Arizona Department of Water Resources

Provisional Report

Salt River Valley Model Geology Update

ARIZONA DEPARTMENT OF WATER RESOURCES

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Executive Summary

The Arizona Department of Water Resources Modeling Report No. 6 (published in 1993) and No. 8 (published in 1994) focused on the hydrologic system of the Salt River Valley. Since the development of the Salt River Valley groundwater model the cities within the model area have grown substantially.

In conjunction with this growth, substantial groundwater exploration and development has occurred in many areas where hydrogeologic data were previously limited, or non-existent. Newly acquired drilling data has improved knowledge about depth to bedrock and the hydrogeologic units throughout the model area. Areas where new drilling data has improved geologic interpretations include: Paradise Valley, some portions of the East SRV near Apache Junction and other areas of the West SRV.

The purpose of the SRV model geology update was to incorporate recently acquired geology information from within these active growth areas, as well as to better define the geology throughout the entire model area. Additionally the newly interpreted geology data needed to be rediscretized into the new SRV model grid, which has cells that are 0.5 mile in length and width.

The geology update process discussed in this report included the following:

- Collection of existing model data in electronic format (Central Phoenix Model, Chandler, Peoria, and Scottsdale/AMEC model);
- Development of a geodatabase for data management and processing;
- Reformatting of existing data into a consistent format;
- Collection of new well log data;
- Review of new well log data and assignment of data qualifiers;
- Input of the data into a consistent format for data processing;
- Construction of three-dimensional maps of existing stratigraphic model layers;

- Overlay of the new well data locations on the current model to focus areas of investigation and identify data gaps and or anomalies;
- Construction of stratigraphic logs of qualified well log data;
- Construction of cross-sections with qualified stratigraphic logs and correlation to existing model layers;
- Identification of new hydrogeologic contacts and surfaces;
- Construction of structure-contour maps of newly proposed hydrogeologic units;
- Tinning of structure contours and distribute through GIS methods elevations associated with each model node;
- Population of a new database with the new elevation data for each hydrogeologic unit.

Although the geology update for the SRV model will result in a more up to date groundwater model, there are still several large areas of data deficiency in the model area. Recommendations are provided to improve future data collection and analysis efforts.

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Acknowledgements

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Purpose and Introduction

Since the development of the Salt River Valley (SRV) groundwater model the cities within the model area have grown substantially. Active growth areas included Avondale, Buckeye, Chandler, Gilbert, and Goodyear, Scottsdale in the Paradise Valley area and Surprise, as well as parts of Phoenix.

In conjunction with this growth, substantial groundwater exploration and development has occurred in many areas where hydrogeologic data were previously limited, or non-existent. Newly acquired drilling data has improved knowledge about depth to bedrock and the extent of hydrogeologic units throughout the model area. In some areas bedrock was found to be shallower than the currently available model had indicated. In other areas hydrogeologic units were non-existent or found to be undistinguishable from other hydrogeologic units. Areas where new drilling data has improved geologic interpretations include: Paradise Valley, some portions of the East SRV near Apache Junction and other areas of the West SRV. Well elevations have also been updated for some areas located in, or near, groundwater contamination sites where the Department's Water Quality Assurance Fund (WQARF) unit has conducted survey-grade GPS surveys as a part of recent well inventories.

The purpose of the SRV model geology update was to incorporate recently acquired geology information from within these active growth areas, as well as to better define the geology throughout the entire model area. Additionally the newly interpreted geology data needed to be rediscretized into the new SRV model grid, which has cells that are 0.5 mile in length and width. The old SRV model grid cells were one mile in length and width.

Previous Investigations

Arizona Department of Water Resources (ADWR) Modeling Report No. 6 (Corkhill et al, 1993) and No. 8 (Corkhill et al, 1994) focused on the hydrologic system of the Salt River Valley and was updated by Bota et al (2004). From this point forward those reports are referred to as the "original model".

Geologic data for the original model were from geophysical logs, drillers' logs, geologists' logs, particle-size logs, gravity surveys, and other reports. Locations of wells from the original model are presented in Figure 1. Sources providing these data included ADWR files, the United States Geological Survey (USGS), the Arizona Oil and Gas Conservation Commission, and various water providers. Previous studied, such as United States Bureau of Reclamation (USBR) (1976), Laney and Hahn (1986) and Brown and Pool (1989) were also utilized (Corkhill et al, 1993).

Hydrogeologic Unit Description

The three hydrogeologic units defined in the original model (in descending order) include the Upper Alluvial Unit (UAU), the Middle Alluvial Unit (MAU) and Lower Alluvial Unit (LAU).

Upper Alluvial Unit

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.

Middle Alluvial Unit

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.

Lower Alluvial Unit

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 SRV model area refer to Corkhill et al (1993).

Geology Update Data Search

As part of the SRV model geology update an initial list of wells from the 55-registry database was compiled using Microsoft Access and ESRI ARCMAP 9.1, which included wells (within a buffered boundary) that had been drilled from 1986 through 2005 (Figure 2). The geology boundary in Figure 2 was used during data collection for the original SRV model. A one-mile buffer was added during the update to capture well logs that could be useful in areas of limited data. The year 1986 was chosen because the estimated cut-off date for geology data collection from registered logs during the original model was 1986. The search resulted in over 15,000 wells that were organized using the geodatabase feature within ESRI ARCMAP 9.1.

The search for useful logs from wells on the initial list concentrated on those drilled deeper than 500 ft because they would likely provide the best source for contacts between the UAU, MAU and LAU. As the search progressed and there was a need for data within specific areas, the list was expanded in those areas to include wells shallower than 500 ft and registered wells older than 1986 that had not been used in the original model. The revised list included approximately 15,600 new wells of various depths throughout the SRV area.

The revised list was cross-referenced with well owner information in various ADWR well registry databases (Wells55, Wells35 and GWSI) to identify wells registered to municipalities, water service providers, irrigation districts, the Oil and Gas Commission, Indian communities and various other sources of potential new geology information. Geologic data requested from these sources included geologists' logs, geophysical logs, particle-size logs, drillers' logs and existing model data.

An additional search was also done using the ADWR Fortis Viewer for drillers' logs submitted to ADWR within the model area. Of the 15,600 new wells included in the revised list, the search resulted in various types of well logs for 860 wells. The new data included geologists' logs, geophysical logs, particle-size logs, fines logs (percentage of fine material) and drillers' logs. Many of the wells reviewed from the revised list were too shallow to provide contact details or did not provide quality descriptions on which to base contact decisions. A summary of new log data obtained during the search has been provided in Table 1.

Table 1: Types and Quantities of New Logs Obtained During the SRV Model Geology Update

Drillers Logs (DL)	512
Geologists Logs (GL)	282
Particle Size Logs / Fines Logs (PSL)	65
Geophysical Logs (GPL)	170
Total New Logs	1029
Total New Wells with Logs	860

During the search process, logs that had been used for the original SRV model geologic analysis were also added and a summary has been provided in Table 2.

Table 2: Types and Quantities of Old Logs Included in the SRV Model Geology Update

Drillers Logs (DL)	555
Geologists Logs (GL)	113
Particle Size Logs / Fines Logs (PSL)	237
Geophysical Logs (GPL)	69
Total Old Logs	974
Total Old Wells with Logs	895

Log Quality Criteria

Each log obtained during the search (drillers, geologist, geophysical, and particle-size) was evaluated for quality. Factors used to establish the quality of a log included the following:

- Sample frequency - a log with one description for a 1200 ft well would be of lower quality than one with 25 descriptions for the same depth well;

- Sample description - a log with description of "rocks" would be of poor quality while a description which includes size and coarseness of grains, percentages of fine verses coarse grain material and types of material would likely be of good quality;

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

- Geophysical logs – since geophysical logs don't rely on a drillers or geologists description a reliable geophysical log can be of good quality or of excellent quality if geologists logs or drillers logs are also available which verify the contacts indicated by the geophysical log.

Well Log Data

Drillers logs were used extensively in an early two-dimensional model of the SRV (Long, et al, 1982) as well as for the SRV three-dimensional model (Corkhill et al, 1993).

Although drillers logs are commonly regarded as subjective and somewhat unreliable, they were utilized during comparisons with other higher quality logs or as a data source for areas where new good quality information was sparse. Approximately 500 new drillers' logs were obtained for this purpose, although most were not given priority for interpretive contouring of geologic contact surfaces due to their 'poor' or 'fair' quality.

Geologists logs used in the SRV model were obtained from reports submitted to ADWR or by consultants for local municipalities and water service providers. If geologists' logs included only the type of lithology encountered (i.e. sandy gravel), the log was considered 'fair' and was therefore not given priority while contouring. However, logs that included descriptions of the lithology encountered [grain size, percentages, Unified Soils Classification System (USCS) symbols, etc.], were considered 'good'. Approximately 280 new geologists logs were obtained for the study.

Particle-size logs were used extensively for the original model and were considered the most reliable source of geologic data available for the study. During this SRV model geology update most of the particle-size logs used were either from the original model or included within geologists logs as percentages of clay and silt, sand, and gravel. If the particle-size data were provided as part of a geologists' log for this study, the geologists log was used during the development of cross-sections. Logs provided by the Gila River Indian Community frequently included particle-size logs. During the data collection process approximately 70 new particle-size logs were obtained, although most were considered of 'fair' quality and therefore not given priority during contouring.

Geophysical logs were obtained during data collection for the previous SRV model (Corkhill et al, 1993). However several of these logs were not considered helpful, as corresponding lithologic logs were not available. During the current data collection process approximately 170 geophysical logs were obtained and over 100 of those geophysical logs were accompanied by either a geologists log or particle-size log and were therefore considered of 'good' or 'excellent' quality.

Locations of wells by log type and quality for the SRV model geology update are presented in Figure 3.

Hydrogeologic Unit Determination

The logs that were submitted were entered into an electronic database for future analysis and contacts for the bottoms of the UAU, MAU and LAU were estimated for each log (where possible). During log analysis the location of the MAU within each log was determined by counting the frequency and thickness of fine-grained samples. A sample was considered fine-grained if it consisted of at least 40% clay and/or silt. Although the fine-grained unit could include some interbedded sand and gravel, the total thickness of the fine-grained samples had to be at least 60 ft. Where log suites were submitted, the contacts from the highest quality logs were used (i.e. geophysical log MAU bottom estimate was given priority over the MAU bottom estimate from a drillers' log). Contacts for the UAU, MAU and LAU bottoms for each log submitted were estimated using the criteria discussed in the definition of hydrogeologic units in Modeling Report No. 6 (Corkhill et al, 1993). Cross-sections from the original model and consultant reports were also considered when estimating contacts.

Comparison With Existing Groundwater Model Data

Sub-regional groundwater flow models prepared for municipalities throughout the SRV study area were reviewed and compared with the original SRV model for layer thickness and horizontal distribution. The Cities of Chandler, Peoria and Scottsdale provided sub-regional groundwater models prepared by consultants for their respective municipalities. Contacts for the bottoms of the UAU, MAU and LAU from each of the groundwater models were compared to the contacts from the original model using geographic information system (GIS) methods. In most cases the sub-regional models geologic structure was developed from the original SRV model. However, in areas where significant differences in unit interpretation were evident a more thorough review was done in that area.

Cross-Section Analysis

The original SRV model report included five generalized representative hydrogeologic cross-sections to illustrate stratigraphic relationships among the three hydrogeologic units of the basin-fill deposits and the hydrogeologic bedrock unit across the study area. Figure 4 shows the locations of all the cross-sections used to establish the relationships between the three hydrogeologic units defined in the original SRV model.

A new series of cross-sections were created using ROCKWORKS® throughout the SRV area as part of the data collection process for the model update (Figure 5). Locations were based on quantity and quality of new data and areas with much thicker or thinner hydrogeologic units based on new information. New cross-sections also incorporated many of the better logs from the original model. The cross-section locations from both the new and the original model are presented in Figure 6.

Six hydrogeologic cross-sections have been prepared to illustrate changes in interpretation from the original SRV model (Figure 7). The sections show the original SRV geologic unit thicknesses plotted (right) with the new geologic unit thickness interpretation (left). In some cases, if new information was not available, the old contact was used in the analysis.

Cross-section AB-AB' (a west-east cross-section that begins in the eastern portion of the east central portion of the West SRV and terminates in the east SRV) indicated the upper alluvial unit in the East SRV was thicker than the original SRV geologic interpretation, while cross-section O-O' (another west-east cross-section in the East SRV) indicated the middle alluvial unit consisted of a thick inter-bedded sand and gravel unit towards the east that was encountered at a shallower depth than the original SRV geologic interpretation indicated. Based on these cross-sections ADWR defined a transition in lithology from mostly a thick upper alluvial unit in north Mesa (adjacent to the Salt-River Indian Community) to a thick middle alluvial unit encountered at a shallower depth (compared to cross-section AB) in south Mesa (adjacent to the City of Gilbert) and east Mesa. Cross-sections AB-AB' and O-O' are presented in Figure 8 and Figure 9 respectively.

Cross-section L-L' in the west SRV included six wells that indicated major modifications in the lithologic interpretation from the original model. The interpretation indicated the UAU was thicker than indicated in the original SRV model southwest of the Luke salt dome and the MAU was thinner (and in some cases shallower) than indicated in the original SRV model in the southwestern area of the salt dome. In the Sun City area the MAU was shallower and in some areas thinner than previous estimates. Cross-section L-L' is presented in Figure 10. Cross-sections M-M' (a north-south cross-section in the Scottsdale area) and Q-Q' (a north-west cross-section through the cities of Glendale and Peoria) were prepared to further define areas not defined by cross-sections in the original model. Cross-sections M-M' and Q-Q' are presented in Figures 11 and 12 respectively. Cross-section U-U' (a south-west to north-east cross-section in the west SRV) indicated that the MAU was thicker than indicated in the original SRV model in the El Mirage area and was thinner than indicated in the original SRV model in the Peoria area. Cross-section U-U' is presented in Figure 13.

Structure Contour Development and Discretization

Following data collection and cross-section analysis the data for the bottom elevations of the UAU, MAU and UAU were hand contoured and digitized. After a thorough quality assurance/quality control (QA/QC) check of the contours utilizing ESRI ARCMAP 9.1 to verify the hand contours were digitized correctly and corresponded to the lithologic interpretation of the good and excellent logs, the contours were converted into a triangulated irregular network (TIN) utilizing ARCSCENE. As defined by ESRI, a TIN is "*a vector data structure that partitions geographic space into contiguous, nonoverlapping triangles. The vertices of each triangle are sample data points with x-, y-, and z-values. These sample points are connected by lines to form Delaunay triangles. TINs are used to store and display surface models.*"

During the tinning process the digitized contours were triangulated as hard lines as opposed to mass points so the contours themselves would be used in the triangulation process. The bottom of the LAU was further defined through the addition of elevation contours for the hard rock areas within and adjacent to the active model area. This method when used on the LAU tin where the bottom of the LAU (or bedrock) was exposed at the surface in these hard rock areas.

The tinned UAU, MAU and LAU bottom elevation surfaces were then overlain and clipped to the active SRV model area and elevations for UAU bottom, MAU bottom and LAU bottom were discretized or assigned (using ARCSCENE's surface spot feature) to the center of each 0.5 mile model grid node in the active model domain. The surface spot procedure was performed using linear interpolation with the tin triangles being interpreted as a series of planes. Each model node was assigned a height or elevation based on the nodes position within the corresponding triangle plane.

Interpretive Thickness Rules

Although the MAU essentially pinches out or is indistinguishable from the UAU and LAU near the margins of the alluvial basin, the three hydrogeologic units were simulated throughout the entire SRV model area using the USGS Modflow code with a three-layer model with a deformed vertical mesh. Since Modflow requires three model layers to exist everywhere within the active model area, a few interpretive rules had to be applied to the elevations produced by ARCSCENE for some of the model nodes where geologic units pinched out or were otherwise indistinguishable from other units (i.e. the MAU at the basin margins).

UAU Thickness Rule

The first rule was applied to model cells where the UAU thickness was greater than 0 ft but less than 100 ft. If this condition existed the bottom of the UAU was set to 100 ft below land surface. A summary of the rules applied to the discretized UAU data is provided in Table 3.

Table 3: Rules Applied to the Discretized UAU Data - SRV Model Geology Update

UAU cells adjusted to a minimum thickness of 100 ft because the thickness of the UAU was greater than 0 ft and less than 100 ft		293
UAU cells adjusted to a minimum thickness of 100 ft because the bottom elevation of the UAU was equal to the surface elevation (due to the tinning and/or discretization process).		1
UAU cells adjusted to a minimum thickness of 100 ft because of lack of data		387

MAU Thickness Rule

The second rule was applied to model cells where the MAU thickness was greater than 0 ft but less than 100 ft. If applicable, the thickness of the MAU was set to 100 ft. A summary of the rules applied to the discretized MAU data is provided in Table 4.

Table 4: Rules Applied to the Discretized MAU Data - SRV Model Geology Update

MAU cells adjusted to a minimum thickness of 100 ft because the bottom elevation of the MAU was greater than the bottom elevation of the UAU (due to the tinning and/or discretization process).		195
MAU cells adjusted to a minimum thickness of 100 ft because the thickness of the MAU was greater than 0 ft and less than 100 ft.		463
MAU cells adjusted to a minimum thickness of 100 ft because the bottom elevation of the MAU was equal to the bottom elevation of the UAU (due to the tinning and/or discretization process).		9
MAU cells adjusted to a minimum thickness of 100 ft because of lack of data.		510

LAU Thickness Rule

The final rule was applied to model cells where the LAU thickness was greater than 0 ft but less than 100 ft. If true, the thickness of the LAU was set to 100 ft. A summary of the rules applied to the discretized LAU data is provided in Table 5.

Table 5: Rules Applied to the Discretized LAU Data - SRV Model Geology Update

LAU cells adjusted to a minimum thickness of 100 ft because the bottom elevation of the LAU was greater than the bottom elevation of the MAU (due to the tinning and/or discretization process).		1546
LAU cells adjusted to a minimum thickness of 100 ft because the thickness of the LAU was greater than 0 ft and less than 100 ft		587

In general these modifications were mainly required along the periphery of the model area where sparse well log data were available and the MAU was either absent or indistinguishable from the UAU and LAU, and combined alluvial unit thickness was estimated to be no more than a few hundred feet. General statistics for the UAU, MAU, LAU, and total alluvial unit obtained during the application of the thickness rules are provided in Table 6.

Table 6: General Statistics - SRV Model Geology Update

Average UAU thickness per cell for 9402 cells		265 ft
Average MAU thickness per cell for 9177 cells		515 ft
Average LAU thickness per cell for 9181 cells		712 ft
Average difference in UAU thickness per cell between the original SRV model and the updated SRV model for 8466 cells *		-14 ft
Average difference in MAU thickness per cell between the original SRV model and the updated SRV model for 8168 cells *		-29 ft
Average difference in LAU thickness per cell between the original SRV model and the updated SRV model for 8166 cells *		100 ft
Average total alluvial unit thickness per cell for 9402 cells		1463 ft
Total number of cells adjusted to a maximum alluvial thickness of 3000 ft.		329

* - A positive difference indicates that the average unit thickness per cell in the original SRV model was great er than the average unit thickness per cell in the updated model. A negative difference indicates that the average unit thickness per cell in the original SRV model was less than the average unit thickness per cell in the updated model.

As with the original model, the basin-fill deposits towards the basin centers were very thick. In these areas the models bottom depth was truncated at a maximum depth of 3,000 ft below land surface. This rule was applied in the West Salt River Valley Sub-Basin area, in the Paradise Valley area between the McDowell Mountains and Union Hills and in the south central to east central portion of the East Salt River Valley Sub-Basin. The 3,000 ft maximum simulated thickness rule was also applied in the original SRV model.

Following the tinning process and interpretive thickness rule application the resulting data were printed in array format and compared to the original SRV model. Arrays included plots of new and old unit thicknesses per model node, new and old unit bottom elevations per node and plots of differences between the original and new model elevations and thicknesses per node. In areas where unexplained differences were encountered, geologic data and interpretations were reviewed, and the contours were modified if appropriate. Following completion of the review the tinning process was repeated.

As a final QA/QC check the new model data were compared using ESRI ARCMAP 9.1 with unit bottom elevations provided with the Peoria ground-water model, the Chandler groundwater model and the Scottsdale/Phoenix ground-water model. Areas with significant differences were analyzed in order to verify that the differences between the sub-regional models and the updated SRV model were in line with new geology information obtained during the data collection process. If localized changes made during the geology update could not be verified during the comparison, the updated model contours were either changed to reflect the original SRV model contour data or to reflect the sub-regional model if well logs were available to support the information.

The final step in the process consisted of retinning the revised contours and reapplying the interpretive thickness rules discussed for the bottoms of the UAU, MAU and LAU (if necessary). The array data were reviewed to verify changes had been incorporated and the elevation information from each of the nodes were used to produce the final three-dimension views and contours provided in Figure 14 through Figure 19.

The discretized bottom elevations for the UAU, MAU and the LAU for each new model cell are listed in Appendix I of this report. Also presented in Appendix II is a listing of the wells used during the update (new and old), the type and quality of log received, and whether that log was used in a cross-section.

Data Deficiencies and Recommendations

There are several large data-deficient areas in the model area (Figure 20). These areas are largely undeveloped desert land within the model area where few wells have been drilled. Due to the lack of data the geology of those areas was interpreted or inferred from regional gravity data and from geologic interpretations of nearby areas. For this reason those areas are regarded with less confidence than other parts of the model area.

During the SRV model geology update several data deficiencies were noted which could limit the accuracy of the geologic interpretation. Recommendations are provided to improve future data collection and analysis efforts. These recommendations include the following: 1) develop a structure and process whereby water service providers could periodically submit geology data to ADWR which could be used during future model updates, 2) conduct gravity surveys in areas where very little information is known about depth to bedrock, 3) examine more cuttings from wells being drilled (deep wells with geologists logs or geophysical logs) in areas where little information is known about depths to the upper, middle and lower alluvial units, 4) conduct a comprehensive study to establish definitive definitions or characteristic lithologic and textural descriptions of the of upper, middle and lower alluvial units and how they correlate throughout the SRV study area, 5) expand upon ADWR's working relationship with water service providers and neighboring Indian communities to assist in information exchange, 6) incorporate future modeling studies in the Hassayampa Basin and Pinal AMA.

Data Management and Availability

Specific well information and interpreted hydrogeologic unit data compiled by SRV model cell were incorporated into a Microsoft Access database, which served as the main storage location for data associated with the update. Information within the database for specific wells and model nodes included location (cadastral and x- and y- coordinates in

North American Datum (NAD) 1927 – Zone 12), surface elevation, and point identification (a unique number assigned to each node and well).

The model node data also included updated SRV model cell, row and column identification and cadastral. The surface elevation for the nodes was derived from quad-based USGS Digital Elevation Model (DEM) data. The aforementioned data are included in Appendix I (see attached CD) of this report.

Specific well records, where available, also include: hydrogeologic unit depth information, database identification (i.e. registry number, well name, other identification number), data source (i.e. Wells55, Wells35, GWSI, etc.), cadastral, surface elevation and northing and easting values in Universal Transverse Mercator (UTM) NAD 1927. Surface elevations for specific model wells were either based on information in ADWR's existing databases (GWSI, Wells35, Wells55) or on WQARF survey-grade GPS data collected at groundwater contamination sites throughout the state. Where available, survey grade data were given priority, followed by GWSI surface elevations, Wells35 surface elevations, and Wells55 surface elevations. A listing of wells used in the SRV geology update (new and old) as well as the cadastral, database identification and data source for each well, are included in Appendix II (see attached CD) of this report. The data included in these databases will soon be available as downloadable zip files from the ADWR internet website at http://www.azwater.gov.

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