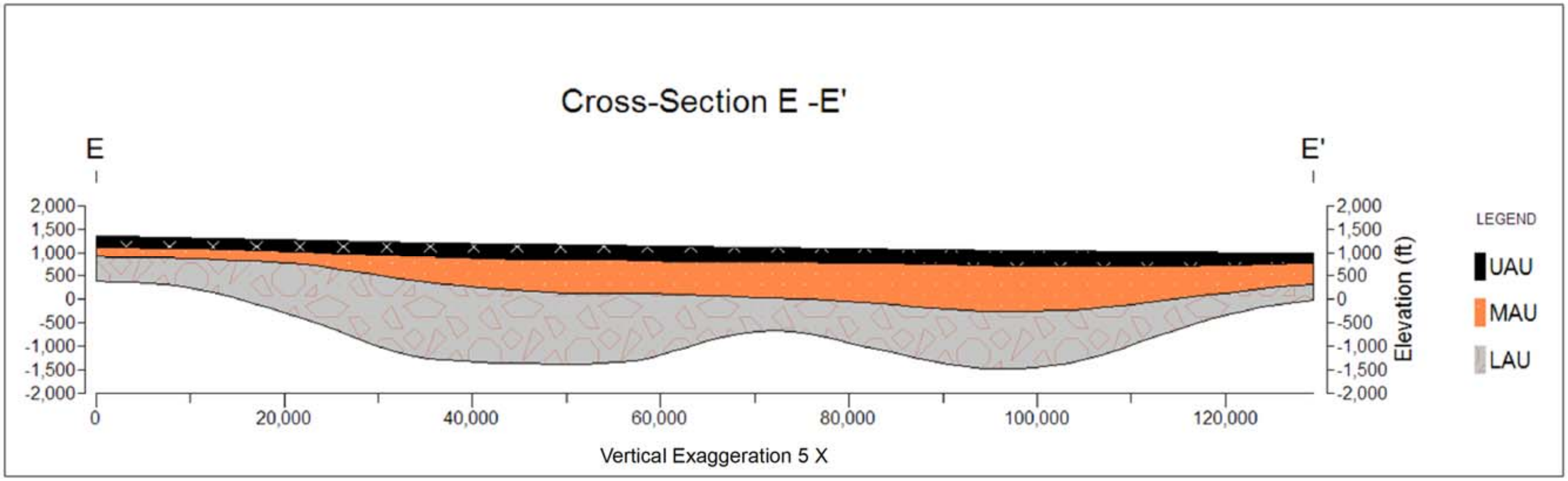
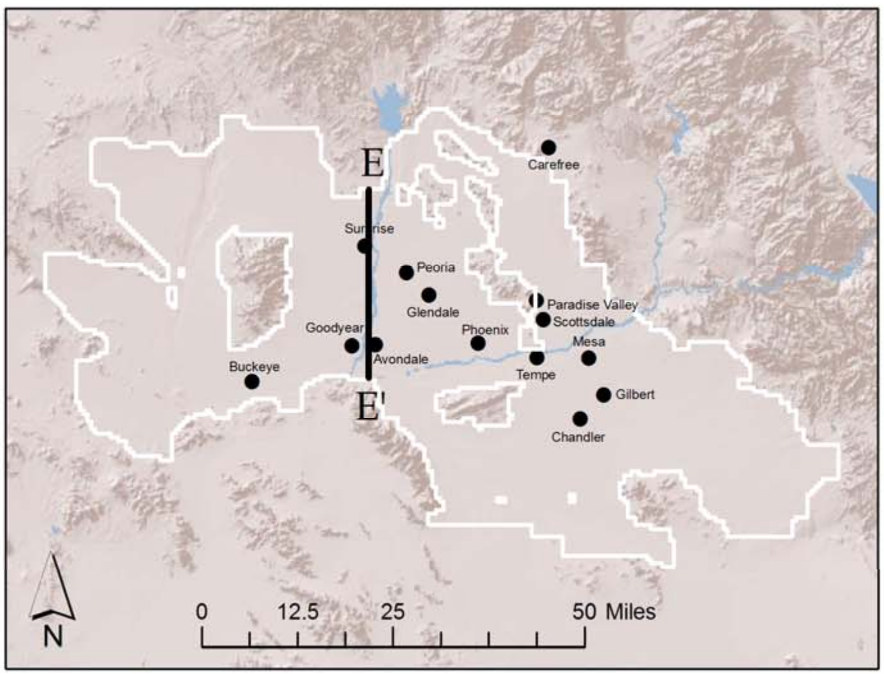
Figure 27



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section E-E'

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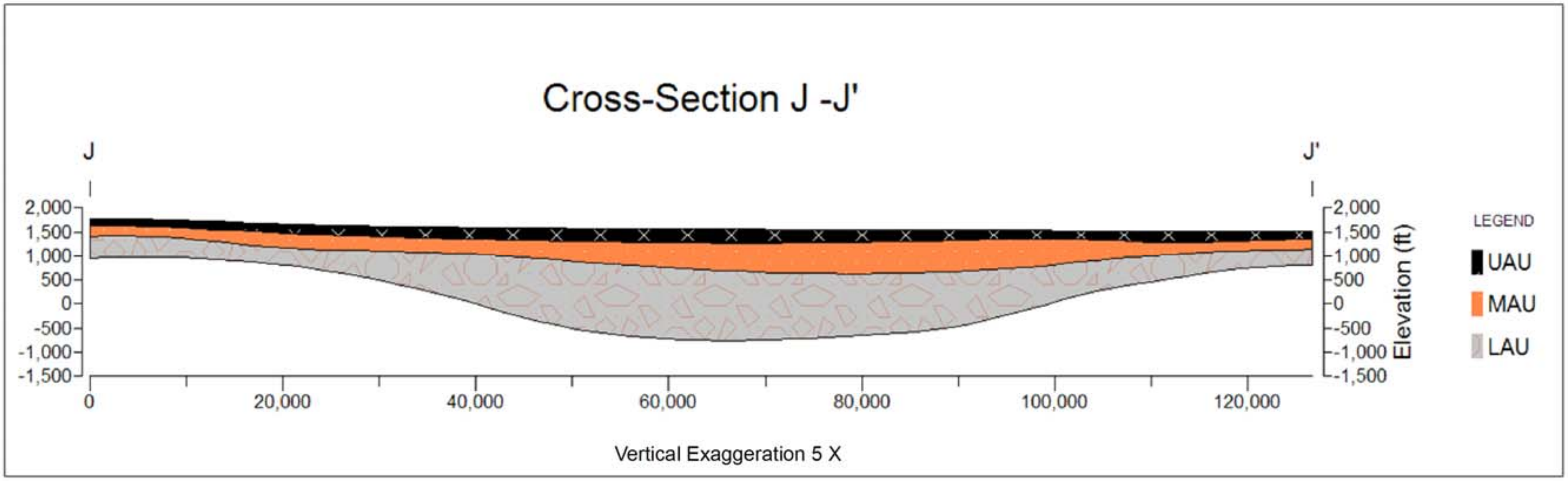
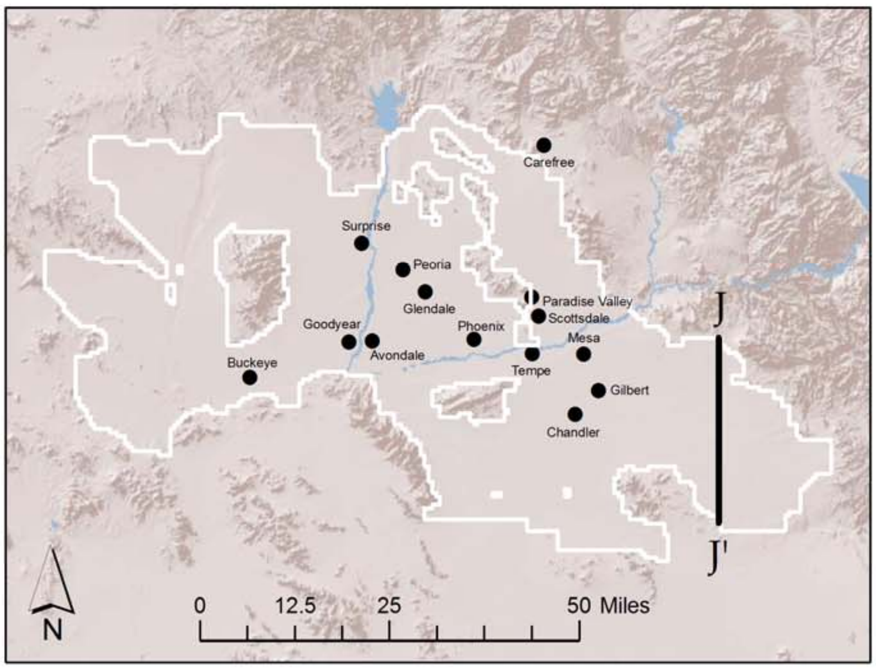
Figure 28



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section J-J'

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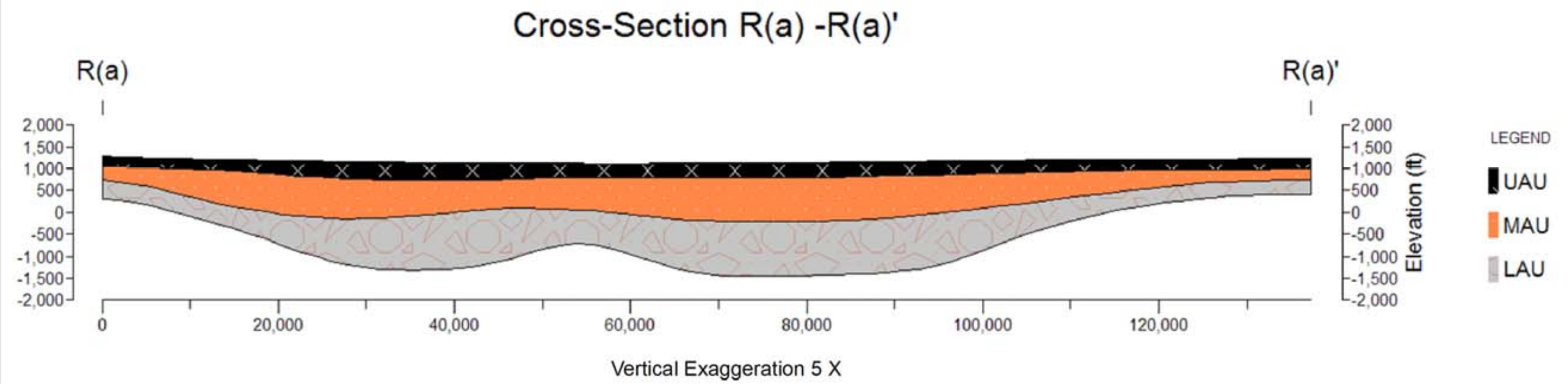
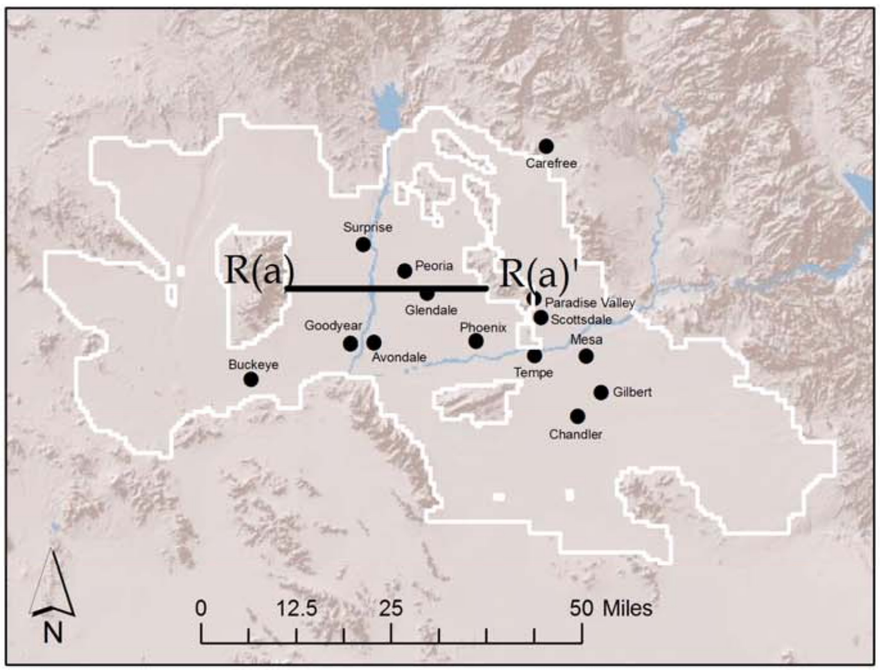
Figure 29



X-Axis - Distance in Feet

Y-Axis - Elevation in Feet above mean sea level



Map showing the cross-section and location map for cross-section R(a)-R(a)'

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Figure 30

Map showing data deficient areas: UAU logs reviewed location map

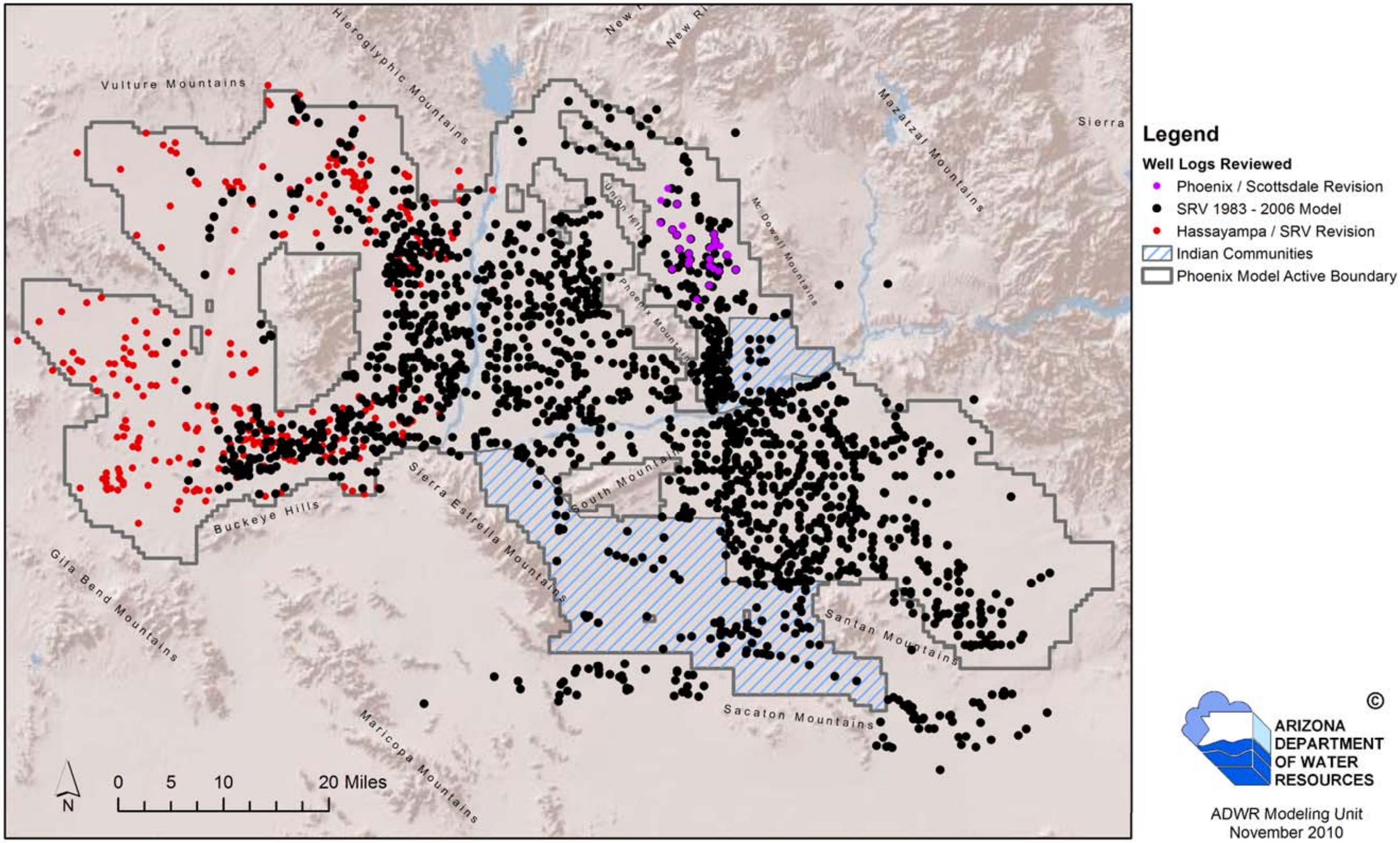

Figure 31

Map showing data deficient areas: MAU logs reviewed location map

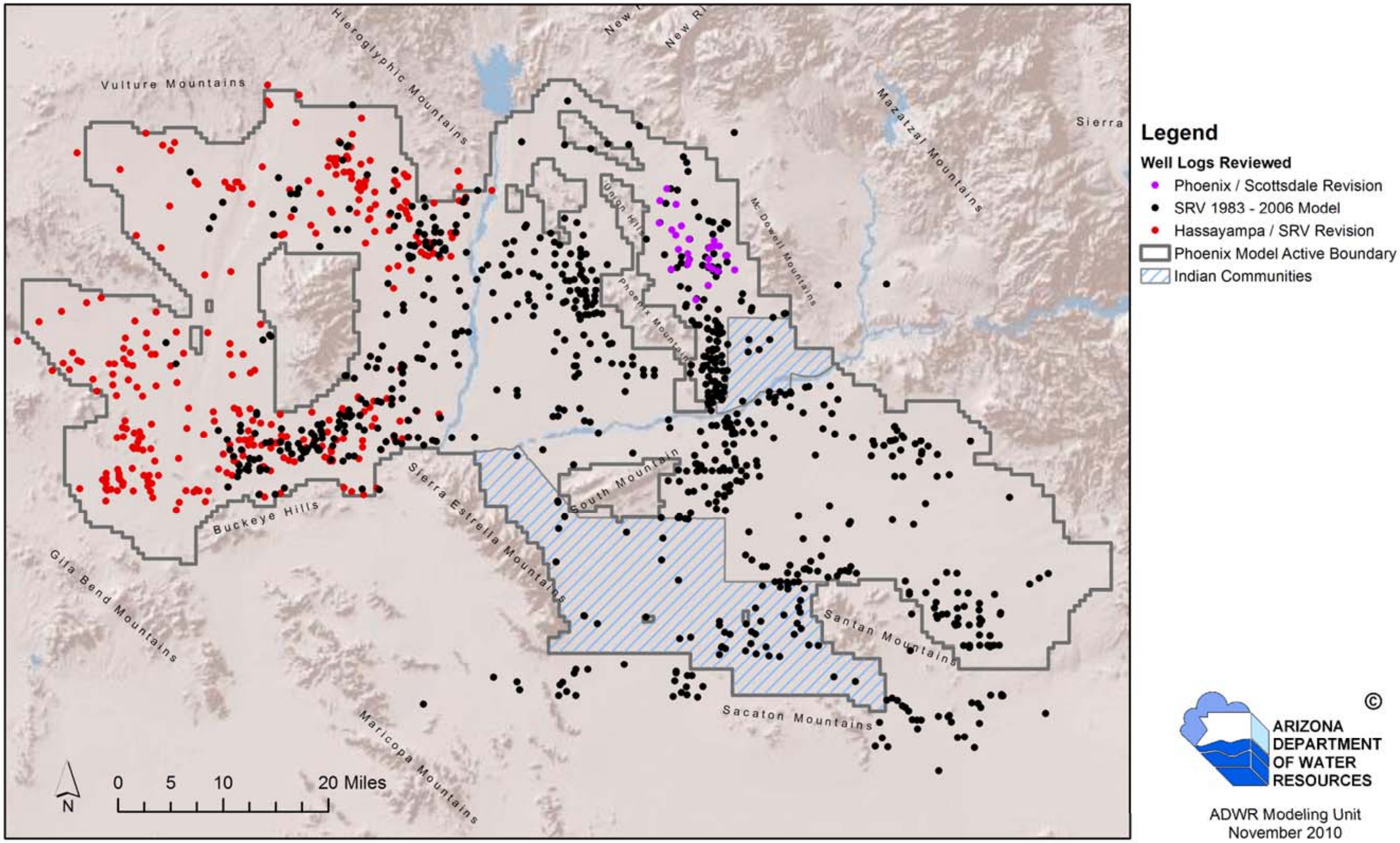

Figure 32

Map showing data deficient areas: LAU logs reviewed location map