FINAL REPORT

February 17, 2010

Prepared for:

Resolution Copper Mining

Interim Results of Groundwater Monitoring

Upper Queen Creek and Devils Canyon Watersheds
Resolution Copper Mining LLC
Pinal County, Arizona

Prepared by:

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UPPER QUEEN CREEK AND DEVILS CANYON WATERSHEDS
RESOLUTION COPPER MINING LLC
PINAL COUNTY, ARIZONA

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LIST OF ABBREVIATIONS

ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
ALT	Apache Leap Tuff
AZGS	Arizona Geological Survey
bls	below land surface
m	meters
M&A	Montgomery & Associates
mg/L	milligrams per liter
pCi/L	picocuries per liter
RCM	Resolution Copper Mining LLC
TDIC	Total Dissolved Inorganic Carbon
TDS	Total Dissolved Solids
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

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1.0 EXECUTIVE SUMMARY

1. Groundwater monitoring in the upper Queen Creek and Devils Canyon watersheds was initiated by RCM in early 2004 with the completion of five hydrologic characterization wells in the Oak Flat area. Additional wells have been added to the monitoring network as they have been constructed or rehabilitated. The current RCM groundwater monitoring program includes 19 wells, boreholes, or shafts.

2. Based on results of hydrogeologic characterization studies conducted to date, three principal aquifers have been identified in the Upper Queen Creek/Devils Canyon study area, including:

   SHALLOW AQUIFER(S): several small, shallow perched aquifers of limited areal extent hosted in shallow alluvial deposits and the uppermost weathered part of the Apache Leap Tuff;

   APACHE LEAP TUFF (ALT) AQUIFER: fractured-rock aquifer hosted in dacite tuff that extends throughout much of the upper Queen Creek, Devils Canyon, and lower Mineral Creek drainages;

   DEEP GROUNDWATER SYSTEM: a deep fractured-rock groundwater system that underlies the ALT aquifer, is hydraulically connected to the current mine workings, and is separated from the ALT aquifer by the poorly permeable Whitetail Conglomerate; the full extent of this aquifer is currently unknown.

3. The purpose of the groundwater monitoring program is to provide hydrologic data for continued development and refinement of the conceptual hydrogeologic model for the ALT aquifer and adjacent aquifers in the study area that might be impacted by block-

cave mining operations proposed by RCM in the Oak Flat area. Specific goals of the groundwater monitoring program include:

- Establish a groundwater level and groundwater quality baseline for the ALT aquifer and adjacent aquifers in support of pre-feasibility studies and the upcoming environmental impact statement (EIS) process for proposed block-caving mining operations;
- Identify principal sources of groundwater recharge and pathways for groundwater discharge to/from the ALT aquifer and adjacent aquifers;
- Investigate connectivity between the shallow alluvial aquifer and the ALT aquifer and between the ALT aquifer and the deep groundwater system; and,
- Evaluate the connection between the ALT aquifer and springs/surface water in Devils Canyon, Mineral Creek, and along the Apache Leap escarpment.

4. Continuous groundwater level monitoring using dataloggers and transducers is currently conducted at 19 wells, boreholes, or shafts.

5. Groundwater samples for hydrochemical analyses have been obtained from all wells following construction and/or testing. Starting in 2008, six rounds of quarterly groundwater samples were collected from three shallow aquifer wells and six ALT aquifer wells.

6. Three coordinated groundwater/surface water sampling rounds were conducted in third quarter 2008, first quarter 2009, and second quarter 2009. Analysis and interpretation of hydrochemical data from surface water samples collected in the third quarter 2008 are presented in this report. Analysis and interpretation of isotope data from first and second quarters of 2009 are ongoing and will be presented in a future surface water monitoring report.

7. In addition to the results of the quarterly sampling, this report includes:

    - Older geochemical data collected from ALT and shallow wells prior to 2008 during drilling and testing (HRES-series wells) or after being refurbished and tested (wells A-06, MJ-11, Corral Well, and Middle Well);
    - Geochemical data from deep hydrologic test well DHRES-01 that provide information regarding the chemical composition of groundwater in the deep groundwater system;
    - Geochemical data from four locations within the Mineral Creek drainage that were sampled as part of the initial characterization of the drainage in November 2008.

8. The hydrochemical suite for the 2008/2009 quarterly rounds includes:

- Routine parameters and constituents (common ions)
- Trace constituents
- Stable isotopes of hydrogen and oxygen in water ($\delta^{2}H$ and $\delta^{18}O$)
- Stable isotopes of sulfur and oxygen in dissolved sulfate ($\delta^{34}S$ and $\delta^{18}O$)
- Stable isotope of carbon in dissolved carbon ($\delta^{13}C$)
- Radioactive isotope of carbon in dissolved carbon (^{14}C)
- Radioactive isotope of hydrogen in water (^{3}H)
- Radiogenic isotopes of uranium (^{234}U, ^{235}U, ^{238}U)
- Radiogenic isotope of strontium ($^{87}Sr/^{86}Sr$)

1.1 CONCLUSIONS

The following conclusions are based on review and analysis of results from the 2004-2009 RCM groundwater monitoring program and the 2008 Q3 surface water sampling:

1. Shallow aquifers in the study area are very responsive to seasonal rainy periods, with aquifer water levels responding within days of specific events. However, precipitation events must be of sufficient magnitude, duration, and frequency for recharge to occur. Magnitude of response from the 2007-2008 winter rainy period at the JI Ranch shallow aquifer wells was nearly 2 meters (m).

2. Residence times are short in the shallow aquifer located in Hackberry Canyon, on the order of less than 5 to perhaps as much as 50 years. Residence times are longer at JI Ranch varying from less than 50 years to as long as 700 years in the deeper part of the shallow aquifer hosted in the upper weathered portion of the Apache Leap Tuff.

3. Water quality in the shallow aquifers is variable with locally elevated total dissolved solids (TDS), sulfate, chloride and nitrate, potentially due to anthropogenic activities such as livestock watering, septic system effluent, and/or historic mining and mineral processing activities in the region (dry fall). In the shallow aquifer at JI Ranch, nitrate concentrations in one sample exceed U.S. Environmental Protection Agency (EPA) primary drinking water standards. Sulfate and TDS commonly exceed U.S. EPA secondary standards; pH is out of compliance with secondary standards in all samples collected at JI Ranch.

4. Based on chemical and isotopic data there does not appear to be direct, fast-path communication between the shallow aquifer and the underlying ALT aquifer at JI Ranch.

5. Groundwater levels in the ALT aquifer have shown a slight overall decline (<1 m) during the monitoring period starting in 2003-2004. This water level decline is likely the result of less than average precipitation in the region leading up to and including the period of record.

6. Response to seasonal rainy periods are observed at several ALT aquifer wells for the period of record, but are limited to the more significant 2004-2005 and 2007-2008 winter rainy periods. Magnitude of response is less than ½ m.

7. No discernible response was observed at other ALT aquifer wells from these same rainy periods. Varied water level responses in ALT aquifer to precipitation events are likely due to non-uniform distribution of recharge flow pathways across the Apache Leap Tuff outcrop belt. Focused recharge occurs along principal surface drainage ways such as Devils Canyon above the perennial reach and below stock ponds along tributaries to Queen Creek and Devils Canyon.

8. Groundwater quality in the ALT aquifer is excellent, with TDS concentrations generally less than 250 milligrams per liter (mg/L).

9. In general, the ALT aquifer is chemically and isotopically homogeneous and there is no evidence of water entering the aquifer from adjacent areas through other units such as the Paleozoic carbonates to the west or the Tertiary-Cretaceous Schultze Granite or Precambrian Pinal Schist to the northeast. However, groundwater composition does vary with depth becoming more sodium-rich in the deeper portions of the ALT aquifer. The larger sodium concentrations are likely a result of longer residence times and interaction with sodium-rich minerals in the lower ALT aquifer.

10. The ALT aquifer discharges to springs and supports base flow in the perennial reach of Devils Canyon. Results from multiple hydrochemical and isotopic data sets support this conclusion.

11. The ALT aquifer also appears to discharge to a spring and support surface water flow in the Mineral Creek drainage. Hydrochemical characterization of springs and surface water in the Mineral Creek drainage is ongoing; however, preliminary data support this idea.

12. Groundwater movement in the ALT aquifer generally follows surface water drainage patterns in the upper Queen Creek and Devils Canyon watersheds. In the upper Queen Creek basin, groundwater generally moves towards a point of discharge at Shaft No. 9. In the Devils Canyon basin, groundwater moves from the north and west to the south and southeast to groundwater discharge areas along the perennial reaches of Devils Canyon and Mineral Creek.

13. Residence times in the ALT aquifer vary from 1000 to 2000 years at JI Ranch to the north to 3000 to 5000 years down-gradient in Oak Flat and east side Devils Canyon areas. There is no evidence of systematic residence-time variation from east to west, as groundwater from Oak Flat and east Devils Canyon wells are of similar ages.

14. The deep groundwater system has not been fully characterized. However, results from one sample indicate that residence times are much longer than in the ALT aquifer, perhaps on the order of 10,000 to 20,000 years. Composition of stable isotopes suggests that this groundwater system could represent recharge from areas beyond the ALT outcrop belt and/or under different climatic conditions.

15. Due to low uranium concentrations in groundwater and surface waters sampled in the study area, analysis of isotopic ratios of uranium was not useful as a hydrochemical mapping tool for this study.

16. Results of strontium isotope analyses indicate that strontium isotope ratios are relatively homogeneous within both groundwater and surface water systems, and do not provide a useful method for differentiation of groundwater flow paths or groundwater/surface water interaction for this study.

1.2 RECOMMENDATIONS

Based on review and analysis of results of the 2004-2009 RCM groundwater monitoring program, Montgomery & Associates (M&A) has the following recommendations:

1. Quarterly groundwater level monitoring should continue for all shallow aquifer and ALT aquifer wells. Although all wells are equipped with transducers and dataloggers, it is important to continue manual measurements and data downloads on a quarterly basis to ensure proper datalogger function and maintain the quality of the water level database. Continuous groundwater level monitoring using automated equipment should continue for wells and boreholes completed in the deep groundwater system.

2. M&A recommends that hydrochemical sampling from shallow aquifer and ALT aquifer wells be suspended until the 2010 drilling program is complete. As new wells are added to the RCM hydrologic monitoring system, an initial groundwater sample should be collected during aquifer testing at each well. Once the new HRES-series wells are completed, a comprehensive sampling round should be conducted that includes all project monitor wells equipped for sampling.

   The analytical suite should include:

   - Routine Parameters and Common Constituents
   - Trace Constituents
   - Radiological Constituents
   - Deuterium and oxygen-18 in water
   - Sulfur-34 and oxygen-18 in dissolved sulfate
   - Carbon-13
   - Carbon-14
   - Tritium

3. Based on results of the comprehensive sampling round and assessment of project needs reactivation of a groundwater sampling program may be recommended or required.

4. At well HRES-08, hydraulic testing will be conducted once water levels stabilize in the lower part of the well. After testing, the lower part of the well should be abandoned or isolated, and a permanent pump should be installed for testing and sampling of the ALT aquifer at this location.

5. Surface water inventories should continue in Devils Canyon and upper Queen Creek drainages. Interpretation of surface water chemistry data with respect to conceptual understanding of groundwater/surface water interaction, and with respect to baseline sampling in support of the EIS, is ongoing and will be presented in a future surface water report. Once baseline assessment is complete M&A will provide a recommendation regarding further required surface water sampling.

6. Surface water inventories and hydrochemical sampling, including the extended analytical suite, should continue as presently scoped for springs and surface water in the Mineral Creek drainage. In addition, samples should be obtained from Government Springs to document this potential input to Mineral Creek surface water flow and subflow.

7. Continued efforts should be made to obtain representative hydrochemical samples for the deep groundwater system, both from the two existing deep

wells (DHRES-01 and DHRES-02) and from proposed future deep hydrologic test wells. Present understanding is based principally on one sample from DHRES-01, and as such, our understanding of the potential hydraulic connection between the ALT aquifer and deep groundwater system is very limited. Preliminary results of deep groundwater system characterization will be provided in a technical memorandum (in preparation) along with recommendations on potential approaches for obtaining additional groundwater samples from the deep groundwater system.

8. M&A and RCM have developed recommendations for installation of additional hydrologic characterization wells for the Upper Queen Creek/Devils Canyon study area. Proposed wells include 7 wells completed in the ALT aquifer, 5 wells in the deep groundwater system, 1 well in the Whitetail Conglomerate. Hydrogeologic data obtained from these wells will be important for continued refinement of the conceptual hydrogeologic model for the integrated shallow, ALT and deep groundwater systems.

9. In addition to hydrologic test wells proposed above, two additional ALT aquifer wells are recommended for installation on State of Arizona land in the southeast part of the study area (HRES-Q and HRES-Y). Purpose of these two additional wells is to evaluate aquifer conditions in the ALT aquifer between Mineral Creek and the Devils Canyon basin. Data obtained from these wells will be important for evaluating groundwater discharge from the ALT aquifer to Mineral Creek, and identify other potential sources of groundwater discharge to Mineral Creek.

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INTERIM RESULTS OF GROUNDWATER MONITORING UPPER QUEEN CREEK AND DEVILS CANYON WATERSHEDS RESOLUTION COPPER MINING LLC PINAL COUNTY, ARIZONA

2.0 INTRODUCTION

At the request of Mr. Greg Ghidotti, Resolution Copper Mining LLC (RCM), Montgomery & Associates (M&A) has prepared this report summarizing the status and interim results of the groundwater monitoring program for the Upper Queen Creek and Devils Canyon watersheds. This report provides a detailed description of the present groundwater monitoring program, gives a summary of groundwater monitoring data obtained to date, and describes interim results and interpretation of these data. In addition, preliminary recommendations are given for continuation of the program to address both the needs of the on-going RCM Pre-Feasibility Study (PFS), and requirements for development of an Environmental Impact Statement (EIS) for the project. Final recommendations for hydrochemical monitoring of groundwater will be developed once interim results have been reviewed by the RCM hydrology team.

RCM groundwater monitoring program for the Upper Queen Creek/Devils Canyon study area (the study area) was initiated in late 2003/early 2004, following instrumentation of an existing well and construction of five hydrologic test wells by RCM in the Oak Flat area (Montgomery & Associates, 2005). Design of the RCM groundwater and surface water monitoring programs has been developed in cooperation with RCM and Golder Associates

Inc. (Golder). A location map showing groundwater monitoring sites in the study area is shown on **Figure 1**. Geologic units in the study area are shown on **Figure 2**.

2.1 CONTEXT

RCM is proposing to develop a block-cave mining operation for extraction of mineralized rock from a deep ore body located from 1,800 to 2,200 m beneath Oak Flat in the upper Queen Creek basin east of Superior, Arizona. RCM is currently conducting a PFS for proposed mining operations that includes hydrologic evaluations for the area of proposed mine development. In addition, RCM is preparing to initiate the EIS process for the Resolution project. Block-cave mining operations will result in removal of a large volume of mineralized rock from the ore zone, and will require dewatering of the ore zone and the cave zone above the ore body. Hydrogeologic investigations being conducted by M&A and others for the PFS and EIS are designed to evaluate the potential dewatering requirement for proposed mining operations, as well as potential hydrologic impacts from mining operations on groundwater and surface water resources in the project area. The groundwater monitoring program discussed in this report is an essential component of these on-going hydrogeologic investigations.

2.2 PURPOSE AND SCOPE

The primary purpose of the groundwater monitoring program is to provide hydrologic data for continued development and refinement of the conceptual hydrogeologic model for principal aquifers in the upper Queen Creek and Devils Canyon watersheds that might be impacted by block-cave mining operations proposed by RCM in the Oak Flat area. Based on results of preliminary hydrogeologic characterization conducted by M&A on behalf of RCM

(Montgomery & Associates, 2001, 2005, 2008), three principal aquifers have been identified in the study area, including:

SHALLOW AQUIFER(S): several small, shallow perched aquifers of limited areal extent hosted in shallow alluvial deposits and the uppermost weathered part of the Apache Leap Tuff;

APACHE LEAP TUFF (ALT) AQUIFER: fractured-rock aquifer hosted in dacite tuff that extends throughout much of the upper Queen Creek, Devils Canyon, and lower Mineral Creek drainages;

DEEP GROUNDWATER SYSTEM: a deep fractured-rock aquifer that underlies the ALT aquifer, is hydraulically connected to the current mine workings, and is separated from the ALT aquifer by the poorly permeable Whitetail Conglomerate; the full extent of this aquifer is currently unknown.

Specific goals of the groundwater monitoring program are to: 1) establish a groundwater level and groundwater quality baseline for the ALT aquifer and adjacent aquifers in the vicinity of proposed block-cave mining operations; 2) identify principal sources of groundwater recharge and pathways for groundwater discharge to/from the ALT aquifer and adjacent aquifers; 3) define the connectivity between the shallow perched aquifer and the ALT aquifer and between the ALT aquifer and the deep groundwater system; and 4) evaluate the connection between the ALT aquifer and springs/surface water in Devils Canyon, Mineral Creek, and the Apache Leap escarpment.

The scope of the present groundwater monitoring program is focused on areas within, and immediately adjacent to, the upper Queen Creek and Devils Canyon watersheds east of Superior. M&A and RCM are also currently monitoring aquifer conditions in the basin-fill deposits west of the Apache Leap escarpment in the Superior area **(Figures 1 and 2)**. Results of RCM groundwater monitoring activities west of the Apache Leap will be integrated into the hydrogeologic characterization program once more data become available.

This report focuses primarily on groundwater monitoring results for the ALT aquifer and overlying shallow aquifers. Some discussions of groundwater level monitoring and groundwater quality for the deep groundwater system are included in this report. A more detailed discussion of groundwater levels in the deep groundwater system, including a discussion of the relationship between the deep basin-fill deposits aquifer near Superior and the deep groundwater system beneath Oak Flat, will be included in a future submittal on preliminary hydrologic analyses from the RCM underground mine dewatering program that is presently underway.

In order to evaluate questions regarding surface water/groundwater connectivity isotope data from spring and surface water samples collected during the third quarter of 2008, are presented in this report. Isotopic data from spring and surface water samples collected in the first two quarters of 2009 are also included in this report; however, analysis and interpretation are ongoing and will be presented in a future surface water monitoring report to be submitted to RCM in May 2010. Routine hydrochemistry from surface water and spring sampling conducted between 2002 and 2009 are reported by Golder (2006, 2009a, 2009b). A limited subset of these data is discussed in the current report for purposes of comparison with routine groundwater hydrochemistry.

2.3 BACKGROUND

Since 2001, M&A has conducted hydrogeologic investigations to evaluate groundwater conditions for all three aquifers in the study area (Montgomery & Associates, 2001, 2002, 2005, and 2008). Starting in 2002, M&A worked in cooperation with Golder on initial stages of baseline surface water investigations for Queen Creek, Devils Canyon, and adjacent areas (Golder, 2006). The goal of M&A participation in the baseline surface water investigations was to identify springs and seeps in the study area that represent aquifer discharge points, and to identify potential intermittent or perennial stream reaches in the study area where flow is supported by aquifer discharge.

2.3.1 Shallow and Apache Leap Tuff Aquifers

In early 2003, M&A conducted a field inventory of existing wells and boreholes in the study area, and identified several wells which could be utilized for groundwater monitoring (Montgomery & Associates, 2005). Groundwater monitoring in the Apache Leap Tuff aquifer was initiated in October 2003 with installation of automated groundwater level monitoring equipment in the Oak Flat well (**Figures 1 and 2**). In early 2004, the groundwater monitoring program was expanded to include five new hydrologic test wells (HRES-01 through HRES-05) and two existing wells completed in shallow alluvial deposits (Hackberry Windmill and Gibson Well). In April 2007 a new hydrologic test well (HRES-06) was completed in the Apache Leap Tuff at JI Ranch and two shallow wells (the Middle Well and the Corral Well) at JI Ranch were evaluated and re-equipped as monitor wells. In September 2007, two existing stock wells located on the east side of Devils Canyon (wells A-06 and MJ-11) were rehabilitated and tested. Both were equipped with dataloggers for water level monitoring and permanent pumps for hydrochemical sampling. In late 2007, hydrologic test well HRES-07 was completed in the Apache Leap Tuff, and test well HRES-08 was completed in both the Apache Leap Tuff and Whitetail Conglomerate.

Although automated water level monitoring was initiated at each site following construction or rehabilitation, routine groundwater quality monitoring did not commence until 2008. Prior to 2008, groundwater samples were collected following construction or rehabilitation and testing activities only, and were analyzed for routine and trace constituents, radiological constituents, and stable isotopes. In 2006, after a long-term pumping test was conducted at HRES-04, a groundwater sample was analyzed for a suite that included tritium, carbon-14, and stable isotopes of sulfur and carbon. Beginning in April 2007, this suite was further expanded to include uranium and strontium isotope ratios for samples collected from new or rehabilitated wells.

In early 2008, RCM initiated a quarterly groundwater hydrochemical sampling program for selected shallow aquifer and ALT aquifer wells. As part of this program, M&A implemented several coordinated groundwater/surface water monitoring rounds in collaboration with Golder that included sample locations in Devils Canyon and Queen Creek watersheds as well as along the Apache Leap escarpment to the west, and in the Mineral Creek drainage to the southeast. All samples were analyzed for the comprehensive suite of routine and trace constituents and routine parameters, radiological constituents, stable isotopes, and radioisotopes.

2.3.2 Deep Groundwater System

In 2002, RCM initiated manual measurement of water levels in the deep groundwater system at RCM exploration boreholes RES-01, RES-02, RES-03, RES-04, and RES-07. Monitoring at RES-01 and RES-07 was quickly discontinued as the boreholes appeared to be disconnected from the hydraulic regime of the deep groundwater system; however, monitoring at RES-02, RES-03, and RES-04 continued until mid-2007 (**Figure 1**). In December 2007, RES-03 was equipped with a datalogger and transducer to permit continuous water level measurement. In 2008, two deep hydrologic test wells, DHRES-01 and DHRES-02, were completed in the deep groundwater system. In addition to measurement of water levels in the DHRES-01 and DHRES-02 wellbores, multiple piezometers were grouted into the annulus of each conductor casing and provide continuous monitoring of hydraulic heads in the Apache Leap Tuff and Whitetail Conglomerate. Details of the installation of the grouted-in piezometers and analysis of the resulting data are included in a separate technical memorandum (Montgomery & Associates, 2010).

3.0 GROUNDWATER LEVEL MONITORING PROGRAM

Groundwater monitoring locations are shown on **Figures 1 and 2**. A summary of current methods and frequency of groundwater level monitoring at each location is given in **Table 1**. The current groundwater level monitoring network in the study area includes 19 wells, boreholes, or shafts. Additional groundwater level data have been obtained periodically from several other wells and boreholes in the study area starting in early 2003, but are not included in the present groundwater monitoring program due to access difficulties or close proximity to more appropriately completed wells or boreholes.

Groundwater level monitoring is conducted for three wells completed in shallow aquifers in the study area, including the Corral and Middle wells at JI Ranch, and Hackberry Windmill in Hackberry Canyon south of Oak Flat **(Figures 1 and 2)**. Eleven wells provide groundwater level data for the ALT aquifer, including hydrologic test wells HRES-01 through HRES-08, the Oak Flat Well, Well A-06, and Well MJ-11. One of these wells, HRES-08, also provides water level information for the Whitetail Conglomerate; further hydraulic testing is planned at well HRES-08 in early February 2010. Water levels in the deep groundwater system are currently monitored at five locations, including RCM exploration borehole RES-03, deep hydrologic test wells DHRES-01 and DHRES-02, and Shafts No. 9 and No. 3. Pore pressures are also being monitored in the Whitetail Conglomerate and the ALT aquifer using grouted annular piezometers installed at DHRES-01 and DHRES-02, however these data are discussed in a separate technical memorandum (Montgomery & Associates, 2010). Well completion data for wells included in the monitoring program are given in **Table 2**, and schematic diagrams of well construction are included in **Appendix A** (**Figures A-1 through A-15)**.

3.1 PRECIPITATION

Because infiltration of surface water runoff from precipitation events is the principal source of natural recharge to groundwater systems in the southwestern United States, interpretation of groundwater level monitoring data should include comparison with both long-term and short-term precipitation records for the region. Shallow aquifers hosted in unconsolidated alluvial deposits along active stream channels are typically very responsive to short-term precipitation trends and seasonal patterns. Intermediate and deep groundwater systems tend to have a dampened response to short-term precipitation trends, with groundwater level trends typically reflecting long-term precipitation trends.

Figure 3 is a graph showing annual total precipitation for the two stations in the Superior region with the longest periods of record. Where monthly data are missing, annual total precipitation is not shown on the graph. The Superior station was operated nearly continuously from July 1920 through September 2006; average annual precipitation at the Superior station for the period 1921 through 2005 is about 18.1 inches. The Miami station was operated from February 1914 and continues to operate today; average annual precipitation at the Miami station for the period 1915 through 2007 is about 18.8 inches. Inspection of **Figure 3** indicates that above average precipitation occurred during the period 1978 through 1993, followed by a period of generally below average precipitation from 1995 through 2007. In addition, the lowest amount of total annual rainfall for the periods of record occurred at both stations in 2002. These relations indicate that for the period leading up to and including the RCM groundwater monitoring program (2003 to present), regional precipitation has been generally below normal with respect to the nearly 90-year period of record for these two regional stations.

RCM operates two multi-parameter meteorological stations, including a station at the East Plant Site near Shaft No. 9 (Station KC-1) and a station at the West Plant Site (Station KC-2). These stations were originally installed in 2002-2003, and have operated nearly continuously to present, although Station KC-1 was moved in late 2007 due to RCM construction activities at the West Plant Site. Significant data gaps exist for both of these stations starting in November 2007 and continuing through December 2008. M&A installed a recording rain gage at JI Ranch in July 2007 to augment the precipitation database. Period of record for this gage is July through October 2007 and January 2008 to present.

Figure 4 is a graph showing monthly total precipitation based on data from four stations in the region for the period 2004 through 2008. Because no one station has a complete record for the entire period, data from four stations were used to develop a precipitation profile for the period. Most of the data shown on **Figure 4** are based on records from the Miami station and RCM station KC-1 (East Plant Site). Because the KC-1 station malfunctioned in May 2007, and because data are not currently available for the Miami station for Year 2008, precipitation records for a citizen-operated gage in Superior, and for the gage installed by M&A at JI Ranch in 2008, were used to complete the precipitation profile through Year 2008. Inspection of **Figure 4** indicates a strong seasonal component to the precipitation patterns in the area, with annual summer rains providing generally more consistent precipitation on a year-to-year basis, and winter rains providing overall larger magnitudes of precipitation, but without the year-to-year consistency of the summer rains. The 2004-2005 and 2007-2008 winter rains, and the relatively robust summer rainy season in 2008 appear to be the most significant precipitation events for the period.

3.2 GROUNDWATER LEVELS AND TRENDS

Water level hydrographs for groundwater monitoring locations in the study area are shown on **Figure 5**; annotated water level hydrographs are given in **Appendix B**, **Figures B-1 through B-15.** Manual water level measurements taken at each location for the period of record are summarized in **Appendix C; Table C-1**.

3.2.1 Shallow Aquifers

Unconsolidated alluvial deposits occur in several areas within the Upper Queen Creek/Devils Canyon study area, typically along modern stream channels. Where these deposits are sufficiently thick or laterally extensive, saturated conditions may exist for much of the year. These saturated conditions may locally extend into the uppermost weathered part of underlying rock units such as the Apache Leap Tuff. Areas where more extensive alluvial deposits occur within the study area include the Pinal Ranch area (near Top of the World), Rancho Rio Canyon, and Hackberry Canyon **(Figure 2)**.

3.2.1.1 JI RANCH AREA: The most extensive deposit of unconsolidated alluvial sediments in the study area occurs in the Pinal Ranch area, which is located west from Top of the World (**Figure 2**). In the vicinity of Pinal Ranch, alluvial deposits extend across an area about 2 kilometers long by about ½ - 1 kilometer wide. Pinal Ranch is located within a small basin at the head of Iron Canyon, a tributary to Devils Canyon. A number of privately-owned shallow wells less than 30 m deep are completed in shallow alluvial deposits and uppermost weathered part of the Apache Leap Tuff in the Pinal Ranch area. Present use of the shallow alluvial aquifer in the Pinal Ranch area is not known, although anecdotal information suggests that there is only limited use for stock watering due to poor reliability and water quality issues.

JI Ranch is located at the west end of the Pinal Ranch alluvial deposits outcrop belt (**Figure 2**). In the JI Ranch area, the shallow aquifer occurs within unconsolidated alluvial deposits and the uppermost weathered portion of the Apache Leap Tuff. At least four shallow wells are located on the JI Ranch property, which is owned by RCM. Water level measurements have been obtained at one of these wells, the Corral well, starting in June 2004. In May 2007, two of these wells, the Corral and Middle wells, were evaluated and equipped for long-term monitoring of groundwater level and water quality for the shallow aquifer system; both wells were equipped with dataloggers for continuous water level monitoring. The Corral and Middle wells are completed in the shallow aquifer to depths of 25 and 16 m, respectively; schematic diagrams of well construction are shown in **Appendix A; Figures A-1 and A-2**. Although geologic logs are not available for these wells, thickness of the alluvial deposits is probably on the order of 6 m or less.

Water level hydrographs for the Corral and Middle wells are shown on **Figure 5**, and are given in **Appendix B; Figures B-1 and B-2.** Groundwater level in Corral well ranged from about 1.2 to 4 m bls over the period of record (June 2004 to present). Groundwater level at Middle well ranged about 4 to 6 m bls from May 2007 to present. **Figure 6** shows monthly total precipitation for the monitoring period 2004 through 2008 and water level hydrographs for the Corral and Middle wells for the same period. **Figure 6** also includes a water level hydrograph for nearby ALT aquifer well HRES-06.

Although the period of continuous water level record for these wells is limited, inspection of **Figure 6** indicates that the shallow aquifer at JI Ranch is quite responsive to rainy periods, with as much as 2 m of water level rise observed at Middle well within one month of onset of the 2007-2008 rainy period. Aquifer response to this rainy period was dampened at Corral well, although aquifer response was ultimately of a similar magnitude to that observed at Middle well. This is likely because Middle well lies closer (30 m) to the principal stream channel of Iron Canyon wash (main source of recharge) than Corral well which is about 100 m from the channel.

In addition to the 2007-2008 winter rainy period, both wells showed a response to the 2008 monsoon rainy period. However, neither well responded to the 2007 monsoon rainy period (**Figure 6**). These relations suggest that precipitation events must be large enough, and of sufficient frequency and duration, to result in a discernible recharge response in the shallow aquifer system.

Other factors that may influence water levels in the shallow aquifer at JI Ranch include: 1) local groundwater use adjacent to the JI Ranch property, 2) local return flow to the aquifer from seasonal stock watering operations near the Corral well, 3) return flow from leach fields of septic systems on JI Ranch and adjacent properties, and 4) groundwater withdrawal resulting from transpiration of trees in the JI Ranch area.

3.2.1.2 HACKBERRY CANYON: The Hackberry Windmill well is located at the east end of a small embayment of alluvial deposits in Hackberry Canyon south from Oak Flat (**Figures 1 and 2**). Measured depth of Hackberry Windmill well is about 13 m below land surface. Although construction details and geologic logs are not available for this well, it is likely completed in the shallow alluvium and the uppermost weathered part of the Apache Leap Tuff. Based on the close proximity to Hackberry Windmill of Apache Leap Tuff outcrops, thickness of the alluvial deposits is probably less than 3 m. A water level hydrograph for Hackberry Windmill is shown on **Figure 5** and is given in **Appendix B, Figure B-3.** Groundwater level ranged from about 1 to 3 m bls over the period of record (June 2004 to present). As with the Corral well at JI Ranch, water levels appear to respond to seasonal variations in precipitation. Local features that may also influence water level at Hackberry Windmill include a large stock pond located adjacent to the well. The earthen dam creating the pond has periodically been breached resulting in changes in storage capacity of the pond, which may impact water levels in the shallow aquifer system.

3.2.2 Apache Leap Tuff Aquifer

The Apache Leap Tuff extends across much of the Upper Queen Creek/Devils Canyon study area (**Figure 2**). Results of hydrologic characterization drilling by RCM have delineated an extensive fractured-rock aquifer within the ALT aquifer. Schematic diagrams of well construction for ALT aquifer wells are provided in **Appendix A; Figures A-3 through A-13.** Where penetrated by wells to date, saturated aquifer thickness ranges from 25 m at well HRES-08, to 500 m at well HRES-03.

Water level hydrographs for the 11 wells completed in the ALT aquifer are shown on **Figure 5**; annotated water level hydrographs are given in **Appendix B; Figures B-4 through B-14**. Manual water level measurements taken at each location for the period of record are summarized in **Appendix C; Table C-1**. Depth to groundwater level in the ALT aquifer ranges from about 57 m bls at HRES-08 in the southwestern part of the Devils Canyon watershed, to more than 360 m bls at HRES-01 near Shaft No. 9. Depth to groundwater in the Oak Flat area generally ranges from about 88 to 122 m bls.

Review of water level hydrographs for ALT aquifer wells in **Appendix B** indicates that groundwater levels within the ALT aquifer are relatively stable for the period of record, although deviations from background water level trends are observed at several wells that are located adjacent to ongoing mineral exploration or deep hydrologic test well drilling activities. Wells with extended periods of record (2004 to present) including HRES-02, HRES-03, HRES-04, HRES-05, Oak Flat well, A-06, and MJ-11, show an overall water level decline of less than 1 m during the period (**Figures B-5 through B-8, and B-12 through 14)**. Wells with shorter periods of record (2008 to present), including HRES-07 and HRES-08 also show a slight overall decline (**Figures B-10 and B-11)**. Observed declines are likely the result of the extended period of below average precipitation that began in 1995 and has continued to date (**Figure 3**). One exception to the observed overall decline in the ALT aquifer water levels is well HRES-06 at JI Ranch, which showed a rise of about 1 m during the period June 2007 to June 2009 (**Figure B-9 and Figure 5**).

Several ALT aquifer wells appear to respond to seasonal rainy periods in a similar manner to the shallow aquifer wells at JI Ranch, although onset of aquifer response is delayed to varying degrees and magnitude of response is more subdued. **Figure 7** shows monthly total precipitation for the monitoring period 2004 through 2008 and water level hydrographs for Oak Flat well, and for wells HRES-02, HRES-04, HRES-05, and HRES-06. Inspection of **Figure 7** indicates that Oak Flat well and HRES-02 responded to the 2004-2005 and 2007-2008 winter rainy periods, with a slight rise in water level (less than

1 meter). There appears to have been little or no impact from specific rainy periods at wells HRES-04 or HRES-05. These varied water level responses in the ALT aquifer to precipitation events are likely due to the non-uniform distribution of recharge pathways across the Apache Leap Tuff outcrop belt. Focused recharge likely occurs along principal surface water drainages and below stock ponds along tributaries to Queen Creek and Devils Canyon.

Groundwater level fluctuations at well HRES-06 appear to be larger than those observed at Oak Flat well and HRES-02 (**Figures 6 and 7**). However, these fluctuations do not correlate well with the precipitation record, and may also reflect impacts from local water usage in the JI Ranch area.

Expanded-scale views of the hydrographs for Oak Flat well, and wells HRES-02 and HRES-05 are shown along with monthly total precipitation for Years 2004-2008 on **Figure 8**. Inspection of the Oak Flat well hydrograph on **Figure 8** indicates that onset of water level rise during the 2004-2005 rainy period occurred in early December 2004, while at well HRES-02, onset of water level rise occurred in early January 2005. A similar delay in response is observed at these two wells for the 2007-2008 rainy period, while no response to either of these rainy periods is evident in the hydrograph for HRES-05. The 1-month delay in ALT aquifer response between Oak Flat well and HRES-02 likely reflects differences in recharge flowpaths in the vicinity of these two sites. For example, Oak Flat well is located adjacent to Devils Canyon (about 550 m), where the deeply incised canyon substantially reduces the potential length of the recharge flowpath from the canyon bottom to the ALT aquifer. Although depth to groundwater at Oak Flat well is around 90 m, projected groundwater level beneath Devils Canyon adjacent to the Oak Flat well is less than 30 m. Depth to groundwater at well HRES-02 is also about 90 m, but the local surface water drainage and stock pond are at nearly the same land surface elevation as HRES-02 resulting in a substantially longer recharge flowpath at this site.

Where wells are located adjacent to active mineral exploration or deep groundwater system characterization drill sites, as is the case with wells HRES-01, HRES-02, and HRES-04, locally significant fluctuations in groundwater level are sometimes observed when lost-circulation events occur during pre-collar drilling activities through the ALT aquifer. Specific observations and departures from regional water level trends at several wells are noted below:

HRES-01 (**Figure B-4**): Large fluctuations in water level of more than 160 m observed during the period from April – July 2005 were the result of a series of lost circulation events that occurred during drilling of RCM exploration borehole RES-08, which is located about 80 m north from well HRES-01. A more detailed analysis of this period of water level fluctuation is provided in Montgomery & Associates (2007).

In August 2006, a packer was installed at a depth of 335 meters to separate the upper perforated zone from the lower two zones (**Figure A-3**). A subsequent separation of water level occurred, with groundwater level representing the aquifer adjacent to the upper perforated zone stabilizing about 100 m above groundwater level representing the aquifer adjacent to the lower two perforated zones. After packer inflation, water levels remained relatively stable, with occasional fluctuations or shifts resulting from packer and/or transducer maintenance or removal.

HRES-02 (**Figure B-5**): An anomalous spike in water level of about 0.5 m occurred in early March 2005, which may be due in part to drilling activities in the Apache Leap Tuff during drilling of the conductor casing borehole at RCM exploration borehole RES-07, which is located about 160 m to the north. During drilling activities at RES-07, groundwater was encountered at 120 m bls on March 3, 2005, and conductor casing was set and cemented to a depth of 1,057 m bls on March 19, 2005, which coincides with the period of anomalous water level response at HRES-02. This spike occurred at a time when water levels were already rising as a result of recharge from the 2004-2005 winter rainy period.

A second spike in water level of about 1 m occurred in early July 2008, and was the result of lost circulation in the Apache Leap Tuff during drilling of the conductor casing borehole at a depth range of 147.8 to 187.5 m bls at deep hydrologic test well DHRES-02, which is located about 150 m to the north.

HRES-04 (**Figure B-7**): Several disturbances, including a rapid water level decline of more than 11 m, occurred during the period September – December

2006, and were the result of activities leading up to and including the long-term aquifer test at well HRES-04 (Montgomery & Associates, 2008). Water level does not appear to have fully recovered from the pumping test indicating that some additional well development occurred during pumping.

Spikes in water level (rise and decline) of up to 12 m were observed during the period April – June 2008, and were the result of activities related to drilling and construction of deep hydrologic characterization well DHRES-01.

HRES-08 (**Figure B-11**): Inspection of water level data from HRES-08D, which is completed in the Whitetail Conglomerate indicate that water levels have not stabilized. In December 2008, the packer deflated due to a valve malfunction at land surface, which resulted in water levels equilibrating with the ALT aquifer. The packer was reinflated in March 2009, and water levels have not stabilized. Hydraulic testing is planned once water levels stabilize, at which point modification of the well will be recommended in order to seal off the lower part of the well and permit sampling of the ALT aquifer.

3.2.3 Deep Groundwater System

A deep fractured-rock aquifer occurs beneath the ALT aquifer in the study area, and is separated from the ALT aquifer by the Whitetail Conglomerate. The deep groundwater system is in communication with the existing underground mine workings from the former Magma mine, and groundwater levels in the deep groundwater system have been recovering since dewatering was discontinued in 1998. In March 2009, dewatering operations were reinitiated by RCM, and deep groundwater system water levels have begun to decline once again. Although an analysis of deep groundwater system water level data is beyond the scope of this report, data are provided and discussed to put the deep groundwater system in context with the ALT aquifer and shallow aquifers. Water level hydrographs for RCM boreholes RES-02 through 04, and Shafts No. 3 and No. 9 are shown in **Appendix B; Figure B-15**. Water level hydrographs for deep hydrologic test wells DHRES-01 and DHRES-02, and RCM borehole RES-03 for the period June 2008 through December 2009 are shown on **Figure B-16.** Depth to groundwater level in the deep groundwater system is more than 600 m below land surface.

3.3 VERTICAL CONNECTIVITY WITHIN APACHE LEAP TUFF AQUIFER

Results of hydrogeologic characterization to date have indicated that, in general, the ALT aquifer behaves as one vertically-continuous, fractured-rock aquifer with hydraulic conductivity generally decreasing with depth (Montgomery & Associates, 2005, 2008). To confirm the degree to which the upper and lower parts of the ALT aquifer are hydraulically connected, packers were installed in HRES-01, HRES-02, HRES-05 and HRES-07. In addition, well HRES-03 was completed with one deep perforated zone (HRES-03D), and a shallow piezometer installed in the annulus (HRES-03S). At HRES-02, HRES-05 and HRES-07, water level data confirm that the ALT aquifer behaves as a single, continuous aquifer as there is little or no difference in water level elevation above and below the packers at each well (**Figure B-5, B-8, and B-10**). Exceptions to this behavior are observed at wells HRES-01 and HRES-03. After the packer was installed in HRES-01 in August 2006, a head difference of ~ 100 m rapidly developed between the deep (~410-487 m bls) and shallow (315-339 m bls) perforated zones (**Figure B-4**). We interpret this as indicating that the lower part of the ALT aquifer open to well HRES-01 is better connected to fracturing and faulting that intercept Shaft No. 9 and is draining more readily to the shaft, than the upper part of the ALT aquifer. At well HRES-03, water level elevation at HRES-3D (~440-460 m bls) is about 2 m higher than water level elevation at HRES-03S (~100-120 m bls) (**Figure B-6**). The hydraulic head difference between HRES-03S and HRES-03D indicates a small upward vertical component to the hydraulic gradient in the Apache Leap Tuff at this location.

3.4 GROUNDWATER MOVEMENT IN THE APACHE LEAP TUFF AQUIFER

A groundwater level contour map for the ALT aquifer has been developed and is shown on **Figure 9.** The contours shown on **Figure 9** are based on groundwater level elevation from December 2008 at nearly all currently monitored wells completed in the Apache Leap Tuff (HRES-01 through HRES-08, well A-06, well MJ-11, and the Oak Flat

Well) and the elevation of springs believed to be discharge points of the ALT aquifer (DC8.2W, DC6.1E, and MC3.4W).

In general, direction of groundwater movement in the ALT aquifer follows surface drainage patterns in the study area, with groundwater moving from areas of recharge near the watershed margins and along the principal drainage ways to areas of discharge such as Shaft No. 9 and Devils Canyon. In the upper Queen Creek watershed, groundwater moves locally towards the principal ALT aquifer discharge point at Shaft No. 9. In the Devils Canyon watershed, groundwater moves from the upper part of the basin south towards discharge points along the perennial reach of Devils Canyon. In addition, results of groundwater and surface water monitoring in 2008 have identified Mineral Creek as another likely discharge point for the ALT aquifer. As a result, the water level contours shown on **Figure 9** were developed to incorporate spring MC3.4W which discharges from the Apache Leap Tuff. Based on this interpretation, some groundwater in the ALT aquifer moves out of the Devils Canyon watershed and into the adjacent watershed to the southeast where it then discharges to Mineral Creek. Hydrochemical data from Mineral Creek drainage are consistent with discharge from the ALT aquifer to springs and the Mineral Creek stream channel; these data are discussed later in this report. Additional hydrologic characterization wells are planned by RCM to improve definition of groundwater conditions in the ALT aquifer in the study area, and will provide important data for refinement of the water level contour map.

Figure 10 shows estimated saturated thickness of the Apache Leap Tuff based on the projected water level contours shown on **Figure 9** combined with elevation data for the base of the Apache Leap Tuff as identified by the ALT aquifer wells and numerous mineral exploration boreholes that were drilled in the study area. The preliminary interpretation of ALT saturated thickness shown on **Figure 10** indicates that saturated thickness is largest in the Oak Flat area (>500 meters), thinning substantially in the Pinal Ranch area and to the south of Pinal Ranch. In addition, potential saturated thickness of the Apache Leap Tuff appears to increase to the southeast near Mineral Creek. Again, additional hydrologic characterization wells planned by RCM will provide important data for refinement of the ALT estimated saturated thickness map.

3.5 DISCUSSION

Routine groundwater level monitoring is an important tool for evaluating occurrence and movement of groundwater, identifying principal aquifers and areas of recharge to and discharge from these aquifers, and understanding the nature and magnitude of stresses to the aquifers from natural processes, or from human-based activities. Analysis of water level data from nearly 5 years of groundwater monitoring in the study area by M&A on behalf of RCM has confirmed many aspects of the conceptual hydrogeologic model for the ALT aquifer that was originally developed by M&A in 2005 (Montgomery & Associates, 2005). Salient observations based on this analysis include:

1. The shallow aquifers in the study area are very responsive to seasonal rainy periods, with aquifer water levels responding within days of specific events. However, precipitation events must be of sufficient magnitude, duration, and frequency for any recharge to occur. Magnitude of response from the 2007-2008 rainy period at the JI Ranch shallow wells was nearly 2 m.

2. Groundwater levels in the ALT aquifer have shown a slight overall decline (<1 m) during the monitoring period starting in 2003-2004. This water level decline is likely the result of less than average precipitation in the region leading up to and including the period of record.

3. Response to seasonal rainy periods are observed at several ALT aquifer wells for the period of record, but are limited to response to the 2004-2005 and 2007-2008 winter rainy periods. Magnitude of response is less than ½ m.

4. No discernible response was observed at other ALT aquifer wells from these same winter rainy periods. Varied water level responses in ALT aquifer to precipitation events are likely due the non-uniform distribution of recharge flow pathways across the Apache Leap Tuff outcrop belt. Focused recharge occurs along principal surface drainage ways such as Devils Canyon above the perennial reach, and below stock ponds along tributaries to Queen Creek and Devils Canyon.

Results of hydrogeologic characterization drilling in 2007 at well HRES-08, and subsequent groundwater monitoring in the study area, have led to a reinterpretation of ALT aquifer groundwater flow patterns in the Devils Canyon basin. With completion of well HRES-08 in 2007, and subsequent monitoring of groundwater levels in the ALT aquifer at this location, this part of the ALT aquifer is now considered to be an area of recharge, with groundwater moving from HRES-08 towards Devils Canyon (**Figure 9)**. In addition, for development of the water level contours shown on **Figure 9**, we are incorporating a spring (MC3.4W) in the Mineral Creek drainage that appears to be a discharge point for the ALT aquifer. Results of hydrochemical analyses presented later in this report suggest that flow at this spring, as well as surface water flow in the lower reach of Mineral Creek, are supported in part by discharge from the ALT aquifer. Additional water level control from new ALT aquifer wells proposed by RCM is required to confirm this interpretation.

Estimated saturated thickness of the ALT aquifer shown on **Figure 10** was developed based in part on the water contours shown on **Figure 9**. Although saturated thickness appears to largest in the Oak Flat area, results of drilling and testing for hydrologic characterization of the ALT aquifer indicate that, in general, permeability of the ALT aquifer decreases with depth, and "effective" aquifer thickness in parts of the Oak Flat area may be significantly smaller. Additional data for evaluating thickness of the ALT aquifer will be developed from new ALT aquifer hydrologic test wells.

4.0 HYDROCHEMICAL MONITORING AND CHARACTERIZATION

Hydrochemical sampling was undertaken in order to refine the conceptual hydrogeologic model for the ALT aquifer and adjacent aquifers. The principal goals of the hydrochemical monitoring and characterization program include: 1) establish groundwater quality baseline for the ALT aquifer and adjacent aquifers in the vicinity of proposed block-cave mining operations; 2) identify principal sources of groundwater recharge and pathways for groundwater discharge to/from the ALT aquifer and adjacent aquifers; and 3) define the connectivity between the shallow alluvial aquifers, the ALT aquifer, and the deep groundwater system. An additional objective was to evaluate the usefulness of several isotopic approaches in addressing these goals within the Upper Queen Creek/Devils Canyon study area.

Data presented in this section include those collected in 2004 and 2007 as new hydrologic monitoring wells were completed and existing wells were refurbished. However, the focus is on data collected during six quarterly sampling rounds conducted at three shallow wells and six ALT aquifer wells in February, May/June, August/September, and November/December 2008 and March and June 2009. Groundwater sample locations are shown on **Figure 1** and summarized in **Table 1**. Samples were collected for common and trace constituents, routine parameters, radiological parameters, stable isotopes, and radioactive/radiogenic isotopes. The analytical suite is summarized in **Table 4**; analytical results are summarized in **Appendix D**; **Tables D-1 through D-5**. An explanation of radiocarbon methodologies for estimating residence times is given in **Appendix E**. Discussion of the M&A quality assurance/quality control program is included in **Appendix F**.

In the third quarter 2008 and the first two quarters of 2009, coordinated groundwater/surface water sampling rounds were conducted in collaboration with Golder. In addition to samples for common, trace, and radiological constituents routinely collected by Golder, an extra set of samples was collected for stable and radioactive/radiogenic isotope analyses. The isotope samples were collected from a subset of the surface water and spring sample locations routinely sampled by Golder; sample locations are shown on **Figure 1** and are described in **Table 4**. Results of routine analyses are reported by Golder (2009a, 2009b); results of the isotope analyses are reported in **Tables D-4 and D-5** of this report.

4.1 WATER QUALITY

Hydrochemistry data for all groundwater samples have been compared to U.S. Environmental Protection Agency National Primary and Secondary Drinking Water Regulations (NPDWR and NSDWR). In addition, hydrochemistry data have been reviewed for compliance with the Arizona Numeric Aquifer Water Quality Standards: Drinking Water Protected Use (Arizona Administrative Code Title 18, Chapter 11, Article 4, Section R18-11-406). These two sets of standards are in agreement except with respect to arsenic (As), lead (Pb), nickel (Ni), and gross alpha. Where the standards differ, the more rigorous of the two was applied to the data.

4.1.1 Shallow Aquifers

Groundwater samples collected from wells completed in the shallow aquifers at JI Ranch and from Hackberry Windmill generally meet U.S. EPA and State of Arizona water quality standards (**Tables D-1, D-2 and D-3**). However, there is some evidence that the shallow groundwater at JI Ranch is vulnerable to impacts from local agriculture, regional mineralization, and/or historic mining and mineral processing activities in the region.

Corral Well is completed in the shallow aquifer adjacent to a cattle corral at JI Ranch. Water quality is variable; in general, the water is murky and has a strong odor of decaying organic material, however intermittent discharge of clearer water has been observed. One sample tests above the Maximum Contaminant Level (MCL) for nitrate. All other samples collected at the Corral Well are in compliance with the federal and state primary standards; however, samples of Corral Well water do not comply with U.S. EPA secondary standards for total dissolved solids (TDS), sulfate, and pH. Infiltration of effluent from the livestock corral and local septic systems likely accounts for locally elevated nitrate in the shallow groundwater. Variable sulfate and TDS concentrations and low pH values suggest that alluvial groundwater may have been impacted by historic mining and mineral processing activities (dry fall) in the region.

Middle Well is completed in the surficial alluvium approximately 100 m from Corral Well at JI Ranch. Samples of Middle Well water meet all primary standards (NPDWR) although pH is below the federal secondary standard, and Fe and Mn exceed federal secondary standards in some samples.

Hackberry Windmill Well is completed in the surficial alluvium along Hackberry Creek. Samples of Hackberry Windmill water meet all primary standards (NPDWR) although several samples fall below the secondary standard for pH.

4.1.2 Apache Leap Tuff Aquifer

Review of **Tables D-1 through D-3** indicates that inorganic water quality for all water samples collected from the ALT aquifer is excellent. TDS concentration is on the order of 200-300 mg/L, and for most of the chemical constituents that have been analyzed, no exceedances of federal or state aquifer water quality standards have been noted. There is a single exceedance of the MCL for arsenic in an April 2004 sample collected from well HRES-02. Federal secondary standards for Fe, Mn, and pH were exceeded in some samples.

4.1.3 Deep Groundwater System

Water quality in the deep groundwater system has not been intensively characterized. M&A has collected samples of groundwater from the deep groundwater system from deep hydrologic monitor wells DHRES-01 and DHRES-02. The sample collected after a 72-hour constant-rate pumping test at well DHRES-01 in November 2008 is considered to be the most representative sample collected to date. However, it must be noted that the specific conductance of the discharge had not entirely stabilized by the end of the test, which indicates that new sources of water were still potentially contributing to the well discharge. All other deep groundwater system samples are impacted by drilling fluids and are not considered representative of the deep groundwater. Accordingly only data from the sample collected after the 72-hour pumping test at well DHRES-01 are reported (**Tables D-1 through D-5**).

For the chemical constituents that have been analyzed, no exceedances of federal or state primary aquifer water quality standards have been noted in the deep groundwater sample collected after the 72-hour pumping test at well DHRES-01. However, secondary standards for Fe, Mn, F, and TDS were exceeded (**Tables D-1 and D-2**).

4.2 DISTRIBUTION OF HYDROCHEMICAL FACIES

Trilinear (or Piper) and Stiff diagrams are used to display groundwater and surface water compositions in terms of proportions of the major ions. Trilinear diagrams are used to: 1) classify waters into hydrochemical facies (or types) on the basis of relative proportions of the major ions, and 2) identify potential mixing relationships within and between sample populations (Drever, 1982). Trilinear diagrams are constructed by plotting the proportions of major cations (sodium plus potassium (Na^+ + K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+})) on a single triangular plot and the major anions (chloride (Cl^-), bicarbonate (HCO_3^-), and sulfate (SO_4^{2-})) on another. The information on the two triangular diagrams is then combined into a central quadrilateral that shows the relative proportions of all the major ions in each sample.

Figure 11 is a trilinear diagram showing data for groundwater samples that were collected prior to the beginning of quarterly monitoring as part of well completion and testing as well as data from each of the 2008 quarterly monitoring rounds. **Figure 12** is a trilinear diagram showing surface water and spring compositions from the coordinated surface water/groundwater sampling conducted in the third quarter of 2008. The field occupied by data from ALT aquifer on **Figure 11** is provided on **Figure 12** for reference.

Stiff diagrams are a useful means of comparing and correlating different water types (Hem, 1985). Water types are displayed on a single vertical axis with three horizontal axes; concentrations are plotted in milliequivalents per liter (meq/L) with anion concentrations to the left of the central vertical axis and cation concentrations to the right. As with trilinear diagrams, the standard anion groups are sodium plus potassium (Na^+ + K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}); the three cations are chloride (Cl^-), bicarbonate (HCO_3^-), and sulfate (SO_4^{2-}). The resulting shape indicates the relative concentrations of the major ion groups and the overall size of the diagram is representative of the TDS concentration.

Figure 13 shows Stiff diagrams for surface and groundwater samples plotted on a map of the project area. This map provides information regarding the spatial distribution of water types and indicators of surface water/groundwater interactions. Most of the Stiff diagrams shown on **Figure 13** are for samples obtained during the third quarter of 2008 coordinated groundwater/surface water sampling round. For those locations not sampled in the third quarter of 2008, the most recent data are shown.

4.2.1 Shallow Aquifers

The shallow groundwater sampled from the Corral Well at JI Ranch is calcium-sulfate type; groundwater sampled nearby at Middle Well is calcium-bicarbonate-sulfate type with approximately equal weighting of carbonate and sulfate (**Figure 11**). TDS concentrations range from 550 mg/L to 750 mg/L at Corral Well and from 240 mg/L to 310 mg/L at Middle Well. Groundwater in the shallow alluvial system represented by samples collected from Hackberry Windmill Well is calcium-bicarbonate type with bicarbonate accounting for about 80 percent of the anion content (**Figure 11**). TDS concentrations range from 135 mg/L to 230 mg/L at Hackberry Windmill Well.

4.2.2 Apache Leap Tuff Aquifer

The inorganic chemistry data for the Apache Leap Tuff generally plot into one of two groups based on depth: the upper ALT aquifer group and the lower ALT aquifer group (**Figure 11**). TDS concentrations range from 155 mg/L to 300 mg/L in samples from the ALT aquifer; there does not appear to be any systematic variation in TDS concentrations between the upper and lower parts of the aquifer. Groundwater from the upper part of the ALT aquifer is generally calcium-sodium-bicarbonate type with approximately equal cation weighting of calcium and sodium. Groundwater from the lower part of the ALT aquifer is sodium-bicarbonate type. Studies by Peterson (1961) and Woodhouse (1997) indicate sodium to be a major cation member of the bulk chemistry of ALT groundmass, and also indicate that clinoptilite, a sodium-rich zeolite, is present as authigenic fracture-filling mineralization. Therefore, a plausible explanation for dissolved sodium in groundwater is rock-water interaction in the lower part of the tuff. Smaller concentrations of sodium in groundwater from upper parts of the ALT aquifer suggest that residence time has been longer for groundwater in the lower part of the tuff, allowing saturation of dissolved sodium to increase (Montgomery & Associates, 2005).

There does not appear to be any substantial difference in chemical composition between groundwater sampled in the ALT aquifer to the east of Devils Canyon and groundwater sampled from the ALT aquifer west from Devils Canyon.

4.2.3 Deep Groundwater System

The groundwater sample collected from the deep groundwater system is sodium-bicarbonate-sulfate type (**Figure 11**). This sample is more sulfate-rich than the ALT aquifer samples and the cation composition is similar to that of the sodium-rich lower ALT samples. TDS concentration is 500 mg/L.

4.2.4 Devils Canyon Springs and Surface Water

Surface water and spring samples from the Devils Creek drainage are calcium-bicarbonate-sulfate type. Calcium accounts for about 60 percent of the cation balance in the majority of the samples and anion proportions are broadly distributed with bicarbonate accounting for between 30 and 90 percent of the major anions (**Figure 12**). TDS concentrations range from 90 mg/L to 230 mg/L in surface waters sampled in 2008 Q3 and from 230 mg/L to 250 mg/L in the two springs sampled (DC8.2W and DC6.1E) (Golder, 2009). In general, surface water in Devils Canyon and its tributaries become progressively more bicarbonate-rich with distance downstream.

Hydrochemical data from Devils Canyon drainage indicate that the ALT aquifer discharges both directly to the stream channel and indirectly via springs. Two surface water samples (DC8.1C and DC6.14C) have chemical compositions very similar to groundwater from the upper ALT aquifer (**Figure 12**) indicating that, within the perennial reach, discharge from the ALT aquifer contributes a substantial proportion of flow to Devils Canyon. Further north in Devils Canyon, where the surface waters are intermittent or ephemeral, waters are more dilute (lower TDS) and have higher sulfate concentration due to a large component of event-driven runoff. Stiff diagrams on **Figure 13** show that the chemical composition and TDS concentration of water from two springs that issue along Devils Canyon (DC8.2W and DC6.1E) are very similar to those of the upper ALT aquifer (e.g., see nearby wells MJ-11, A-06, and HRES-07. This indicates that springs DC8.2W and DC6.1E represent discharge points of the ALT aquifer to Devils Canyon.

4.2.5 Queen Creek and Apache Leap Escarpment Springs and Surface Water

Surface water and spring samples from the Queen Creek drainage are also calcium-bicarbonate-sulfate type; however, they are more calcium or magnesium-rich than the Devils Canyon waters and therefore occupy a field roughly parallel to, but distinct from, the Devils Canyon samples on the ternary diagram (**Figure 12**). TDS concentrations range from 210 mg/L to 290 mg/L for Queen Creek surface water and from 360 mg/L to 570 mg/L for springs located along the Queen Creek drainage. Chemistry in the Queen Creek channel is likely influenced by the change in geology from Apache Leap Tuff to the Paleozoic carbonates and Quaternary alluvial deposits. Exceptions to this distribution are the two Queen Creek tributaries, Number Nine and Oak Flat, which drain the Oak Flat area and have sample compositions and TDS concentrations (93 and 100 mg/L, respectively) similar to ephemeral waters from the upper Devils Canyon drainage (**Section 4.2.4**).

Stiff diagrams on **Figure 13** indicate that the chemical composition of samples from springs along the Apache Leap escarpment are varied. Hidden Spring has a calcium-bicarbonate composition similar to that of Boulder Hole and Karst Spring, which discharge closer to the Queen Creek channel. Bored Spring and Kane Spring are both calcium-magnesium-bicarbonate type, perhaps indicative of interaction with dolomitic rocks within the Paleozoic section. TDS concentrations for Kane, Hidden, and Bored springs range from 370 mg/L to 410 mg/L. Blue Spring is similar in composition and TDS concentration to the ALT groundwater, which is likely due to equilibration with the Apache Leap Tuff block from which it discharges (see geologic map on **Figure 2**). None of these springs show a hydrochemical similarity to the deep groundwater system.

4.2.6 Mineral Creek Springs and Surface Water

Spring and surface water samples from the Mineral Creek drainage are varied in composition (**Figure 12**). Wet Leg Spring water is calcium-bicarbonate type and is similar to ALT groundwater in composition and TDS concentration (220 mg/L) indicating that this spring is a discharge point of the ALT aquifer. Samples collected further upstream at the Ranch Fork Headwater (MC 8.4C) and at Lyons Fork Headwater (LF0.2C) are more sulfate-rich and have higher TDS concentrations (480 mg/L and 460 mg/L, respectively) than the Wet Leg Spring sample. A sample collected from the Mineral Creek channel downstream of Wet Leg Spring is slightly more sulfate-rich than the Wet Leg spring sample and has an intermediate TDS concentration of 310 mg/L. Further characterization of the Mineral Creek drainage is ongoing to determine likely sources of water sampled in the headwaters of Mineral Creek and from the Lyons Fork tributary. However, preliminary indications are that discharge from the ALT aquifer contributes substantial flow to the lower reach of Mineral Creek.

4.3 STABLE ISOTOPES

The 2008/2009 quarterly monitoring program included sampling for three sets of stable isotopes: stable isotope ratios of hydrogen and oxygen in water (δ^2H, $\delta^{18}O$), stable isotopes ratios of sulfur and oxygen in dissolved sulfate ($\delta^{34}S$, $\delta^{18}O_{SO4}$), and carbon stable isotope ratios in dissolved inorganic carbon ($\delta^{13}C$). During all six quarterly sampling rounds, samples were collected from the shallow aquifers and the ALT aquifer and, in the third quarter of 2008 (2008 Q3), the groundwater sampling was coordinated with surface water monitoring routinely conducted by Golder. Stable isotope data are summarized in

Table D-4. In addition to the quarterly monitoring data, this section includes data that represent groundwater from the deep groundwater system and surface/spring waters from the Mineral Creek drainage basin collected in November 2008. This section reports each set of stable isotope data and provides interpretations with respect to groundwater and surface water.

4.3.1 Deuterium and Oxygen-18

Stable isotope ratios of hydrogen and oxygen for groundwater, surface water, and spring samples obtained in the Upper Queen Creek/Devils Canyon study area are plotted on **Figure 14**. All samples were obtained during the 2008 Q3 coordinated groundwater/surface water monitoring round except samples from the Mineral Creek drainage that were collected in November 2008.

Included on **Figure 14** are rainfall data obtained by the University of Arizona during summer and winter seasons, 1989 through 1992 (Bassett et al., 1994). Rainfall samples exhibit a wide variation; ∂^2H values range from -112 to -20 per mil (‰) with a mean of -57‰ and oxygen-18 data (∂^{18}O) range from -15.5 to -1.1‰ with a mean of 9.1‰. The best-fit line through the rainfall samples is represented as the local meteoric water line (LMWL). Also shown is the global meteoric water line (GMWL, Craig, 1961). The fact that ALT aquifer data and associated spring data lie closer to the GMWL than the LMWL is likely due to the relatively short period over which local rainfall data were gathered. ALT data represent an integrated precipitation signal over a much longer period and thus lie closer to the GMWL.

4.3.1.1 GROUNDWATER: **Figure 15** shows data from groundwater samples collected during the period 2004 through 2009. The majority of groundwater samples from the shallow and ALT aquifers plot in a small cluster; average ∂^2H value is about 72‰ and ∂^{18}O is about 9.9‰. The narrow distribution of the groundwater data suggests that water from the shallow aquifers and the ALT aquifer originates in the same source area. Samples plot close to the meteoric water line which indicates integrated values from present-day precipitation with limited evaporation occurring for most of the recharge waters. There does not appear to be any systematic variation in isotopic composition between groundwater from the eastern part of the ALT aquifer (east of Devils Canyon) and the Oak Flat, or western, part of the ALT aquifer.

Data from two ALT groundwater samples lie outside the field occupied by the majority of the ALT aquifer data (**Figure 15**). The lightest of these was collected from well HRES-03 in 2004. This sample was collected after pumping well HRES-03 for only 2 hours and the data may be impacted by makeup water. The other outlier is from a sample that was collected from well HRES-05 in August 2008. This result is not consistent with data from four other samples collected from well HRES-05 (**Table D-4**) and is probably due to sampling or analytical error.

Samples from the shallow aquifer, collected at Hackberry Windmill Well, are slightly enriched with respect to other groundwater samples (i.e., they have less negative $\partial^{2}H$ and $\partial^{18}O$ values). The trend is plotted on **Figure 15**; the slope is slightly shallower than that of the local meteoric water line which is indicative of evaporative processes. This evaporative signature is consistent with the location of Hackberry Windmill, adjacent to a large stock pond.

The deep groundwater sample from DHRES-01 is depleted, showing more negative $\partial^{2}H$ and $\partial^{18}O$ values than groundwater samples from the shallow and ALT aquifers (**Figure 15**). This isotopic composition may suggest: a different recharge source area for the deep groundwater system; recharge during a cooler, wetter climatic period (e.g., late Pleistocene); or, with longer residence times, this may simply represent a longer-term average of meteoric water composition. More data representing the deep groundwater system system are required prior to any further interpretation.

<u>4.3.1.2 SURFACE WATER AND SPRINGS</u>: **Figure 16** shows data from samples obtained from surface water and springs in the Devils Canyon area during the 2008 Q3 monitoring round. The oxygen and hydrogen isotopic signatures of water from two springs that issue from the east and west sides of Devils Canyon (DC 6.1 E, and DC 8.2 W) are very similar to that of the ALT aquifer groundwater which is consistent with these springs being discharge points for the ALT aquifer (**Figure 16**).

Isotopic signatures of surface water samples taken from the channel in Devils Canyon occupy a relatively large range representative of mixtures of the more depleted 2008 summer monsoon precipitation and heavier, or more enriched, ALT groundwater (**Figure 16**). Toward the headwaters of Devils Canyon (DC15.7C and DC14.7C), surface water is dominated by runoff from precipitation events as evidenced by the more depleted (more negative) ∂^2H and ∂^{18}O values (**Figure 16**). Surface waters collected further downstream in Devils Canyon (DC8.1C and DC6.14C) are more enriched due to an increased ratio of ALT groundwater to precipitation-driven surface runoff (**Figure 16**). An intermediate sample, collected upstream of the beginning of the perennial reach (DC13.5C) is also enriched compared with the lighter surface-runoff samples. Although the possibility that the ALT aquifer discharges so far up the drainage is not discounted, it seems unlikely. Therefore this result is tentatively explained as being representative of long-term storage in the shallow system which causes similar averaging of the precipitation signal as that represented by the ALT aquifer data. Surface water inventories conducted by Golder (2006) indicate that this section of Devils Canyon flows most of the year.

Three tributaries to Devils Canyon (Iron Canyon, Rancho Rio Creek, and Hackberry Creek) have widely differing isotopic signatures (**Figure 16**). Rancho Rio plots with the ALT aquifer samples while the Iron Canyon and Hackberry Creek samples are depleted and enriched, respectively. The Iron Canyon isotopic signature suggests that the sample had a strong component of event-driven runoff. The enriched signature of the Hackberry Canyon sample may be due to evaporation.

Figure 17 shows data from surface water and springs samples obtained in the Queen Creek/Apache Leap escarpment area during the 2008 Q3 monitoring round. Four of the six springs sampled in the Queen Creek/Apache Leap escarpment area (Pump Station, Blue, Hidden, and Kane) exhibit stable isotope signatures comparable to those observed in the ALT aquifer samples (**Figure 17**). This result suggests that water discharging from each of these springs is derived from a source that represents a similar integrated precipitation signal to that represented by the ALT aquifer. Karst Spring and Boulder Hole are somewhat depleted with respect to the other four springs which may indicate that the discharge from these springs is a mixture of groundwater and surface run-off.

Surface water samples from Queen Creek occupy a wide range of isotopic compositions. Samples collected from Queen Creek at Magma Avenue and above Magma Wash exhibit relatively depleted values, which suggests that they contain large components of event-driven runoff. In contrast, the sample collected at the uppermost sampling point, (QC27.3C) is highly enriched and falls below the local meteoric water line. Additional sampling at this location is required prior to further interpretation of this result. The two tributaries to Queen Creek, Number Nine and Oak Flat, both exhibit depleted isotopic signatures consistent with event-driven surface runoff.

Figure 18 shows data from surface water and spring samples obtained in the Mineral Creek drainage. Four samples were collected in the Mineral Creek drainage in November 2008. Two surface water samples were collected from Mineral Creek, one high up at the headwaters (MC8.4C), and the other further downstream (MC3.3C). The third surface water sample (LF0.2C) was collected from Lyons Fork, a tributary to Mineral Creek. The fourth sample is from a spring (MC3.4W) which discharges from the west side of Mineral Creek. All four samples exhibit isotopic signatures similar to that of the ALT aquifer (**Figure 18**) which suggests that both spring and surface water flow in the Mineral Creek drainage are supported by groundwater discharge rather than event-driven surface runoff.

4.3.2 Sulfur-34 and Oxygen-18 in Dissolved Sulfate

Stable isotope ratios of sulfur and oxygen in dissolved sulfate ($\delta^{34}S$ and $\delta^{18}O_{SO4}$) for groundwater, surface water, and spring samples obtained in the Apache Leap study area are summarized in **Table D-4**. Bassett et al. (1994) report several sulfur isotope signatures that are useful in the analysis of groundwater and surface water samples from the Superior area:

1. Local, modern-day precipitation samples have an average $\delta^{34}S$ concentration of +8‰
2. Recent atmospheric fallout or dryfall (sulfate particulates) have $\delta^{34}S$ values that are heavier than +6‰
3. Surface runoff $\delta^{34}S$ values range from -4 to +1 ‰. Bassett et al. (1994) attribute the depleted surface runoff signature to interaction with sulfur particulates deposited in the alluvium during operation of the Magma Mine smelter in Superior between 1924 and 1971

In addition to these potential contributions to the $\delta^{34}S$ signatures of surface and groundwater, it is useful to compare the sulfate content of samples. This is done by calculating the ratio of sulfur to a conservative component of the water chemistry such as chloride. In the following discussion sulfate:chloride mass ratios (SO_4/Cl) are coupled with isotopic data in order to gain insight into recharge by identifying those samples impacted by emissions from the Magma Mine smelter.

4.3.2.1 GROUNDWATER: Groundwater samples collected from shallow wells at JI Ranch and Hackberry Windmill have relatively high SO_4/Cl ratios and depleted sulfur isotopic signatures which may be due to interaction with smelter-derived sulfur particulates in the alluvium (**Figure 19**). This depleted isotopic signature indicates that some proportion of the water in the shallow aquifers was recharged since anthropogenic inputs of sulfur to the system occurred.

Groundwater samples collected from the ALT aquifer have lower SO_4/Cl ratios and heavier sulfur isotope signatures than the shallow alluvial systems (**Figure 19**). Sulfur isotope values of ALT groundwater samples cluster around the local precipitation $\delta^{34}S$ of approximately +8 ‰ (Bassett et al., 1994). This is consistent with these groundwaters being recharged to the aquifer prior to anthropogenic inputs of sulfur to the system. However, it should be noted that there is presumably a gradient of groundwater age within the ALT aquifer with older water near the bottom of the aquifer, and newly recharged water near the water table. Thus, wells screened below the water table provide samples of deeper, older, groundwater. In addition any mixing that occurs during sampling causes samples to be representative of a composite groundwater age. Groundwater sampled from well HRES-06 has slightly higher sulfate concentrations than other ALT groundwater; however, $\delta^{34}S$ values lie within the same range as those observed in other ALT aquifer samples. Well HRES-06 is screened across the water table and thus a sample may be expected to represent both older and more recently recharged groundwater. Based on the sulfur isotope evidence, there does not seem to be direct, fast-path communication between the shallow alluvial aquifers and the underlying ALT aquifer in the JI Ranch area.

The sample collected from the deep groundwater system has an enriched $\delta^{34}S$ composition consistent with recharge prior to anthropogenic inputs of sulfur to the system. However, this sample differs from ALT groundwater samples as it exhibits an increased sulfate concentration, presumably due to interaction with an enriched source of sulfur within the deep groundwater system.

4.3.2.2 SURFACE WATER AND SPRINGS: SO_4/Cl mass ratios and $\delta^{34}S$ data from surface water and spring samples collected in the Devils Canyon drainage are shown on **Figure 20.** Springs issuing from the east and west sides of Devils Canyon have dissimilar $\delta^{34}S$ signatures and SO_4/Cl mass ratios (**Figure 20**). Samples from the west side spring (DC8.2W) plot with data from ALT aquifer wells which indicates that this spring represents a discharge point of the ALT aquifer. However, the $\delta^{34}S$ of the east side spring (DC6.1E) is considerably lighter than spring DC8.2W or any of the ALT aquifer samples. Spring DC6.1E is located near the base of the ALT, and $\delta^{34}S$ composition may be influenced by local controls on groundwater and surface water movement. Surface water samples collected along the perennial reach of Devils Canyon (DC6.14C and DC8.1C) have similar $\delta^{34}S$ values and SO_4/Cl mass ratios to groundwater from the ALT aquifer (**Figure 20**). This is interpreted to result from a substantial contribution of ALT groundwater to flow in the perennial reach of Devils Canyon. In contrast, a sample collected in the upper part of the drainage, north of the perennial reach (DC14.7C), displays the depleted $\delta^{34}S$ value and higher SO_4/Cl mass ratio expected from event-driven surface runoff (Bassett et al., 1994; Golder, 2006) (**Figure 20**). Another sample (DC13.5C) collected from the upper part of Devils Canyon has an intermediate $\delta^{34}S$ signature and very low SO_4/Cl mass ratio. This is consistent with discharge from long-term storage in a shallow groundwater system hosted by the near-surface Apache Leap Tuff as suggested by the deuterium and oxygen-18 data (**Section 4.3.1.2**). Sulfur isotope signatures for surface water samples from Devils Canyon tributaries are varied: Iron Canyon (IC1.0C) has a strongly depleted, surface-runoff signature; Rancho Rio (RR1.5C) has an intermediate $\delta^{34}S$ composition, perhaps indicative of contributions from both surface runoff and ALT aquifer discharge; and Hackberry Canyon (H0.1C) has a $\delta^{34}S$ signature that lies on the upper end of the range occupied by ALT groundwater (**Figure 20**). Further analysis of these results together with additional data from 2009 will be provided in a future surface water report.

SO_4/Cl mass ratios and $\delta^{34}S$ data from surface water and spring samples collected in the Queen Creek drainage and along the Apache Leap escarpment are shown on **Figure 21.** Surface waters in the Queen Creek drainage, including the two tributaries, exhibit a relatively constant and depleted $\delta^{34}S$ signature indicating that event-driven surface runoff is the major contributor to flow (**Figure 21**). The exception is the surface water sample from QC27.3C, which is highly enriched with respect to the other Queen Creek surface water samples. Springs in the Queen Creek drainage display a wide range of $\delta^{34}S$ values: Pump Station Spring is very similar to the surface water $\delta^{34}S$ composition; Karst Spring (QC22.6E) is slightly enriched with respect to the surface water samples; and, Boulder Hole is highly enriched with a $\delta^{34}S$ value similar to that observed at the surface water location uppermost in the drainage, QC27.3C (**Figure 21**). Of the three springs sampled along the Apache Leap escarpment, Blue Spring and Kane Spring display $\delta^{34}S$ and SO_4/Cl values that lie within the field occupied by data from the ALT aquifer. The composition of water from Hidden Spring is similar to surface waters sampled within the Queen Creek drainage (**Figure 21**). Further analysis of these results together with additional data from 2009 will be provided in a future surface water report.

4.3.3 Carbon-13 in Total Dissolved Inorganic Carbon

Groundwater samples from all three aquifer systems have been analyzed for the stable isotope of carbon (^{13}C) in total dissolved inorganic carbon (TDIC); ^{13}C samples were not collected for surface water. Several sources contribute to the carbon isotope signature of groundwater: atmospheric CO_2, soil gas (CO_2) in the root zone, and carbon-bearing mineral phases in the geologic units through which water infiltrates. Atmospheric CO_2 has $\delta^{13}C$ values in the range of -7 to -8‰ (Kendall and McDonnell, 1998). The ^{13}C content of soil CO_2 is assumed to be controlled by the type of vegetation that dominates the recharge area because different photosynthetic pathways fractionate carbon in different ways. The Calvin (C_3) photosynthetic cycle results in soil gas with an average $\delta^{13}C$ of -27‰ and a range between -22 and -34‰. The Hatch-Slack (C_4) cycle results in soil gas with an average $\delta^{13}C$ of -12‰ and a range between -9 and -19‰. The crassulacean acid mechanism (CAM) is a metabolic approach that utilizes both C_3 and C_4 photosynthetic pathways and results in soil gas with an average $\delta^{13}C$ of -17‰ (Kendall and McDonnell, 1998). Bassett et al. (1994) conducted a survey of vegetation at the Apache Leap Research Site (ALRS) and concluded that the predominant metabolism types are C_3 and CAM. Soil gas analyses in the Apache Leap area indicate that $\delta^{13}C$ in soil CO_2 averages -20.3‰; water in equilibrium with this soil CO_2 is expected to have a $\delta^{13}C$ value of approximately -12 to -13‰ (Bassett et al., 1994; Clark and Fritz, 1997).

Data regarding the ^{13}C composition of mineral phases in the Apache Leap area are sparse. Weber and Evans (1988) present $\delta^{13}C$ data for authigenic fracture-fill calcites in the

Apache Leap Tuff that range from -6.62 to -11.15‰ presumably reflecting the evolution of the $\delta^{13}C$ signature of carbonate species in infiltrating water from which the calcite precipitated. Underlying the Apache Leap Tuff is the Tertiary Whitetail Conglomerate which contains local detrital material including fragments of Paleozoic limestones (Peterson, 1962). No data are available regarding isotopic composition of the carbonates; however, the local Paleozoic limestones are marine limestones which are known to have $\delta^{13}C$ values close to 0‰ (Faure, 1986). The Cretaceous volcaniclastic and siliciclastic rocks that host the deep groundwater system contain carbonates associated with the ore-bearing alteration assemblages. No isotopic data for these phases are available. Preceding $\delta^{13}C$ information is summarized as follows:

Carbon Source	Reference	$\delta^{13}C$ value (‰)
Atmospheric CO_2 gas	Kendall and McDonnell, 1998	Range: -8 to -7
Soil CO_2 gas		
C3	Kendall and McDonnell, 1998	Range: -34 to -22; average -27
C4		Range: -19 to -9; average -12
CAM		Average: -17
Apache Leap Research Site	Bassett et al., 1994	Average: -20.3
ALT fracture-fill calcites	Weber and Evans, 1988	Range: -11.15 to -6.62
Marine limestones	Faure, 1986	Average: ~0

4.3.3.1 SHALLOW AQUIFERS: Average $\delta^{13}C$ values for samples collected from wells completed in the shallow alluvial aquifer, the ALT aquifer, and the deep groundwater system within the study area are summarized in **Table D-4**. Average values for shallow wells at JI Ranch range from -18.9‰ at Middle Well to -19.7‰ at Corral Well. The other shallow well that was sampled, Hackberry Windmill Well, is enriched in comparison to the shallow JI Ranch wells with an average $\delta^{13}C$ of -14.1‰. The JI Ranch samples are considerably lighter than they would be if their isotopic composition were controlled by isotopic exchange with soil CO_2 with $\delta^{13}C$ of -20.3‰ prior to infiltration (water in equilibrium with CO_2 with $\delta^{13}C$ of -20.3‰ is expected to have a $\delta^{13}C$ value of approximately

-12 to -13‰). A likely explanation for the lighter $\delta^{13}C$ values in the shallow aquifer at JI Ranch is that the soil gas is lighter than that sampled by Bassett et al. (1994). Vegetation at JI Ranch is dominated by Emory Oaks, large trees that utilize the C_3 photosynthetic mechanism which is expected to result in soil gas with an average $\delta^{13}C$ of -27‰. Water in equilibrium with such soil gas would have $\delta^{13}C$ of -19 to -20‰, which is in close agreement with the values of -18.9‰ and -19.7‰ observed in samples of groundwater from the shallow JI Ranch wells. Hackberry Windmill is located in a meadow dominated by grasses and a few large trees. Many summer grasses utilize the C_4 photosynthetic mechanism that results in soil gas with an average $\delta^{13}C$ of -12‰; consequently control of soil gas isotope composition by local vegetation is a reasonable explanation for the heavier isotopic signature of the groundwater sampled at Hackberry Windmill well.

4.3.3.2 APACHE LEAP TUFF AQUIFER: As water percolates from the surface, dissolved carbonate species move toward isotopic equilibrium with soil CO_2. Once the water passes out of the soil zone into the underlying bedrock units, $\delta^{13}C$ of total dissolved inorganic carbon (TDIC) is largely controlled by mixing and by dissolution and precipitation of carbonate minerals. Given the complexity of flow in fractured media coupled with the paucity of data describing flowpaths, mixing, fracture-matrix interaction, and isotope compositions of the mineral phases with which water interacts, it is not possible to quantitatively describe the isotopic evolution of water as it moves from the surface through the Apache Leap Tuff into the underlying units. However, a qualitative understanding of groundwater movement may be obtained by examining the $\delta^{13}C$ values of groundwater extracted from wells completed in the ALT aquifer. Average $\delta^{13}C$ values for samples collected from the ALT aquifer range from -14.1 to -16.2‰. As seen from the shallow well $\delta^{13}C$ values, water recharging the ALT aquifer through the surficial aquifers may be expected to have a wide range of carbon isotopic values ranging from approximately -20‰ to -14‰. In addition, meteoric water that recharges the ALT aquifer through more direct pathways (such as focused flow through fracture zones) will contribute an enriched signal as it will be close to being in equilibrium with atmospheric CO_2. ALT groundwater $\delta^{13}C$ compositions can be explained simply by mixing of waters with soil-zone and meteoric signatures.

4.3.3.3 DEEP GROUNDWATER SYSTEM: The $\delta^{13}C$ of groundwater collected from the deep groundwater system at well DHRES-01 was -7.3‰ (**Table D-4**). This enriched value of $\delta^{13}C$ suggests that carbonate dissolution contributes to the $\delta^{13}C$ composition of the deep groundwater. Speciation and solubility calculations carried out using the geochemical code PHREEQC (Parkhurst and Appelo, 1999) indicate that the deep groundwater is slightly supersaturated with respect to calcite, which supports this idea.

4.4 RADIOACTIVE AND RADIOGENIC ISOTOPES

4.4.1 Carbon-14 and Tritium

Carbon-14 (^{14}C) and tritium (^{3}H) data are shown in **Table D-5**. Groundwater from the shallow, ALT, and deep groundwater systems was sampled for both isotopes; surface water samples were collected for tritium analysis only. Discussion of radiocarbon methodologies for estimation of residence times is given in **Appendix E**. Due to the complexity of flow in the fractured ALT aquifer and the deep groundwater system, and the paucity of data regarding geochemical evolution along flow paths within and between aquifers, further interpretation of the age calculations given in **Appendix E** is not discussed. Despite the limitations of the method, valuable qualitative information regarding the nature of the three main aquifer systems may be gained from analysis of the ^{13}C, ^{14}C, and ^{3}H data (see **Section 4.3.3** for discussion of $\delta^{13}C$ data). **Figure 22** shows clear populations in the ^{14}C and ^{3}H data that provide evidence of the relative residence times of groundwater in the shallow, ALT, and deep groundwater systems.

<u>4.4.1.1 SHALLOW AQUIFERS</u>: Hackberry Windmill Well is completed in an alluvial basin with groundwater levels on the order of 1-3 m bls. Tritium and ^{14}C values from alluvial groundwater sampled from Hackberry Windmill Well are consistent with present-day precipitation (Eastoe et al., 2004) although some contribution from modern (post-bomb) waters cannot be discounted. These data suggest that the groundwater in the shallow alluvial system represented by samples collected at Hackberry Windmill Well has relatively short residence times, on the order of less than 5 to perhaps as long as 50 years.

The shallow aquifer at JI Ranch is hosted in the surficial alluvium and upper, weathered Apache Leap Tuff; groundwater levels range from 2-4 m bls at Corral Well and 4-6 m bls at Middle Well. Groundwater extracted from this shallow aquifer appears to be older than that sampled at Hackberry Windmill Well. Tritium values in samples from both Corral Well and Middle Well range from 2.3 to 4.8 tritium units (TU; one TU = 1 atom ^{3}H per 10^{18} atoms of hydrogen) consistent with modern-day precipitation (Eastoe et al., 2004). Corral Well samples have ^{14}C values of 91 and 94 pmC which could be indicative of recent rainwater, recharge prior to the 1950s, or a mixture of both modern and sub-modern waters; Middle Well data include one slightly higher ^{14}C value of approximately 97 pmC and modern-day ^{14}C value (106 pmC). These data suggest that the shallow aquifer at JI Ranch is likely a mixture of modern and sub-modern waters; with Corral Well perhaps accessing groundwater with slightly longer residence times and a lower proportion of recent recharge than Middle Well. An upper bound on the residence times of the groundwater samples collected from Corral and Middle Wells is given by uncorrected ^{14}C age calculations. The oldest sample from Middle Well has an uncorrected age of roughly 212 years before present (B.P.); the two ^{14}C values from Corral Well indicate maximum groundwater residence times of 446 and 714 years B.P. The relatively low TDIC values, together with depleted $\delta^{13}C$ values suggest that addition of dissolved carbon from detrital marine carbonates is low (**Section 4.3.3**) and that the uncorrected age estimates are the most reasonable. The degree to which pedogenic carbonates (with higher ^{14}C concentrations) are contributing to the TDIC is not known but low TDIC values and undersaturation with respect to calcite suggest that it is probably also low.

4.4.1.2 APACHE LEAP TUFF AQUIFER: Higher concentrations of ^{14}C to the north of the study area (JI Ranch) indicate that groundwater was recharged to the ALT aquifer more recently than the ALT groundwater sampled further to the south (in the Oak Flat and east Devils Canyon areas). Wells completed in the ALT aquifer at JI Ranch (HRES-06 and the House Well) have ^{14}C concentrations of approximately 80 pmC which give uncorrected ages on the order of 1,000 to 2,000 years B.P. (**Table E-1**). These ALT groundwater samples form a group clearly distinct from ALT groundwaters with longer residence times and the shallow aquifers that have much shorter residence times (**Figure 22**).

In the Oak Flat and east Devils Canyon areas, ^{14}C concentrations range from approximately 55 pmC to approximately 67 pmC. These ^{14}C values give uncorrected (and therefore maximum) residence time estimates that range from approximately 3,000 to 5,000 years B.P. (**Figure 22; Table E-1**). Three lines of evidence suggest that ^{14}C age estimates likely have not been substantially impacted by the addition of "dead" carbonate from calcite dissolution and that the uncorrected ages are reasonable:

1. ALT groundwaters are undersaturated with respect to calcite.
2. $\delta^{13}C$ values are depleted although they are slightly heavier than those observed in the shallow alluvial aquifer system ($\delta^{13}C$ values evolve toward 0‰ with the addition of carbon from marine carbonates).
3. If dissolution of mineral carbonate (derived from marine limestone) was controlling TDIC concentrations and ^{14}C values in the ALT aquifer, a strong correlation between ^{14}C and $\delta^{13}C$ would be expected. However, correlation between TDIC concentration and ^{14}C within the ALT aquifer data set is weak (**Figure 23**).

It is important to note that these age estimates do not account for many hydraulic processes that contribute to the residence time distribution within a given aquifer. Residence time estimates based on ^{14}C concentrations are maximum estimates. Tritium levels in samples from the ALT aquifer vary from below detection to as high as 3.3 TU which indicates that groundwaters sampled from the ALT aquifer are a mixture of older and younger waters with different recharge histories and residence times. Such mixing is to be expected in a fractured rock aquifer where rapid preferential flow through fractures is anticipated.

4.4.1.3 DEEP GROUNDWATER SYSTEM: The most reliable sample currently available from the deep groundwater system was collected in November 2008, after a 72-hour constant-rate pumping test at well DHRES-01. The ^{14}C concentration of this sample is 4.9 pmC which gives an uncorrected (maximum) age of 24,876 +/- 1,274 years B.P. However, the chemistry of this sample indicates that it has been impacted by carbonate dissolution (see **Section 4.3.3.3**) and so a correction needs to be applied to the assumed initial ^{14}C activity. If we assume that water recharging the deep groundwater system equilibrated with soil gas with an average $\delta^{13}C$ of -20.3‰ (Bassett et al., 1994) and the observed change in $\delta^{13}C$ is entirely due to dilution of the TDIC with dissolved carbon from dead marine carbonates, the age calculation with the Pearson correction gives approximately 20,000 years B.P. and the Fontes & Garnier correction gives approximately 10,000 years B.P. (see **Appendix E** for explanation of Fontes & Garnier correction). Additional characterization of the deep groundwater system is required to support further interpretation.

4.4.1.4 TRITIUM IN SPRING WATERS: Very low or "dead" tritium values in waters collected from two springs that discharge to Devils Canyon (DC6.1E and DC8.2W; **Table D-5**) support the idea that these springs represent discharge of groundwater from the ALT aquifer. The majority of springs in the Queen Creek drainage and along the Apache Leap escarpment have considerably higher tritium values ranging from 0.9 to 3.4 TU. These values indicate that water from the springs is a mixture of modern and sub-modern waters, potentially with contributions from both groundwater and event-driven surface runoff. An exception to this observation is Blue Spring; tritium is below detection in Blue Spring water which indicates that this spring represents discharge from an aquifer with residence times greater than 50 years.

4.4.2 Uranium Concentration and Uranium-234/Uranium-238

Uranium concentrations are low in the groundwater sampled from all three aquifers in the study area (**Table D-5**). All shallow well samples were below the detection limit of 0.0003 mg/L. In ALT aquifer wells in the Oak Flat area, uranium concentrations range from 0.0006 to 0.0022 mg/L. In the ALT aquifer wells located on the east side of Devils Canyon (A-06 and MJ-11), uranium concentrations in some samples were below the detection limit (<0.0003 mg/L) and others were very close to the detection limit (0.0003 to 0.0004 mg/L). In HRES-06, the ALT aquifer well at JI Ranch, all samples were below the detection limit for uranium. The deep groundwater sample collected from DHRES-01 after the 72-hour pumping test was also below the detection limit. The Devils Canyon spring DC8.2W has uranium concentrations consistent with this spring being a discharge point from the Oak Flat area of the ALT aquifer. No other Devils Canyon samples, either from the channel or from springs, contain uranium at concentrations greater than 0.0003 mg/L. Spring samples in the Queen Creek basin and the Apache Leap/Queen Creek area have variable uranium concentrations ranging from below detection limit (<0.0003 mg/L) to 0.0017 mg/L.

The activities of three naturally-occurring uranium isotopes (^{234}U, ^{235}U, and ^{238}U) were also measured; where data are available, the ratio $^{234}U/^{238}U$ was calculated. This ratio can often be used to identify groundwater source regions and assess mixing of bodies of water with different activity ratios. Due to the low uranium concentrations in the groundwaters that were sampled there is large uncertainty attached to these data and considerable scatter between samples from a given location. **Figure 24** shows $^{234}U/^{238}U$ activity ratios plotted against uranium concentration. On this figure, four samples were plotted that had uranium concentrations below the detection limit but enough uranium activity to calculate activity ratios. In order to include such samples on the plot, they were arbitrarily assigned uranium concentrations at the detection limit (0.0003 mg/L). Based on the current data there does not appear to be a correlation between uranium concentration and activity ratio, nor are there distinct groupings within the data that might suggest discrete groundwater sources within the ALT aquifer (**Figure 24**).

4.4.3 Strontium-87/Strontium-86

Strontium has four naturally-occurring stable isotopes; ^{84}Sr, ^{86}Sr, ^{87}Sr, and ^{88}Sr. The radiogenic isotope, ^{87}Sr, is formed by radioactive decay of rubidium-87 (^{87}Rb) and the concentration of ^{87}Sr is expressed as the ratio of the radiogenic isotope (^{87}Sr) to the stable isotope ^{86}Sr. The current concentration of ^{87}Sr in any given mineral is a function of the initial $^{87}Sr/^{86}Sr$, the initial Rb/Sr ratio, and the age of the mineral. The $^{87}Sr/^{86}Sr$ ratios in groundwater reflect water-rock reaction histories and flow pathways of the waters. Groundwater $^{87}Sr/^{86}Sr$ ratios are inherited from the soil or rock through which groundwater passes and are often useful as a natural tracer of groundwater flow. As water-rock interaction progresses, $^{87}Sr/^{86}Sr$ in groundwater evolves toward the ratio of strontium acquired from the host soil or rock. Generally, carbonates and plagioclase feldspars contain less radiogenic strontium, whereas the highest concentrations are found in potassium-feldspars and micas.

Samples were collected for strontium isotopic composition in order to: 1) identify groundwater entering the ALT aquifer from outside the Apache Leap Tuff outcrop belt, and 2) determine relative contributions from different areas within the ALT aquifer to perennial flow in Devils Canyon. The Schultze Granite is exposed at the surface in the north-eastern portion of the Devils Canyon drainage and into the southwest portion of the neighboring Pinto Creek watershed. Due to the presence of roughly 17 percent potassium feldspar and 4.5 percent biotite (Peterson, 1962), it is expected that any groundwater in equilibrium with the Schultze Granite would have $^{87}Sr/^{86}Sr$ values higher than those exhibited by the ALT groundwater. Similarly, any groundwater in equilibrium with the Paleozoic carbonates to the west is expected to have lower $^{87}Sr/^{86}Sr$ values (roughly 0.708; seawater, and thus marine carbonate, values ranged between 0.7075 and 0.0.7087 from the Pennsylvanian through the Devonian) (Faure, 1986). Such lower $^{87}Sr/^{86}Sr$ values should be easily differentiated from the higher ratios observed in groundwater from the ALT aquifer.

A mixing diagram ($^{87}Sr/^{86}Sr$ vs. 1/Sr) for groundwater samples collected in 2008 is shown on **Figure 25**. All groundwater and surface water samples occupy a relatively narrow range of $^{87}Sr/^{86}Sr$ values with the exception of the deep groundwater sample which is considerably higher. In the ALT aquifer, $^{87}Sr/^{86}Sr$ values range between 0.709882 and 0.710837; strontium concentrations vary between 0.12 and 0.20 mg/L. In the shallow aquifer at JI Ranch strontium concentrations are higher (between 0.27 and 1.00 mg/L) and $^{87}Sr/^{86}Sr$ values lie in the upper end of the ALT aquifer distribution with values ranging between 0.710609 and 0.710693. The other shallow aquifer, sampled at Hackberry Windmill Well, also has higher strontium concentrations (0.24 to 0.29 mg/L); however, the strontium isotope ratios fall just below the range occupied by the ALT aquifer data. Typical $^{87}Sr/^{86}Sr$ values for felsic volcanic rocks range between 0.709 and 0.725 (Faure, 1986), so the ratios observed in samples from the ALT and shallow aquifers are readily explained by interaction with the Apache Leap Tuff and with surficial alluvium that is largely derived from the Apache Leap Tuff. In summary, the strontium data indicate that all groundwater in the ALT aquifer and shallow aquifers have a similar recharge history with respect to strontium. There is no evidence that water that has equilibrated with different units prior to recharge to the ALT aquifer; there is no identifiable signature from the Schultze Granite to the northeast or the Paleozoic carbonates to the west. Due to the relative homogeneity of the strontium signatures within the groundwater, the strontium data have not been useful in the identification of the relative contribution of different areas of the ALT aquifer to perennial flow in Devils Canyon. The deep groundwater sample lies in the same concentration range as the other aquifers with a strontium concentration of 0.61 mg/L; however, the $^{87}Sr/^{86}Sr$ is much higher at 0.716824 (**Figure 25**). This elevated $^{87}Sr/^{86}Sr$ signature is likely due to interaction between the deep groundwater and the older, Cretaceous units that host the aquifer.

In general, the surface water and spring samples are very similar to the ALT aquifer and shallow groundwaters both in strontium concentration and in isotopic composition (**Figure 26**). The upper Devils Canyon surface waters, and the two tributaries to Queen Creek, Number Nine and Oak Flat, are an exception in that they have much lower strontium concentrations, although the $^{87}Sr/^{86}Sr$ values lie within the groundwater range. This is indicative of simple dilution by precipitation-driven runoff; there is no evidence that there is a component of surface flow that is contributing strontium from a different source. Another exception is the isotopic composition of the water sampled at Blue Spring along Arnett Creek; the $^{87}Sr/^{86}Sr$ is higher than that observed in the ALT and shallow groundwater signatures (**Figure 26**). This elevated isotopic signature may be due to interaction of the spring water with the Precambrian rocks that occur in the vicinity of Blue Spring. Strontium concentrations and $^{87}Sr/^{86}Sr$ ratios for Kane Spring and Hidden Spring, located along the Apache Leap escarpment, lie within the field delineated by ALT aquifer data (**Figure 26**). However, both the springs issue from Paleozoic carbonates which would be expected to impart higher strontium concentrations and lower $^{87}Sr/^{86}Sr$ ratios to groundwater. These data suggest that a substantial proportion of the subsurface residence time of these waters has been spent in contact with another unit or units besides the Paleozoic carbonates.

4.5 DISCUSSION

Characterization of the hydrochemical and isotopic composition of the ALT aquifer and associated groundwater and surface water features is an important element of the effort to refine the current understanding of groundwater movement within the ALT aquifer. Hydrochemical data, in conjunction with groundwater level monitoring, help identify principal sources of groundwater recharge and pathways for groundwater discharge to/from the ALT aquifer and adjacent aquifers. They also provide a tool for assessing the connectivity within the ALT aquifer, and between the ALT aquifer and adjacent aquifers. In addition, periodic monitoring of groundwater quality for aquifers in the study area establishes a water quality baseline to be used to identify changes and assess potential impacts from proposed mining activities. Salient results from the hydrochemical monitoring program to date are discussed below:

1. Shallow aquifers in the Upper Queen Creek/Devils Canyon study area are recharged by local precipitation, although in the JI Ranch area, additional recharge from seepage of septic system effluent and livestock watering may occur. Residence times are short in the shallow alluvial system located in Hackberry Canyon, on the order of less than 5 to perhaps as much as 50 years. Residence times are longer at JI Ranch varying from less than 50 years to as long as 700 years in the deeper part of the shallow aquifer hosted in the upper weathered portion of the Apache Leap Tuff.

2. Water quality in the shallow aquifers is variable with locally elevated TDS, sulfate, chloride and nitrate potentially due to anthropogenic activities such as livestock watering, residential septic effluent, and historic mining and mineral processing activities in the region (dry fall). Based on chemical and isotopic data there does not appear to be direct, fast-path communication between the shallow aquifers and the underlying ALT aquifer.

3. Available long-term water level data indicate that the ALT aquifer is largely recharged by infiltration of runoff from precipitation events through focused fracture-flow along principal drainage ways.

4. Residence times in the ALT aquifer vary from 1000 to 2000 years at JI Ranch to the north to 3,000 to 5,000 years down-gradient in Oak Flat and east side Devils Canyon areas. There is no evidence of systematic residence-time variation from east to west, as groundwater from Oak Flat and east Devils Canyon wells are of similar ages.

5. In general, the ALT aquifer is relatively chemically and isotopically homogeneous and there is no evidence of water entering the aquifer from adjacent areas through other units such as the Paleozoic carbonates to the west or the Tertiary-Cretaceous Schultze Granite to the northeast. However, groundwater composition does vary with

depth becoming more sodium-rich in the deeper portions of the ALT aquifer.

6. The ALT aquifer discharges to springs and supports base flow in the perennial reach of Devils Canyon. Results from multiple hydrochemical and isotopic data sets support this conclusion.

7. The ALT aquifer also appears to discharge to springs and support surface water flow in the Mineral Creek drainage. Hydrochemical characterization of springs and surface water in the Mineral Creek drainage is ongoing; however, preliminary data support this idea.

8. The deep groundwater system has not been fully characterized. However, based on result from one sample indicate that residence times are much longer than in the ALT aquifer, perhaps on the order of 10,000 to 20,000 years. Composition of stable isotopes suggests that this groundwater system could represent recharge from a different area and/or under different climatic conditions.

9. Due to low uranium concentrations in groundwater and surface waters sampled in the study area, analysis of isotopic ratios of uranium was not useful as a hydrochemical mapping tool in this study area.

10. Results of strontium isotope analyses indicate that strontium isotope ratios are relatively homogeneous within both groundwater and surface water systems, and do not provide a useful method for differentiation of groundwater flow paths or groundwater/surface water interaction in this study area.

5.0 RECOMMENDATIONS

Based on review and analysis of results of the 2004-2009 RCM groundwater monitoring program, M&A has the following recommendations:

1. Quarterly groundwater level monitoring should continue for all shallow aquifer and ALT aquifer wells. Although all wells are equipped with transducers and dataloggers, it is important to continue manual measurements and data downloads on a quarterly basis to ensure proper datalogger function and to maintain the quality of the water level database. Continuous groundwater level monitoring using automated equipment should continue for wells and boreholes completed in the deep groundwater system.

2. M&A recommends that hydrochemical sampling from shallow aquifer and ALT aquifer wells be suspended until the 2010 drilling program is complete. As new wells are added to the RCM hydrologic monitoring system, an initial groundwater sample should be collected during aquifer testing at each well. Once the new HRES-series wells are completed, a comprehensive sampling round should be conducted that includes all project monitor wells equipped for sampling.

   The analytical suite should include:

   - Routine Parameters and Common Constituents
   - Trace Constituents
   - Radiological Constituents
   - Deuterium and oxygen-18 in water
   - Sulfur-34 and oxygen-18 in dissolved sulfate
   - Carbon-13
   - Carbon-14
   - Tritium

3. Based on results of the comprehensive sampling round and assessment of project needs, reactivation of a groundwater sampling program may be recommended or required.

4. At well HRES-08, hydraulic testing will be conducted once water levels stabilize in the lower part of the well. After testing, the lower part of the well should be abandoned or isolated, and a permanent pump should be installed for testing and sampling of the ALT aquifer at this location.

5. Surface water inventories should continue in Devils Canyon and upper Queen Creek drainages. Interpretation of surface water chemistry data with respect to conceptual understanding of groundwater/surface water interaction, and with respect to baseline sampling in support of the EIS, is ongoing and will be presented in a future surface water report. Once baseline assessment is complete M&A will provide a recommendation regarding further required surface water sampling.

6. Surface water inventories and hydrochemical sampling, including the extended analytical suite, should continue as presently scoped for springs and surface water in the Mineral Creek drainage. In addition, samples should be obtained from Government Springs to document this potential input to Mineral Creek surface water flow and subflow.

7. Continued efforts should be made to obtain representative hydrochemical samples for the deep groundwater system, both from the two existing deep hydrologic test wells (DHRES-01 and DHRES-02) and from proposed future deep hydrologic test wells. Present understanding is based principally on one sample from DHRES-01, and as such, our understanding of the potential hydraulic connection between the ALT aquifer and deep groundwater system is very limited. Preliminary results of deep groundwater characterization will be provided in a technical memorandum (in preparation) along with recommendations on potential approaches for obtaining additional groundwater samples from the deep groundwater system.

8. M&A and RCM have developed recommendations for installation of additional hydrologic characterization wells for the Upper Queen Creek/Devils Canyon study area. Proposed wells include 7 wells completed in the ALT aquifer, 5 wells in the deep groundwater system, and 1 well in the Whitetail Conglomerate. Hydrogeologic data obtained from these wells will be important for continued refinement of the conceptual hydrogeologic model for the integrated shallow, ALT and deep groundwater system. Proposed wells are shown on **Figure 27**.

9. In addition to hydrologic test wells proposed above, two additional ALT aquifer wells are recommended for installation on State of Arizona land in the southeast part of the study area. Purpose of these two additional wells is to evaluate aquifer conditions in the ALT aquifer between Mineral Creek and the Devils Canyon basin. Proposed wells HRES-Q and HRES-Y are shown on **Figure 27**. Data obtained from these wells will be important for evaluating groundwater discharge from the ALT aquifer to Mineral Creek, and identify other potential sources of groundwater discharge to Mineral Creek.

6.0 REFERENCES CITED

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TABLE 1. YEAR 2008/2009 GROUNDWATER MONITORING LOCATIONS
UPPER QUEEN CREEK/DEVILS CANYON STUDY AREA
RESOLUTION COPPER MINING LLC
PINAL COUNTY, ARIZONA

WELL IDENTIFIER	CONTINUOUS WATER LEVEL MEASUREMENT (DATALOGGER)	QUARTERLY WATER LEVEL MEASUREMENT (MANUAL)	QUARTERLY HYDROCHEMICAL SAMPLING
SHALLOW AQUIFERS			
Middle Well (JI Ranch)	X	X	X
Corral Well (JI Ranch)	X	X	X
Hackberry Windmill	X	X	X
APACHE LEAP TUFF AQUIFER			
HRES-01	X	X	
HRES-02	X	X	
HRES-03	X	X	
HRES-04	X	X	X
HRES-05	X	X	X
HRES-06	X	X	X
HRES-07	X	X	X
HRES-08	X	X	
Oak Flat Well	X	X	
A-06	X	X	X
MJ-11	X	X	X
DEEP AQUIFER			
RES-03	X	NA[a]	
DHRES-01	X	NA[a]	X[b]
DHRES-02	X	NA[a]	
SHAFT No. 9	X	NA[a]	X[c]
SHAFT No. 3	X	NA[a]	

[a] NA = not available; manual water levels obtained at time of transducer install only
[b] Hydrochemical samples obtained after 72-hour pumping test at well DHRES-01
[c] Hydrochemical samples obtained periodically from Shaft No. 9 dewatering system discharge

TABLE 2. SUMMARY OF CONSTRUCTION DETAILS FOR SELECTED WELLS AND BOREHOLES
GROUNDWATER MONITORING PROGRAM, RESOLUTION COPPER MINING LLC
PINAL COUNTY, ARIZONA

				……….BOREHOLE……….		…………………..CASING………………..			………..SURVEY COORDINATES[b]……….		
WELL IDENTIFIER	CADASTRAL LOCATION	WELL REGISTRATION NUMBER	DATE COMPLETED	BOREHOLE DIAMETER (inches)	BOREHOLE DEPTH (meters, bls)[a]	DIAMETER (inches)	DEPTH (meters, bls)	PERFORATED INTERVAL (meters, bls)	NORTHING (meters)	EASTING (meters)	SURFACE ELEVATION (meters, amsl)[c]
SHALLOW ALLUVIAL AQUIFER											
Corral Well	(D-1-13) 14DBD	55-609685	1980	NA NA	NA 25.3	8 no casing	0 - 3.0 3.0 - 25.3	--- 3.0 - 25.3[d]	3688841.14	499376.98	1352.0
Middle Well	(D-1-13) 14DBD	NA	NA	NA NA	NA 16.2	8 4	NA 0 - 16.2	--- 0.3 - 16.2	3688777.76	499349.39	1354.2
Hackberry Windmill	(D-2-13) 08ACB	55-615244	NA	NA	13	5 1/2	0 - 13.0	NA	3681543.64	496326.28	1186.6
APACHE LEAP TUFF AQUIFER											
HRES-01	(D-1-13) 32BCA	55-201852	14-Feb-2004	17 1/2 9	0 - 5.8 5.8 - 574.5	12 4	0 - 5.8 0 - 486.9	--- 321.5 - 328.1 414.4 - 427.7 480.8 - 486.9	3684732.34	493714.75	1271.7
HRES-02	(D-1-13) 32DCA	55-201850	21-Feb-2004	17 1/2 9	0 - 5.8 5.8 - 483.8	12 4	0 - 5.8 0 - 399.3	--- 199.9 - 206.6 312.7 - 319.4 383.8 - 399.3	3683886.30	494479.32	1214.3
HRES-03	(D-1-13) 28DDB	55-201851	28-Feb-2004	17 1/2 9	0 - 5.8 5.8 - 645.0	12 4	0 - 5.8 0 - 457.2	--- 103.2 - 121.3[e] 443.9 - 457.2	3685330.96	496379.29	1241.4
HRES-04	(D-1-13) 33CCD	55-201849	5-Mar-2004	17 1/2 9	0 - 5.8 5.8 - 532.5	12 4	0 - 5.8 0 - 438.9	--- 178.1 - 190.3 220.8 - 233.0 391.4 - 397.5 432.6 - 438.9	3683616.17	495322.30	1243.5
HRES-05	(D-2-13) 05CCB	55-201848	11-Mar-2004	17 1/2 9	0 - 5.8 5.8 - 349.6	12 4	0 - 5.8 0 - 321.6	--- 117.3 - 129.5 178.3 - 184.4 309.4 - 315.5	3682274.63	495523.29	1218.3
HRES-06	(D-1-13) 14DBC	55-214967	12-Apr-2007	17 1/2 9	0 - 5.5 5.5 - 457.2	12 4	0 - 5.5 0 - 243.8	--- 103.6 - 243.8	3688855.46	499198.67	1350.3
HRES-07	(D-2-13) 08AAA	55-907947	16-Nov-2007	14 3/4 8 3/4	0 - 6.0 6.0 - 325.5	10 4	0 - 6.0 0 - 317.3	--- 102.1 - 228.3 247.5 - 310.6	3681952.96	496851.23	1223.3
HRES-08	(D-2-13) 08CBB	55-907946	28-Nov-2007	14 3/4 8 3/4	0 - 6.0 6.0 - 443.5	10 4	0 - 6.0 0 - 311.5	--- 59.1 - 90.5 241.6 - 304.8	3680752.81	495620.02	1232.7
Oak Flat Well	(D-1-13) 29DCC	55-526592	28-Apr-1990	19 12 1/4 9 1/2	0 - 6.1 6.1 - 337.7 337.7 - 522.1	14 10 3/4 no casing	0 - 6.1 0 - 337.7 337.7 - 522.1	--- 122.2 - 131.7 337.7 -522.1[f]	3685360.33	496371.67	1241.8
A-06	(D-2-13) 04BBD	55-615241	1976	NA 8	NA 353.6	8 no casing	0 - 3.0 3.0 - 353.6	--- 3.0 - 353.6[d]	3683231.67	497365.71	1269
MJ-11	(D-2-13) 09ABD	55-615246	1970	NA 6	NA 239.3	6 no casing	0 - 3.1 3.1 - 239.2	--- 3.1 - 239.3[d]	3681789.24	498075.79	1193

TABLE 2. SUMMARY OF CONSTRUCTION DETAILS FOR SELECTED WELLS AND BOREHOLES
GROUNDWATER MONITORING PROGRAM, RESOLUTION COPPER MINING LLC
PINAL COUNTY, ARIZONA

				……….BOREHOLE……….		…………………..CASING………………..			………..SURVEY COORDINATES[b]……….		
WELL IDENTIFIER	CADASTRAL LOCATION	WELL REGISTRATION NUMBER	DATE COMPLETED	BOREHOLE DIAMETER (inches)	BOREHOLE DEPTH (meters, bls)[a]	DIAMETER (inches)	DEPTH (meters, bls)	PERFORATED INTERVAL (meters, bls)	NORTHING (meters)	EASTING (meters)	SURFACE ELEVATION (meters, amsl)[c]
DEEP AQUIFER											
RES-03	NA	NA	NA	NA	1129	4 1/2	0 - 1102 1102 - 1129	--- 1102 - 1129[d]	3683706.56	494493.90	1215.4
DHRES-01	(D-1-13) 33CCD	55-217406	23-Jun-2008	19 12 1/2 12 1/4 6 3/4	0 - 7.5 7.5 - 202.7 202.7 - 1383.2 1383.2 - 1834.3	14 7 5/8 4 1/2	0 - 7.5 0 - 1383.8 1348.7 - 1829.4	--- --- --- 1460 - 1517 1616 - 1672 1704 - 1712 1772 - 1809	3683612.63	495319.69	1241.9
DHRES-02	(D-1-13) 32DBD	55-217407	11-Sep-2008	19 12 1/4 6 1/8 6	0 - 12.2 12.2 - 1015.0 1015.0 - 1714.5 1714.5 - 2046.1	14 7 5/8 4 1/2	0 - 12.2 0 - 1013.5 975.4 - 1998.0	--- --- 1069 - 1138 1800 - 1831 1960 - 1991	3684037.29	494513.47	1211.4
SHAFT No. 9	NA	---	1970	---	NA	---	1447.8	---	3684887.6	493697.6	1277.11
SHAFT No. 3	NA	---	NA	---	NA	---	1493.52	---	3684929.17	491380.71	1046.45
BASIN-FILL DEPOSITS AQUIFER - SUPERIOR BASIN											
DHRES-03	(D-1-12) 35BCD	55-910437	15-Feb-2009	12 1/4 6 3/4 6 1/2	0 - 12.2 12.2 - 251.5 251.5 - 598.0	7 5/8 3	0 - 11.9 0 - 590.8	--- ---	3684348.67	490073.08	921.1
DHRES-04	(D-1-12) 35BCD	55-218676	28-Feb-2009	19 12 1/4 6 1/2	0 - 12.2 12.2 - 462.7 462.7 - 713.2	14 7 5/8 4 1/2	0 - 12.2 0 - 458.6 436.7 - 713.2	--- --- 539.5 - 706.7	3684343.91	490094.91	921.1
DHRES-05	(D-1-12) 34DBC	55-218677	5-Mar-2009	17 12 1/4 6 3/4	0 - 6.1 6.1 - 348.1 348.1 - 920.8	14 7 5/8 4 1/2	0 - 6.1 0 - 347.1 335.3 - 920.7	--- --- 496.3 - 721.4 862.8 - 888.5	3683951.42	488957.20	847.0

[a] bls = below land surface
[b] Universal Transverse Mercator Zone 12 North, North American Datum 1927
[c] amsl = above mean sea level
[d] open borehole
[e] annular piezometer
[f] formally abandoned

NA = not available
--- = not applicable

TABLE 3. SUMMARY OF ANALYTICAL SUITE FOR GROUNDWATER AND SURFACE WATER SAMPLING, RESOLUTION COPPER MINING LLC PINAL COUNTY, ARIZONA

Routine Parameters		
pH	Temperature	
Electrical Conductivity (EC)	Total Dissolved Solids (TDS)	
Common Constituents		
Calcium (Ca)	Sulfate (SO_4)	
Magnesium (Mg)	Silica (SiO_2)	
Sodium (Na)	Bromide (Br)	
Potassium (K)	Fluoride (F)	
Chloride (Cl)	Nitrate (NO_3)	
Carbonate (CO_3)	Nitrite (NO_2)	
Bicarbonate (HCO_3)		
Trace Constituents		
Aluminum (Al)	Cobalt (Co)	Manganese (Mn)
Antimony (Sb)	Copper (Cu)	Nickel (Ni)
Arsenic (As)	Cyanide (CN)	Selenium (Se)
Barium (Ba)	Iron (Fe)	Silver (Ag)
Beryllium (Be)	Lead (Pb)	Sulfide (S)
Boron (B)	Mercury (Hg)	Thallium (Tl)
Cadmium (Cd)	Molybdenum (Mo)	Zinc (Zn)
Chromium (Cr)		
Radiological Consituents		
Gross Alpha	Radium-226 (Ra-226)	Uranium (U)
Gross Beta	Radium-228 (Ra-228)	
Stable Isotopes		
Oxygen-18 ($\delta^{18}O$) in water	Carbon-13 ($\delta^{13}C$) in dissolved inorganic carbon	Oxygen-18 in dissolved sulfate ($\delta 18O_{SO4}$)
Deuterium ($\delta^{2}H$) in water	Sulfur-34 ($\delta^{34}S$) in dissolved sulfate	
Radioisotopes		
Tritium (^{3}H)	Strontium (Sr)	Uranium-234 (^{234}U)
Carbon-14 (^{14}C)	Strontium-87/Strontium-86 ($^{87}Sr/^{86}Sr$)	Uranium-235 (^{235}U) Uranium-238 (^{238}U)

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TABLE 4. SUMMARY OF SURFACE WATER AND SPRING SAMPLE STATIONS
RESOLUTION COPPER MINING LLC
PINAL COUNTY, ARIZONA

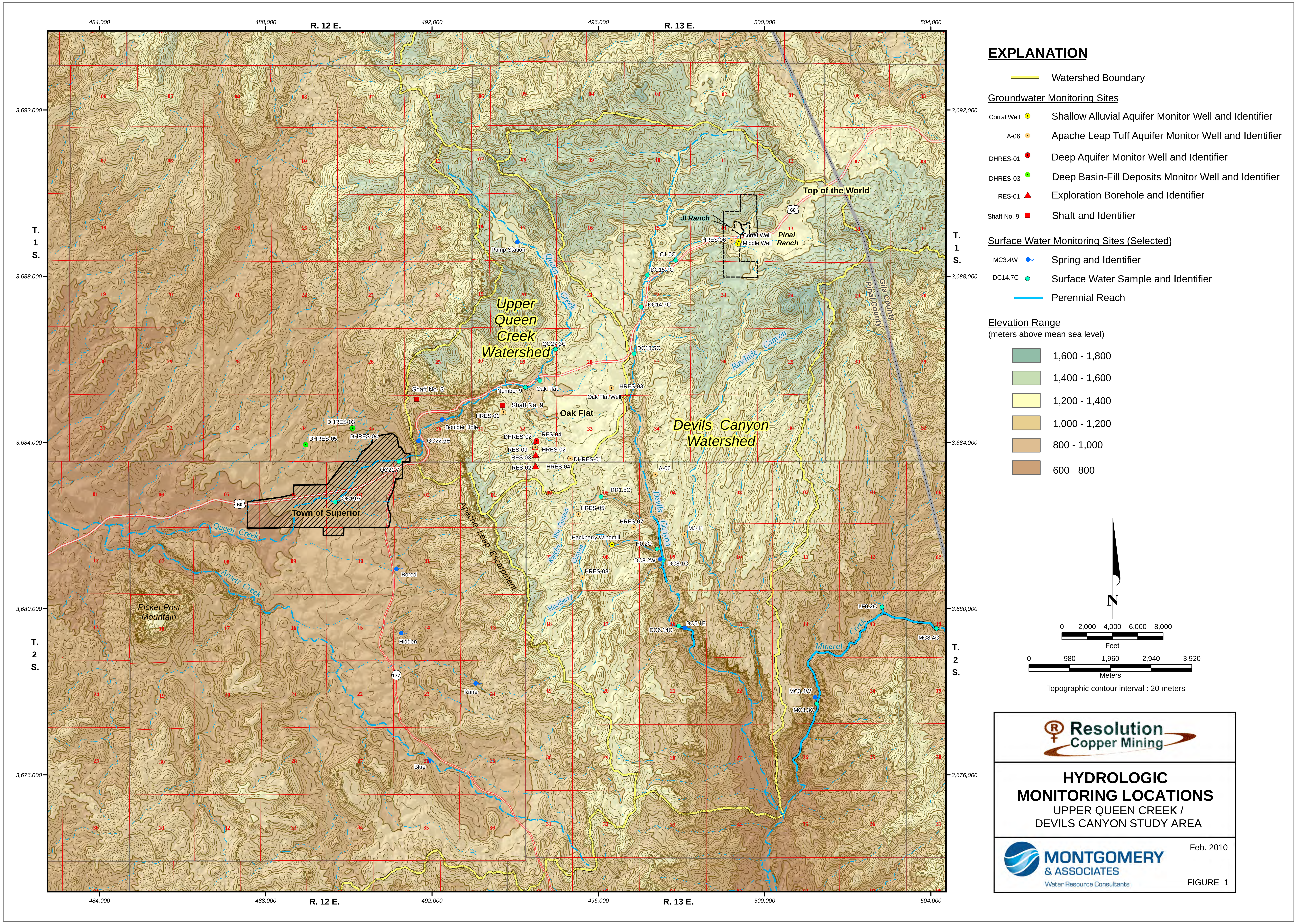
STATION IDENTIFIER	UTM COORDINATES[a] EASTING (meters)	NORTHING (meters)	APPROXIMATE ELEVATION (meters, amsl)[b]	TYPE	LOCATION
DEVILS CANYON WATERSHED					
DC 15.5 C	497,181	3,688,022	1,244	Reach	channel - bedrock with pools immediatlely above confluence with Iron Canyon
IC 1.0 C (Iron Canyon)	497,860	3,688,383	1,280	Reach	Small bedrock nick point. Drainage on northside of US 60 ~ 30 meters upstream of small parking area on south side of highway
DC 14.7 C /US 60 Bridge	497,035	3,687,263	1,219	Reach	Devils Canyon at US 60 Bridge
DC 13.5 C	496,860	3,686,136	1,189	Reach	channel
RR 1.5 C	496,066	3,682,698	1,183	Reach	Approximately 100 meters downstream from parking area (that's just beyond breached stock tank)
H 0.1 C	497,410	3,681,438	1,097	Reach	Approximately 20 meters upsteam of large pool ("hackberry pool")
DC 8.2 W	497,540	3,681,190	1,079	Spring	~ 1 meter above main channel on west bank
DC 8.1 C	497,565	3,681,168	1,073	Reach	Pool approximately 75 meters downstream of DC8.2W - Nice outcrop on eastbank (river left) to mount sonde
DC 6.14 C	497,932	3,679,581	1,000	pool/reach	First Crater Tank
DC 6.1 E	498,130	3,679,540	963	Spring	Hanging Garden emanating from Apache Leap
APACHE LEAP ESCARPMENT					
Bored Spring	491,192	3,680,961	878	Spring	Small drainage immediately east of AZ highway 177 - sample from pipe disharging into cement trough
Hidden Spring	491,312	3,679,413	927	Spring	Below Apache Leap
Kane Spring	493,099	3,678,202	963	Spring	Below Apache Leap
Blue Spring	491,980	3,676,333	899	Spring	Arnett Creek Channel
UPPER QUEEN CREEK WATERSHED					
Pump Station	494,104	3,688,819	1,338	Spring	channel
QC 27.3 C (Upper QC)	494,970	3,686,239	1,204	Reach	intermittent channel - slot/incised portion of canyon
Oak Flat	494,590	3,685,490	1,172	Reach	Sandy bottom reach with bedrock coming down to creek on southside (river left) (~75 meters above confluence with QC)
Number Nine	494,248	3,685,326	1,146	Reach	Bedrock pool drops visible from US 60 (~50 meter above confluence with QC)
Boulder Hole	492,297	3,684,549	933	Seep	channel
QC 22.6 E (Karst Spring)	491,722	3,684,033	896	Spring	Solution void in limestone on east bank of creek (~3 meters from channel) - immediately upstream of old highway bridge
QC 21.7 C (Magma Avenue)	491,204	3,683,540	867	Reach	Approximately 100 meters upstream of Magma Avenue Bridge. Approximately 30 meters downstream from large boulder on river left and 10 meters upstream of powerlines crossing channel

TABLE 4. SUMMARY OF SURFACE WATER AND SPRING SAMPLE STATIONS
RESOLUTION COPPER MINING LLC
PINAL COUNTY, ARIZONA

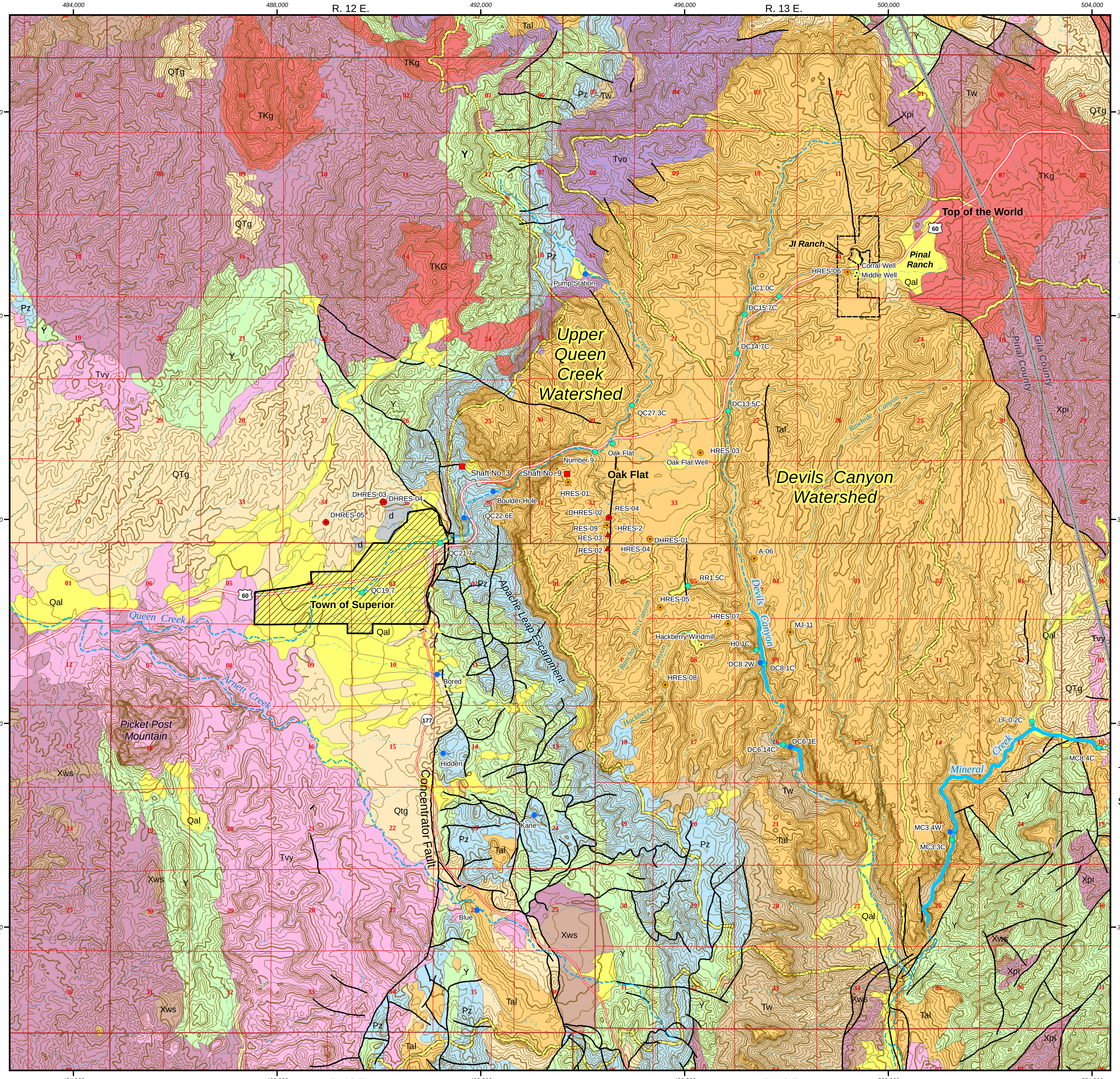
STATION IDENTIFIER	UTM COORDINATES[a] EASTING (meters)	NORTHING (meters)	APPROXIMATE ELEVATION (meters, amsl)[b]	TYPE	LOCATION
LOWER QUEEN CREEK WATERSHED					
QC 19.7 C (Queen above Magma Wash)	489,674	3,682,567	817	Reach	Along high cut bank on river left
MINERAL CREEK WATERSHED					
MC 8.4 C (Mineral Creek ("Ranch Fork") Headwaters Spring)	504,135	3,679,521	878	Spring	First Apache Leap pinch point along drainage with Government Ranch (Mineral Creek)
LF 0.2 C (Lyons Fork Headwater Spring)	502,820	3,680,039	859	Spring	Lyons Fork Spring - Approximately 100 meters above confluence with Mineral Creek
MC 3.3 C	501,254	3,677,715	766	Reach	Approximately 3/4 of ways down perennial reach - in bedrock channel immediately upstream of first outcrop of vitrophere
MC 3.4 W (Wet Leg Spring)	501,266	3,677,866	810	Spring	Largest Spring emenating from river right

REFERENCE: Golder Associates Inc., 2009, **Third and fourth quarters 2008 - surface water monitoring results:** Prepared for Resolution Copper Mining LLC, March 12, 2009

[a] Universal Transverse Mercator 1927 North American Datum Zone 12 North
[b] amsl = above mean sea level



\GIS-Tuc\Projects\605\605.5\SITE_LOCATION_March2009.mxd\16Feb2010



EXPLANATION

Watershed Boundary

Groundwater Monitoring Sites

- Corral Well — Shallow Alluvial Aquifer Monitor Well and Identifier
- A-06 — Apache Leap Tuff Aquifer Monitor Well and Identifier
- DHRES-01 — Deep Aquifer Monitor Well and Identifier
- DHRES-03 — Deep Basin-Fill Deposits Monitor Well and Identifier
- RES-01 — Exploration Borehole and Identifier
- Shaft No. 9 — Shaft and Identifier

Surface Water Monitoring Sites (Selected)

- MC3.4W — Spring and Identifier
- DC14.7C — Surface Water Sample and Identifier
- Perennial Reach

Geologic Units

d	Disturbed Surficial Deposits
Qal	Quaternary Alluvial Deposits
QTg	Quaternary-Tertiary Basin-Fill Deposits
Tvy	Tertiary Younger Volcanic Rocks
Tal	Tertiary Apache Leap Tuff
Tvo	Tertiary Older Volcanic Rocks
Tw	Tertiary Whitetail Conglomerate
TKg	Cretaceous-Tertiary Intrusive Rocks
Pz	Paleozoic Sedimentary Rocks
Y	Younger Precambrian Sedimentary, Volcanic, and Intrusives Rocks
Xws	Willow Spring Granodiorite
Xpi	Older Precambrian Pinal Schist

Geologic Fault

0 2,000 4,000 6,000 8,000
Feet

0 930 1,860 2,790 3,720
Meters

Topographic contour interval : 20 meters

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GEOLOGIC UNITS

UPPER QUEEN CREEK / DEVILS CANYON STUDY AREA

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FIGURE 2

Geology generalized from Spencer, Richard, and Pearthree (compilers) 1996 and 1998, and Spencer (compiler) 1998.

\GIS-Tuc\Projects\605\605.5\GeologyMap_2009.mxd\15Feb2010

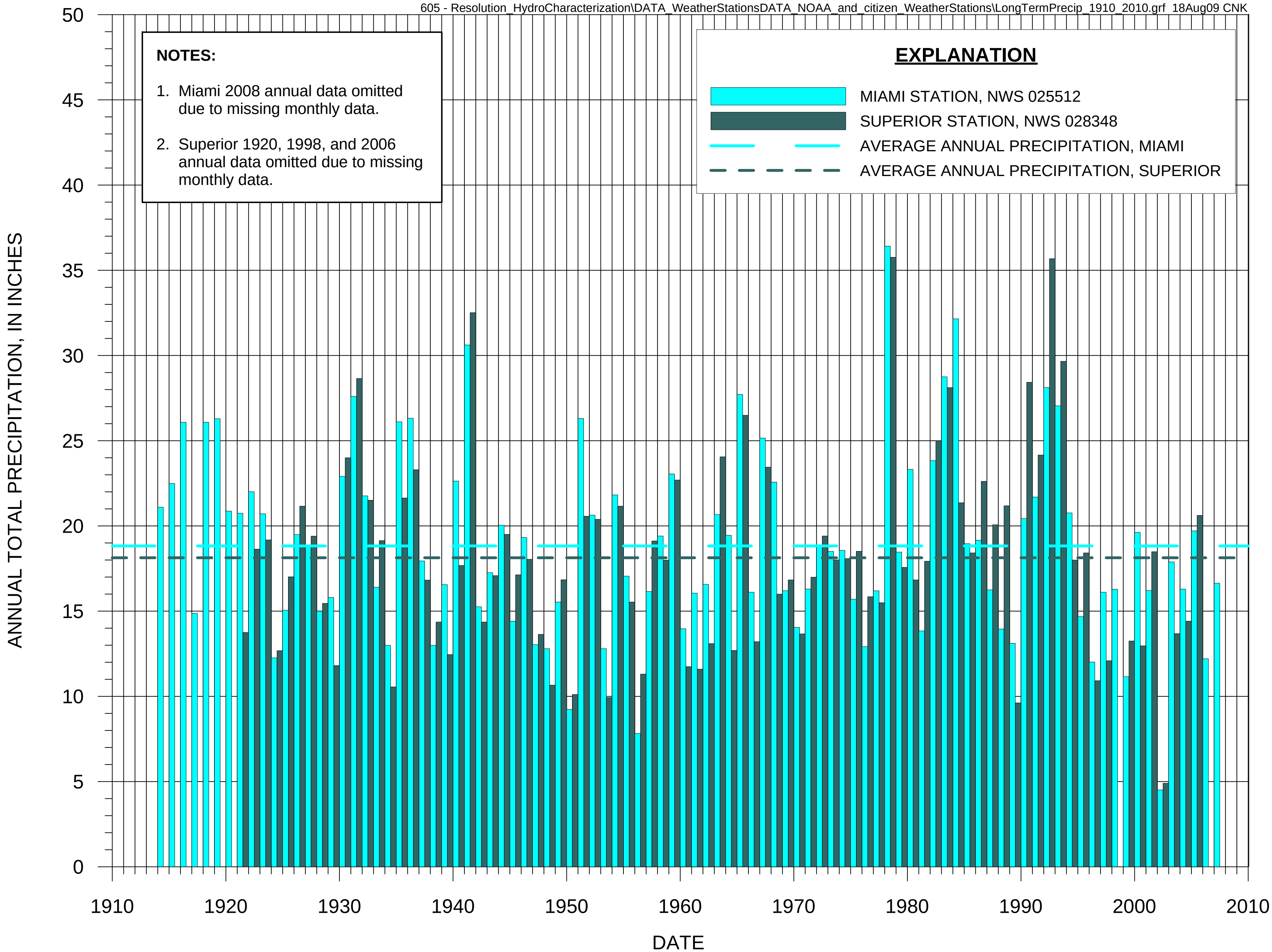

FIGURE 3. ANNUAL TOTAL PRECIPITATION, MIAMI AND SUPERIOR, ARIZONA

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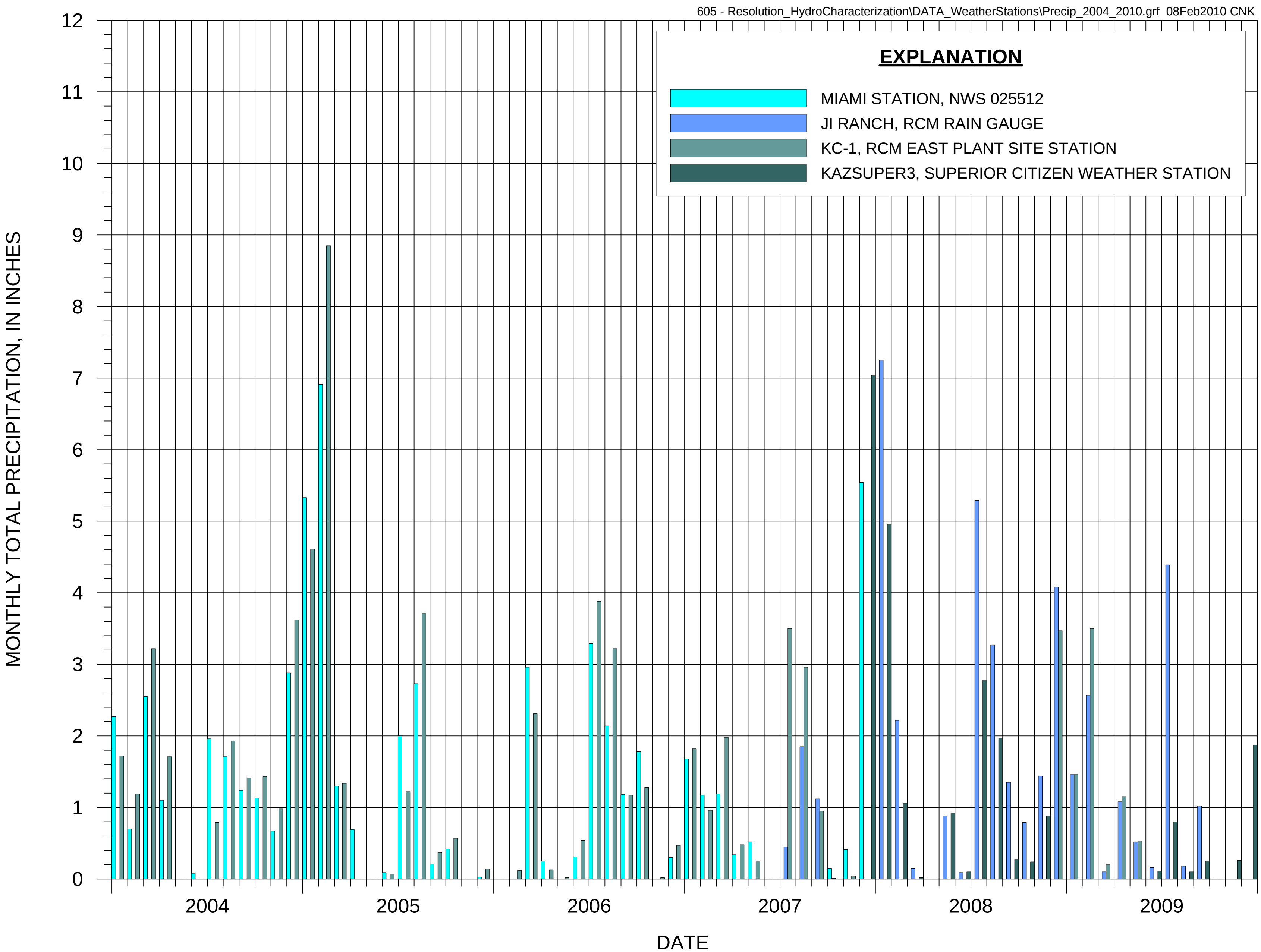

FIGURE 4. MONTHLY TOTAL PRECIPITATION RECORDED BY WEATHER STATIONS IN THE VICINITY OF OAK FLAT, PINAL AND GILA COUNTIES, ARIZONA

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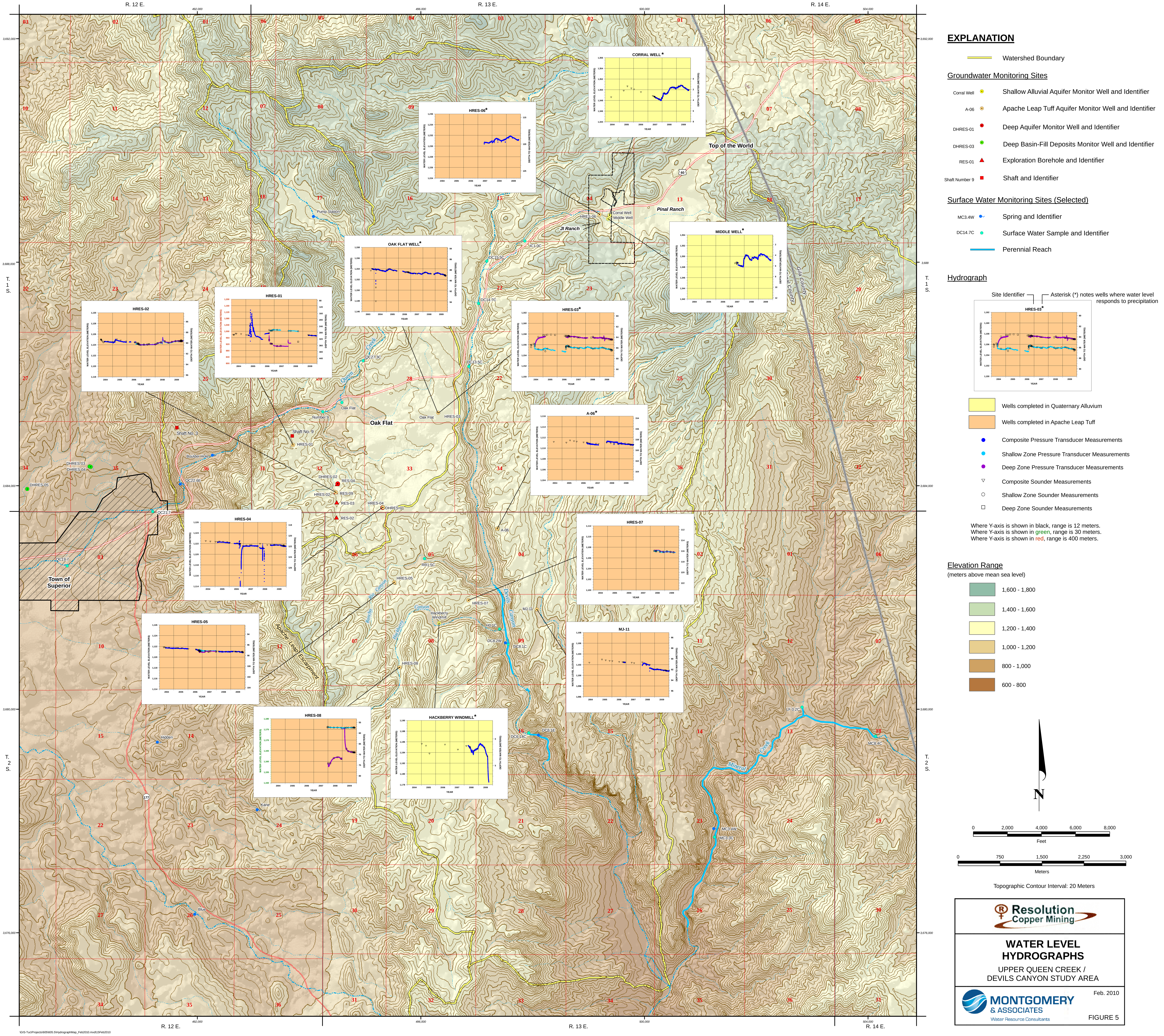

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WATER LEVEL HYDROGRAPHS

UPPER QUEEN CREEK / DEVILS CANYON STUDY AREA

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FIGURE 5

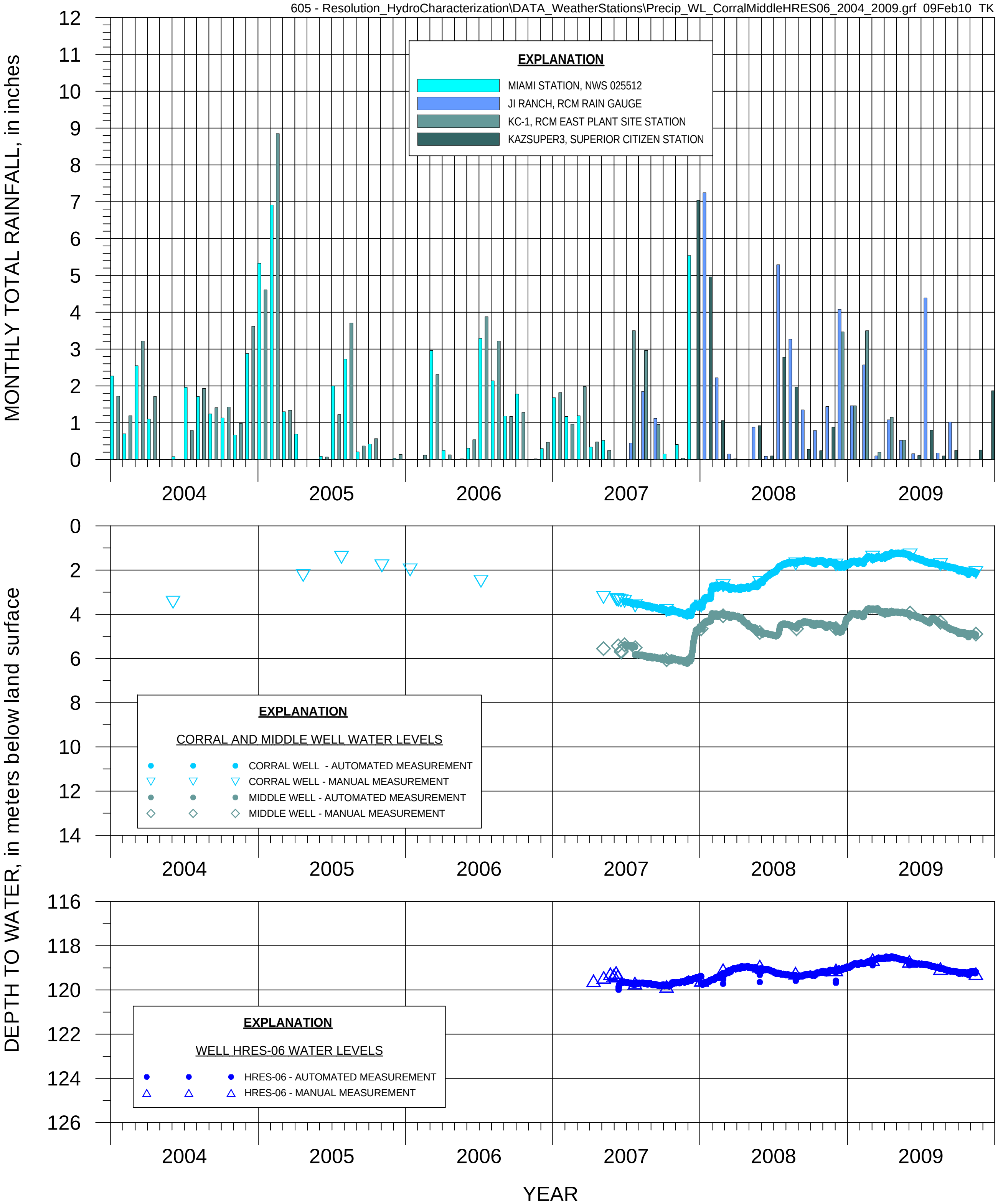

FIGURE 6. MONTHLY TOTAL PRECIPITATION, AND WATER LEVEL HYDROGRAPHS FOR CORRAL WELL, MIDDLE WELL AND WELL HRES-6, YEARS 2004 THROUGH 2009

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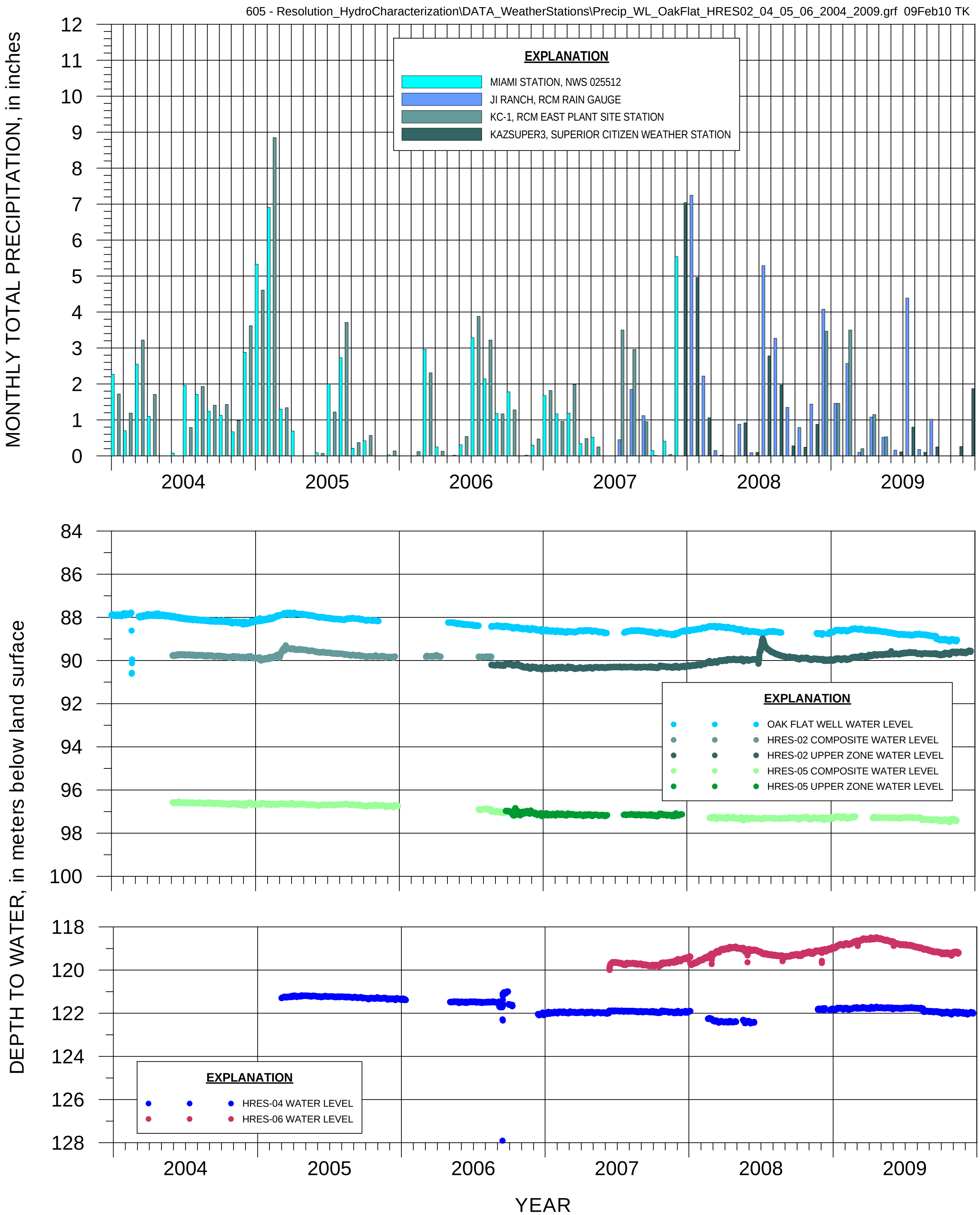


FIGURE 7. MONTHLY TOTAL PRECIPITATION, AND WATER LEVEL HYDROGRAPHS FOR OAK FLAT WELL, AND WELLS HRES-02 HRES-04, HRES-05, AND HRES-06, YEARS 2004 THROUGH 2009

MONTGOMERY & ASSOCIATES

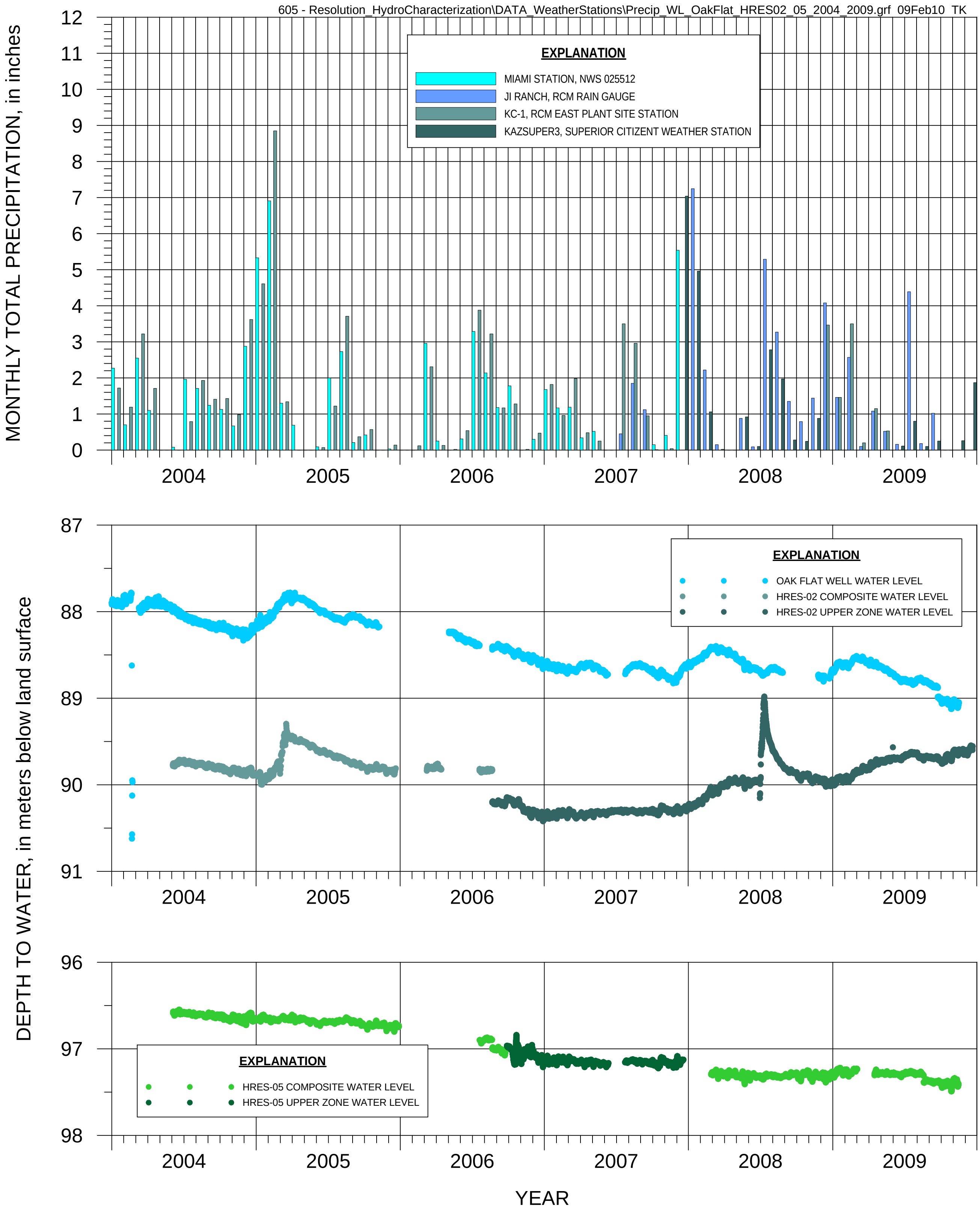
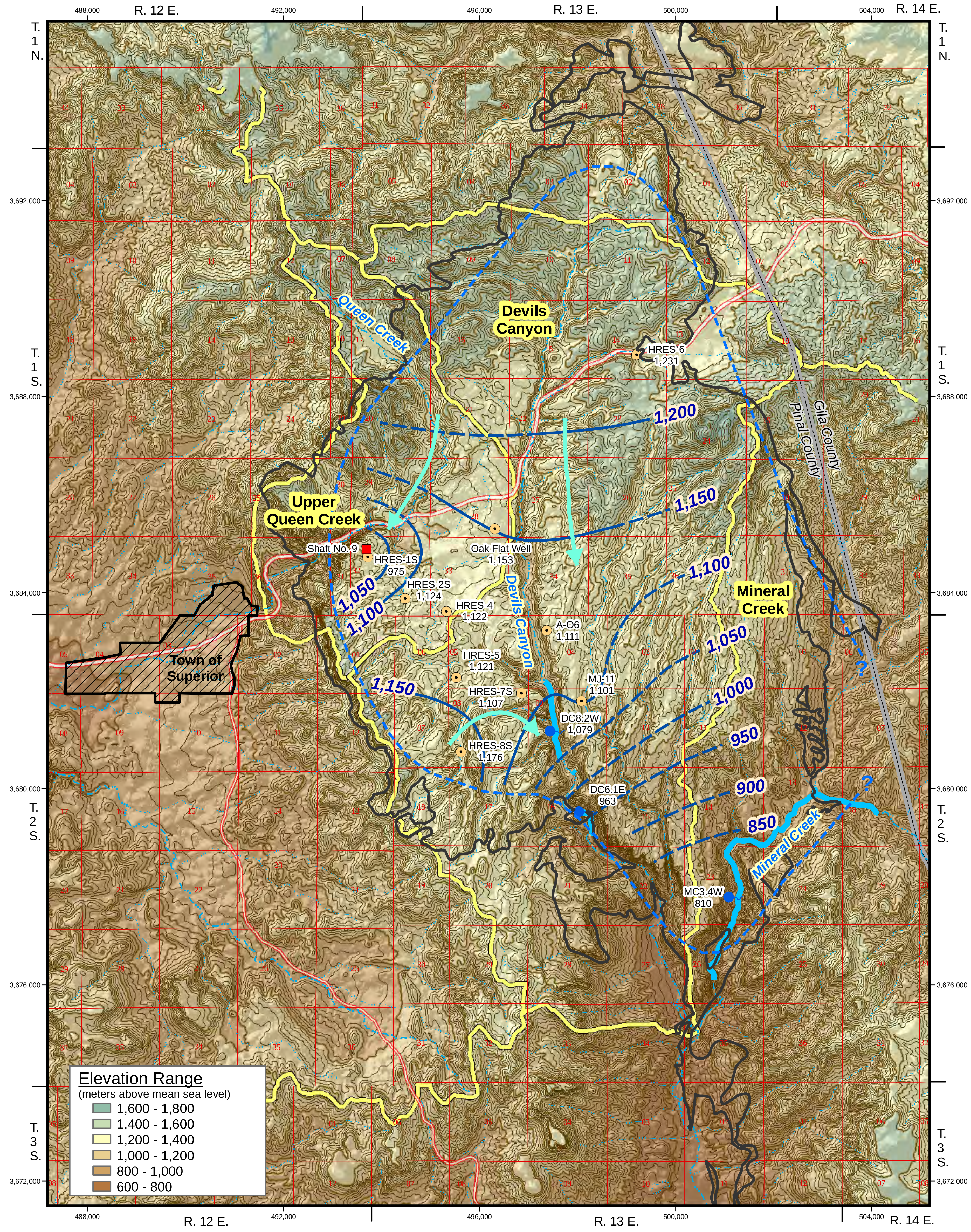


FIGURE 8. MONTHLY TOTAL PRECIPITATION, AND WATER LEVEL HYDROGRAPHS FOR OAK FLAT WELL, AND WELLS HRES-02 AND HRES-05, YEARS 2004 THROUGH 2009

MONTGOMERY & ASSOCIATES



EXPLANATION

- HRES-8S 1,176 — Well and Identifier; Water Level Elevation, in meters, December 2008
- Spring
- Shaft
- Perennial Reach
- Approximate Extent of Apache Leap Tuff Aquifer
- Extent of Outcrop of Apache Leap Tuff
- Watershed Boundary
- –1,050 – Contour of Equal Groundwater Elevation (dashed where projected)
- Direction of Groundwater Movement

N

0 2,000
Meters

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WATER LEVEL CONTOURS
APACHE LEAP TUFF AQUIFER
DECEMBER 2008

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FIGURE 9

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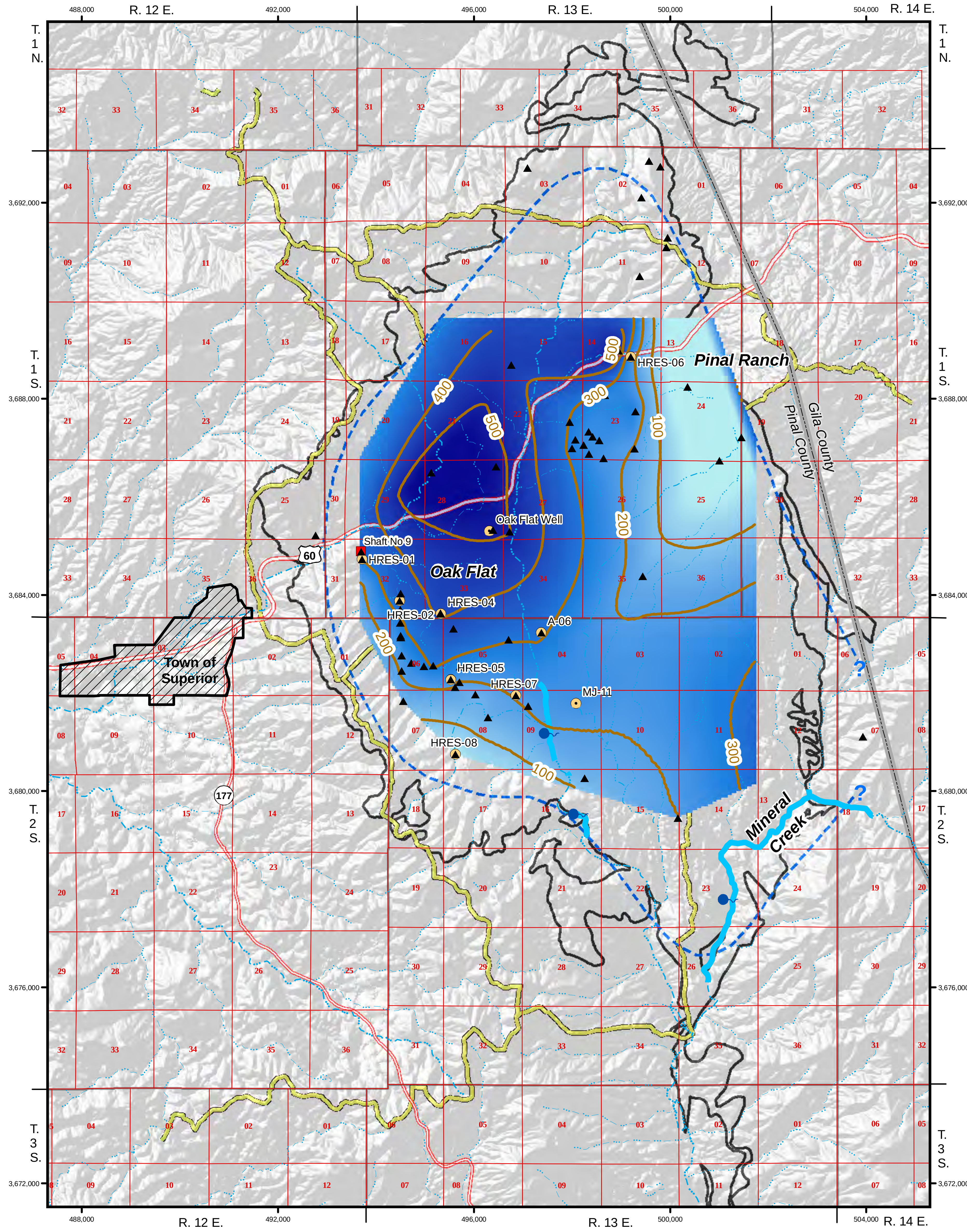

EXPLANATION

- HRES-02 Well and Identifier
- Spring
- Shaft
- Mineral Exploration Borehole
- Perennial Reach
- Approximate Extent of Apache Leap Tuff Aquifer
- Extent of Outcrop of Apache Leap Tuff
- Watershed Boundary
- 200 Contour of Equal Saturated Thickness, in meters

N

0 2,000
Meters

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ESTIMATED SATURATED THICKNESS
APACHE LEAP TUFF AQUIFER
DECEMBER 2008

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FIGURE 10

\GIS-Tuc\Projects\605\605.5\Saturated Thickness_modified.mxd\16Feb2010

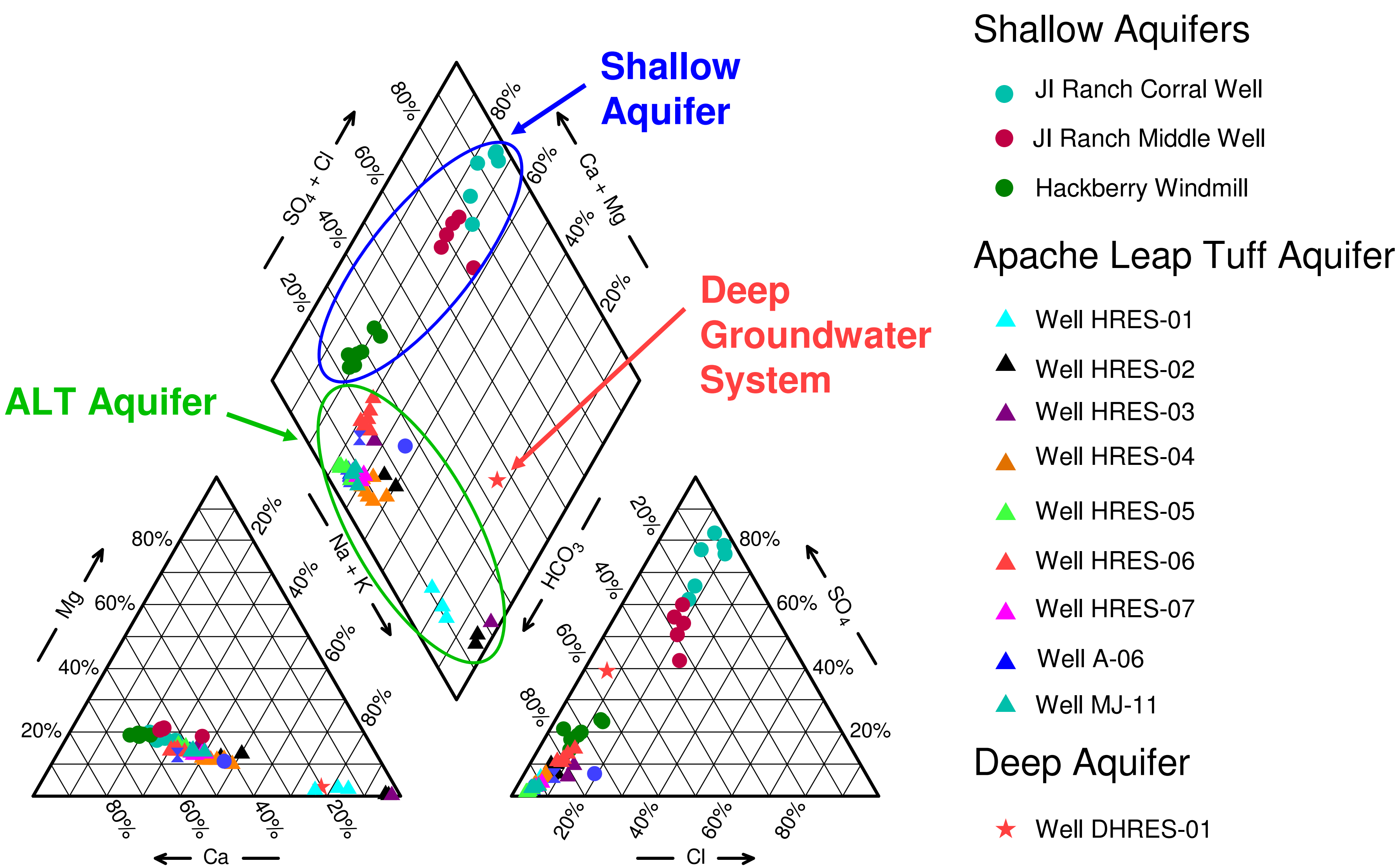

FIGURE 11. TRILINEAR DIAGRAM OF 2004 - 2009 GROUNDWATER COMPOSITIONS, RESOLUTION PROJECT

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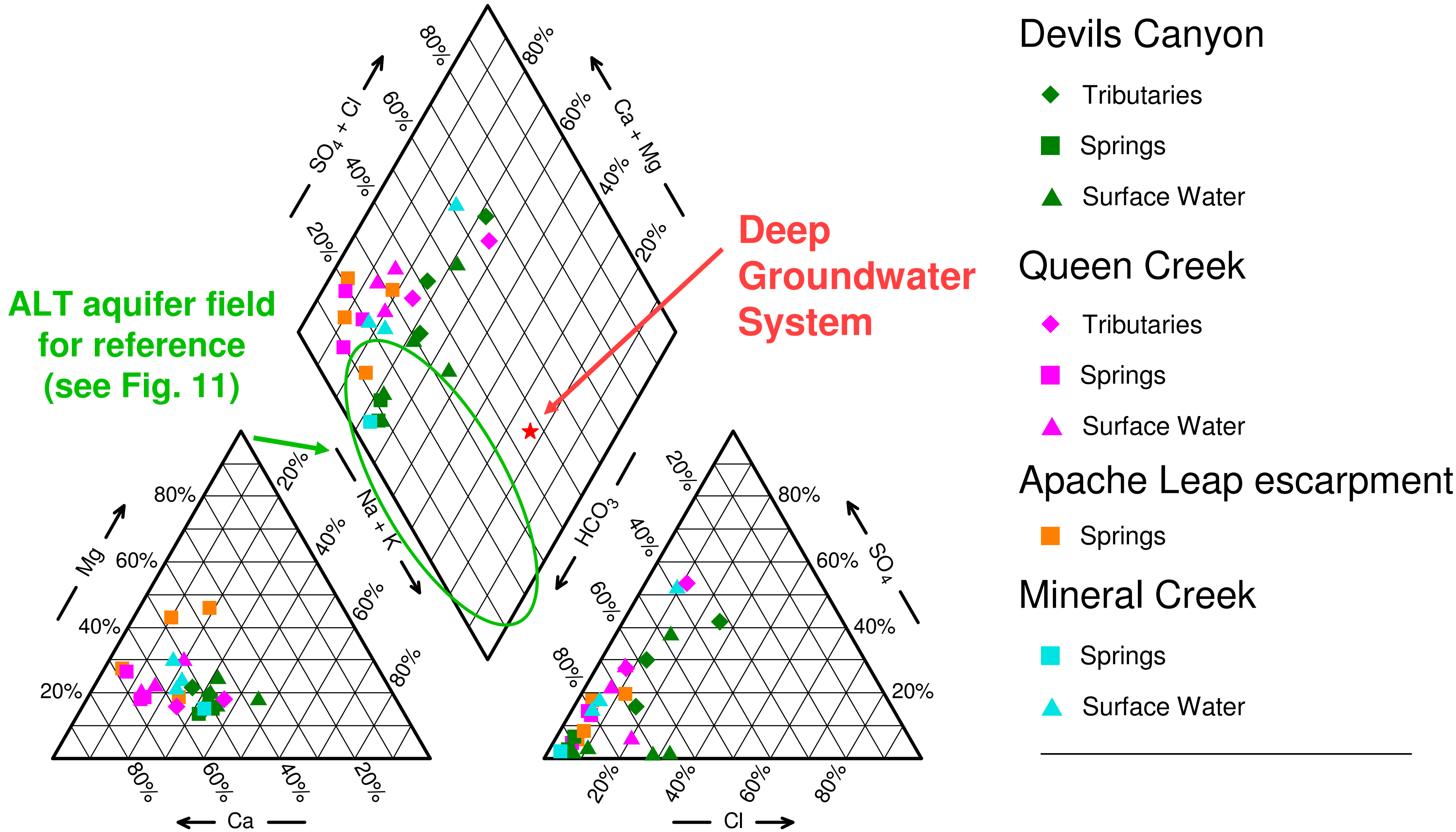

FIGURE 12. TRILINEAR DIAGRAM OF 2008 - QUARTER 3 SURFACE WATER AND SPRING COMPOSITIONS WITH APACHE LEAP TUFF AQUIFER AND DEEP GROUNDWATER COMPOSITIONS SHOWN FOR REFERENCE, RESOLUTION PROJECT

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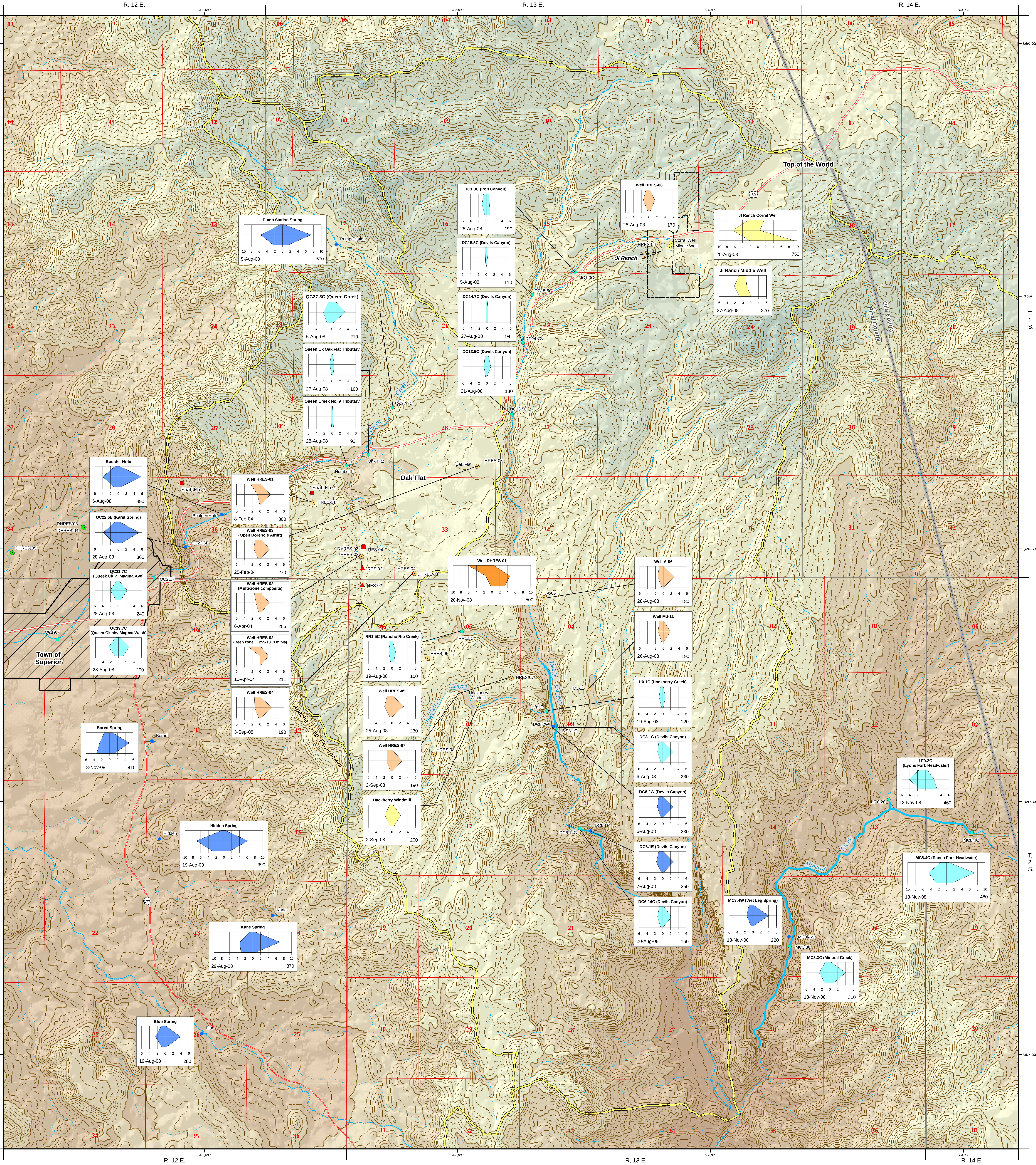


EXPLANATION

Watershed Boundary

Groundwater Monitoring Sites

Corral Well — Shallow Alluvial Aquifer Monitor Well and Identifier

A-06 — Apache Leap Tuff Aquifer Monitor Well and Identifier

DHRES-01 — Deep Aquifer Monitor Well and Identifier

DHRES-03 — Deep Basin-Fill Deposits Monitor Well and Identifier

RES-01 — Exploration Borehole and Identifier

Shaft Number 9 — Shaft and Identifier

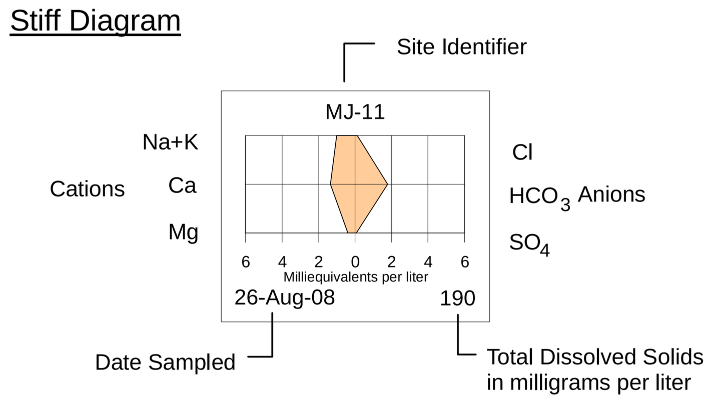
Surface Water Monitoring Sites (Selected)

MC3.4W — Spring and Identifier

DC14.7C — Surface Water Sample and Identifier

Perennial Reach

Stiff Diagram



Surface Water

Spring

Groundwater

Shallow Aquifers

Apache Leap Tuff Aquifer

Deep Aquifer

Elevation Range

(meters above mean sea level)

1,600 - 1,800

1,400 - 1,600

1,200 - 1,400

1,000 - 1,200

800 - 1,000

600 - 800

0 2,000 4,000 6,000 8,000 Feet

0 750 1,500 2,250 3,000 Meters

Topographic Contour Interval: 20 Meters

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STIFF DIAGRAMS

UPPER QUEEN CREEK / DEVILS CANYON STUDY AREA

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FIGURE 13

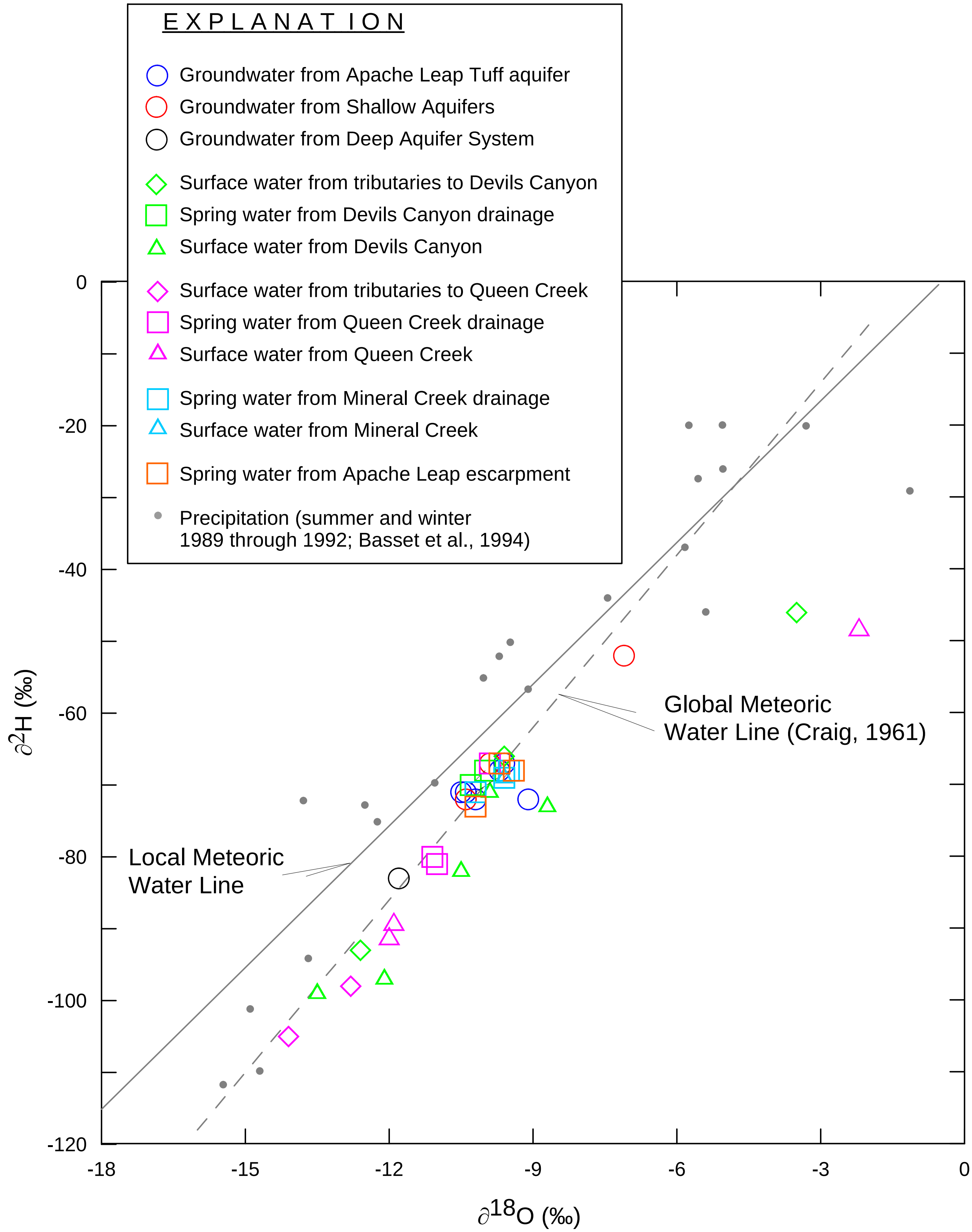

FIGURE 14. ∂^2H AND ∂^{18}O COMPOSITION FOR 2008 Q3 GROUNDWATER, SURFACE WATER AND SPRING SAMPLES OBTAINED IN THE UPPER QUEEN CREEK/ DEVILS CANYON STUDY AREA, RESOLUTION PROJECT

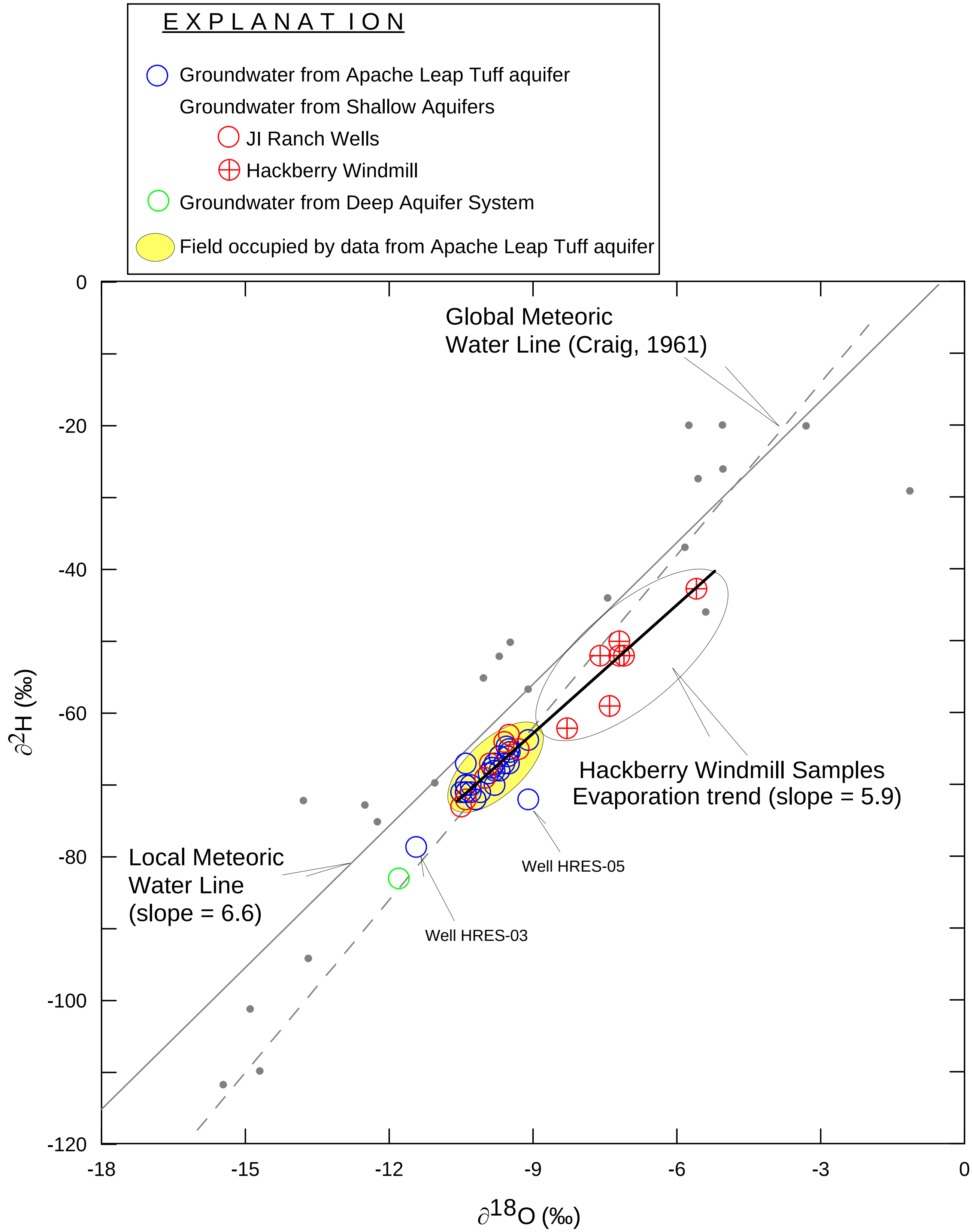

FIGURE 15. ∂^2H AND ∂^{18}O COMPOSITION OF GROUNDWATER SAMPLES OBTAINED IN THE UPPER QUEEN CREEK/DEVILS CANYON STUDY AREA FROM 2004 TO 2008, RESOLUTION PROJECT

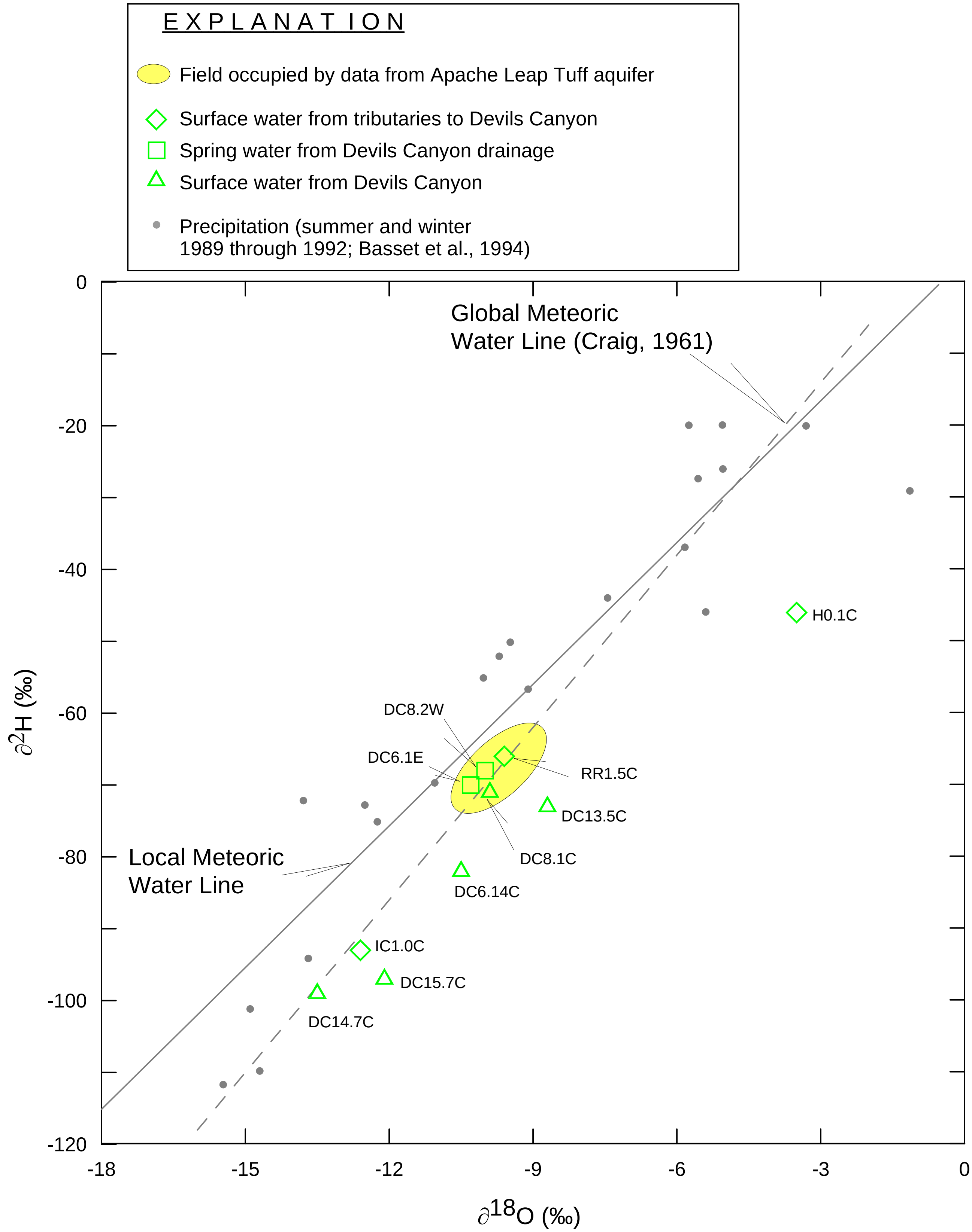

FIGURE 16. ∂^2**H AND** ∂^{18}**O COMPOSITION OF SURFACE WATER AND SPRING SAMPLES OBTAINED IN THE DEVILS CANYON DRAINAGE IN 2008 Q3, RESOLUTION PROJECT**

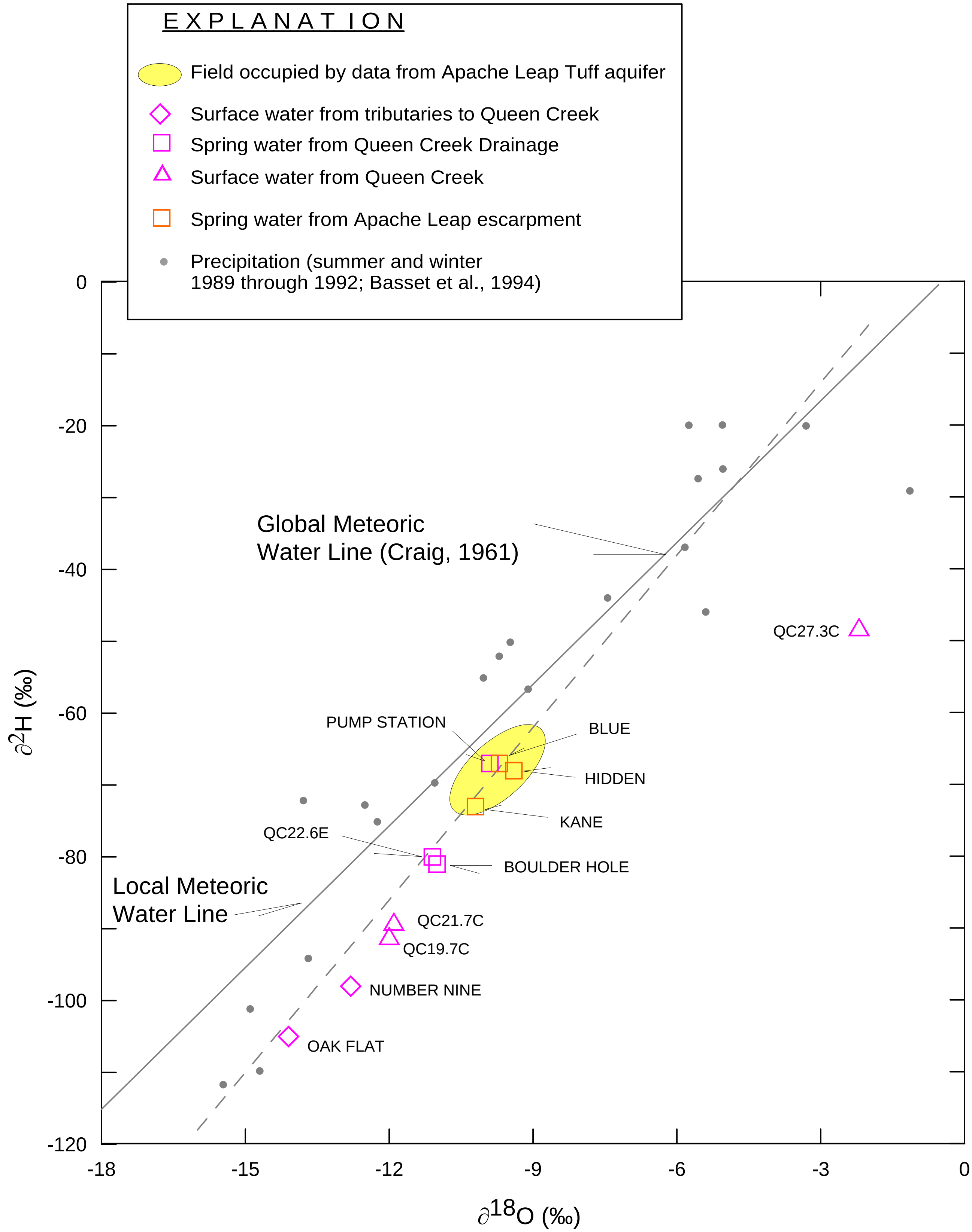

FIGURE 17. ∂^2**H AND** ∂^{18}**O COMPOSITION OF SURFACE WATER AND SPRING SAMPLES OBTAINED IN THE UPPER QUEEN CREEK DRAINAGE AND APACHE LEAP ESCARPMENT IN 2008 Q3, RESOLUTION PROJECT**

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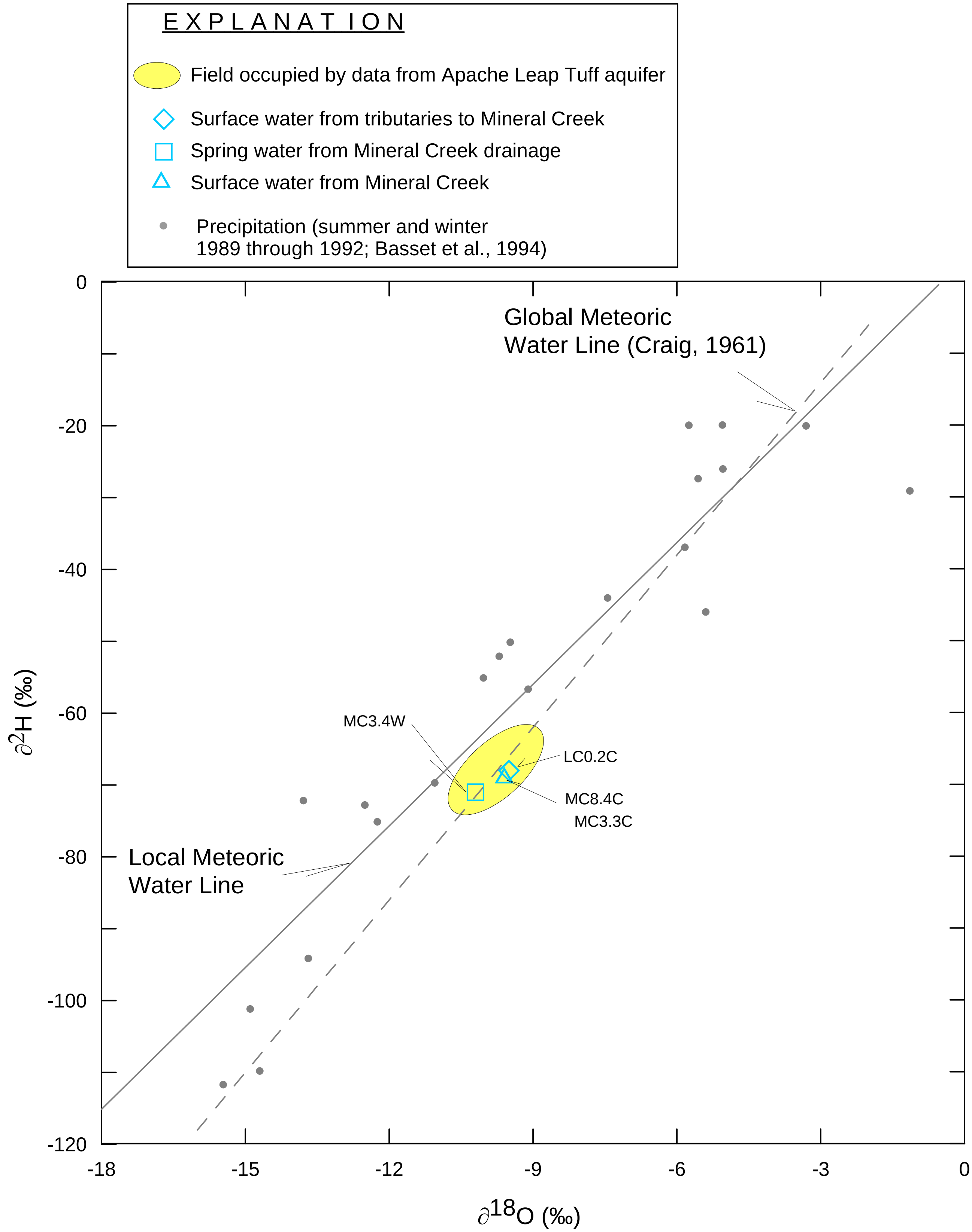

FIGURE 18. ∂^2**H AND** ∂^{18}**O COMPOSITION OF SURFACE WATER AND SPRING SAMPLES OBTAINED IN THE MINERAL CREEK DRAINAGE IN 2008 Q3, RESOLUTION PROJECT**

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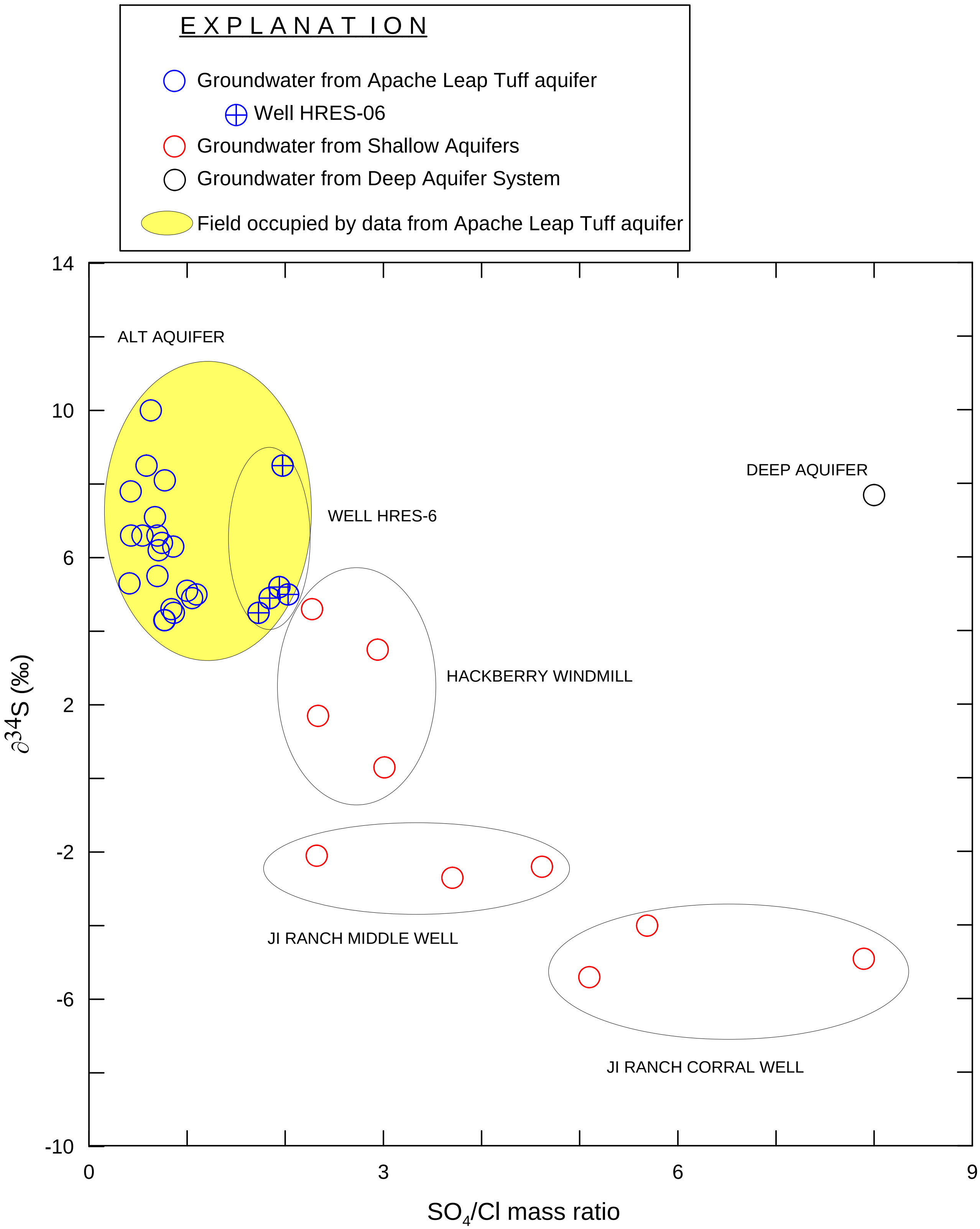

FIGURE 19. ∂^{34}**S AND** SO_4**/Cl MASS RATIO FOR 2008 GROUNDWATER SAMPLES OBTAINED IN THE UPPER QUEEN CREEK/DEVILS CANYON STUDY AREA, RESOLUTION PROJECT**

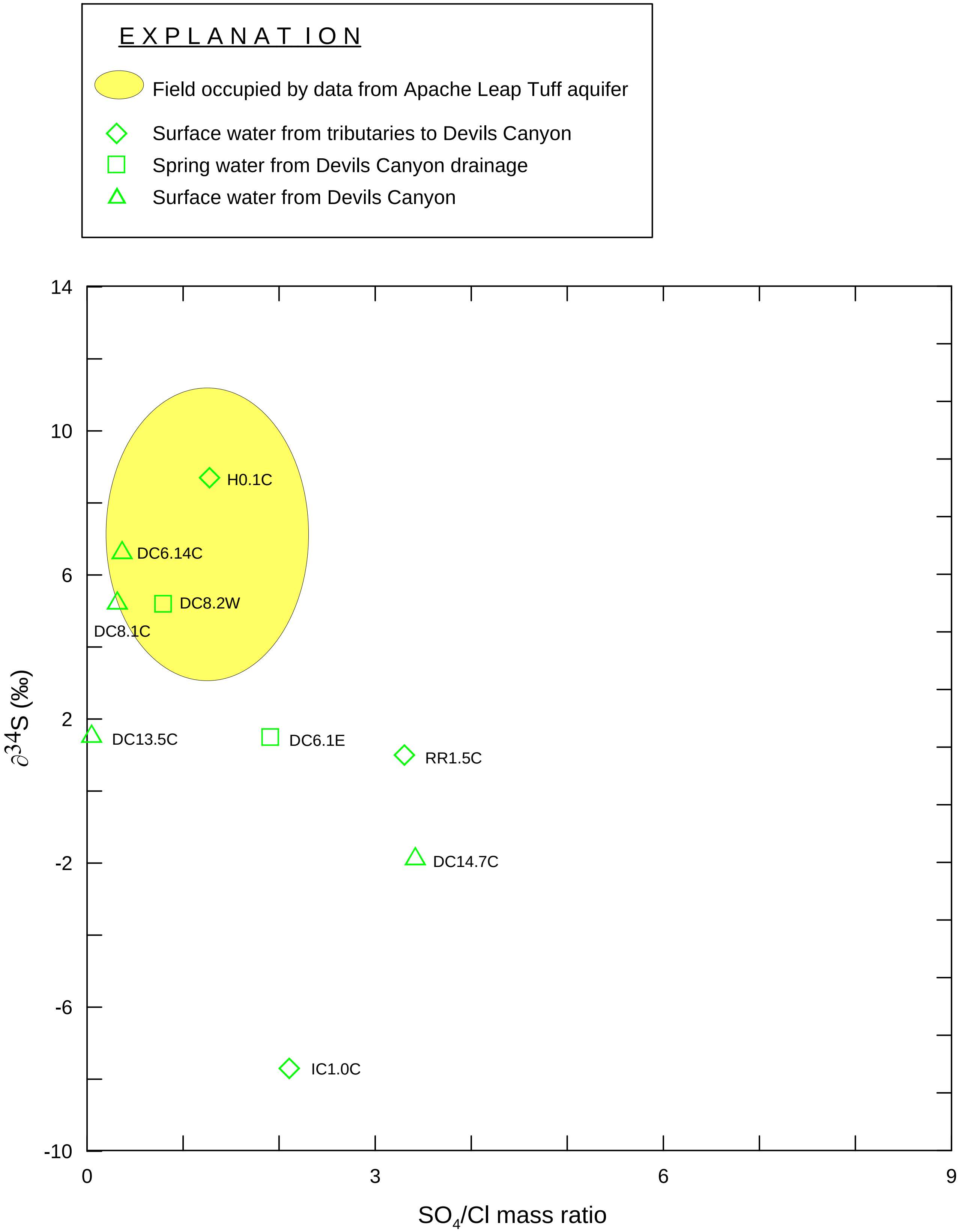

FIGURE 20. $\partial^{34}S$ **IN DISSOLVED SULFATE VS.** SO_4**/Cl MASS RATIO FOR SURFACE WATER AND SPRING SAMPLES OBTAINED IN THE DEVILS CANYON DRAINAGE IN 2008 Q3, RESOLUTION PROJECT**

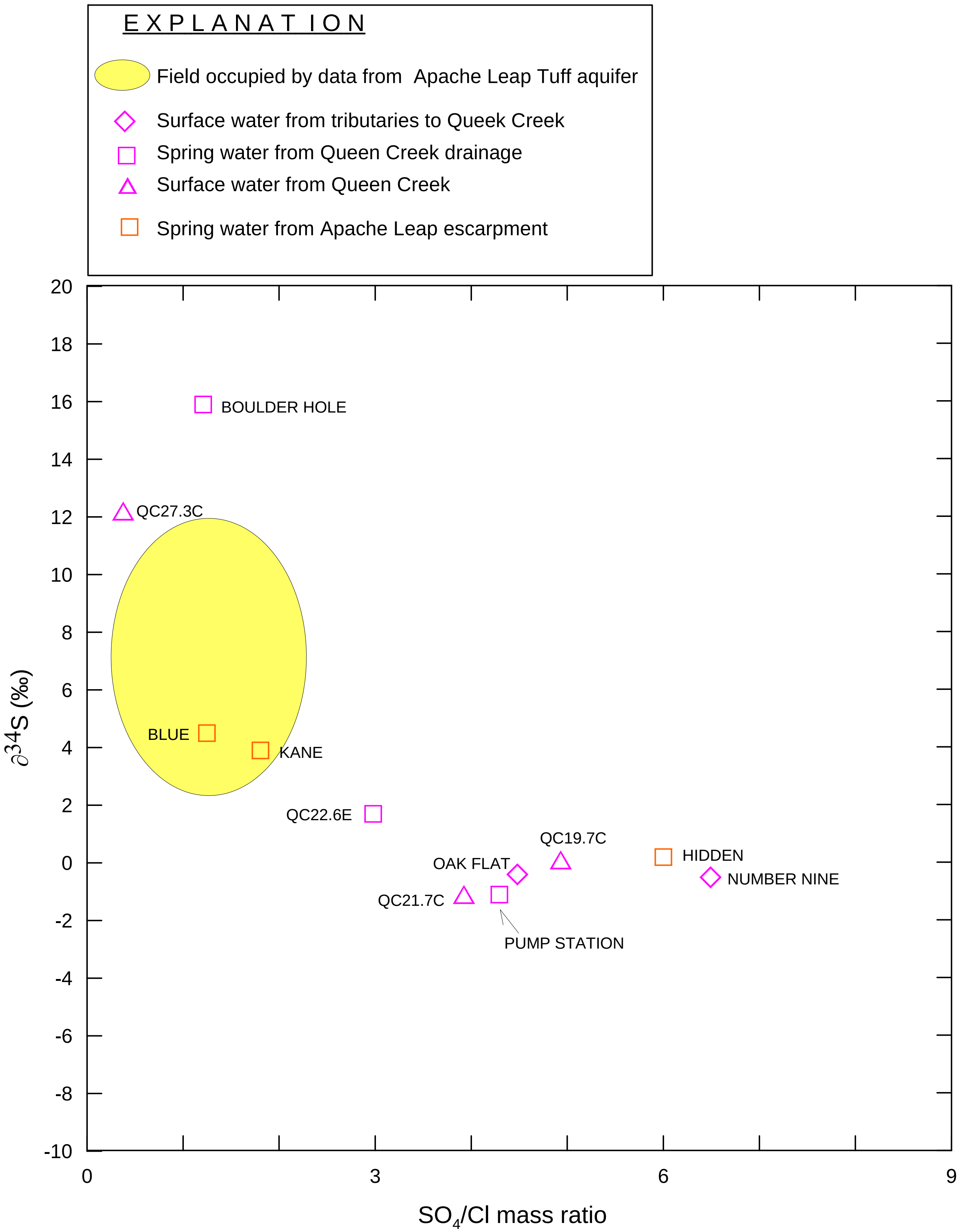

FIGURE 21. ∂^{34}**S IN DISSOLVED SULFATE VS.** SO_4**/Cl MASS RATIO FOR SURFACE WATER AND SPRING SAMPLES OBTAINED IN THE QUEEN CREEK DRAINAGE AND APACHE LEAP ESCARPMENT IN 2008 Q3, RESOLUTION PROJECT**

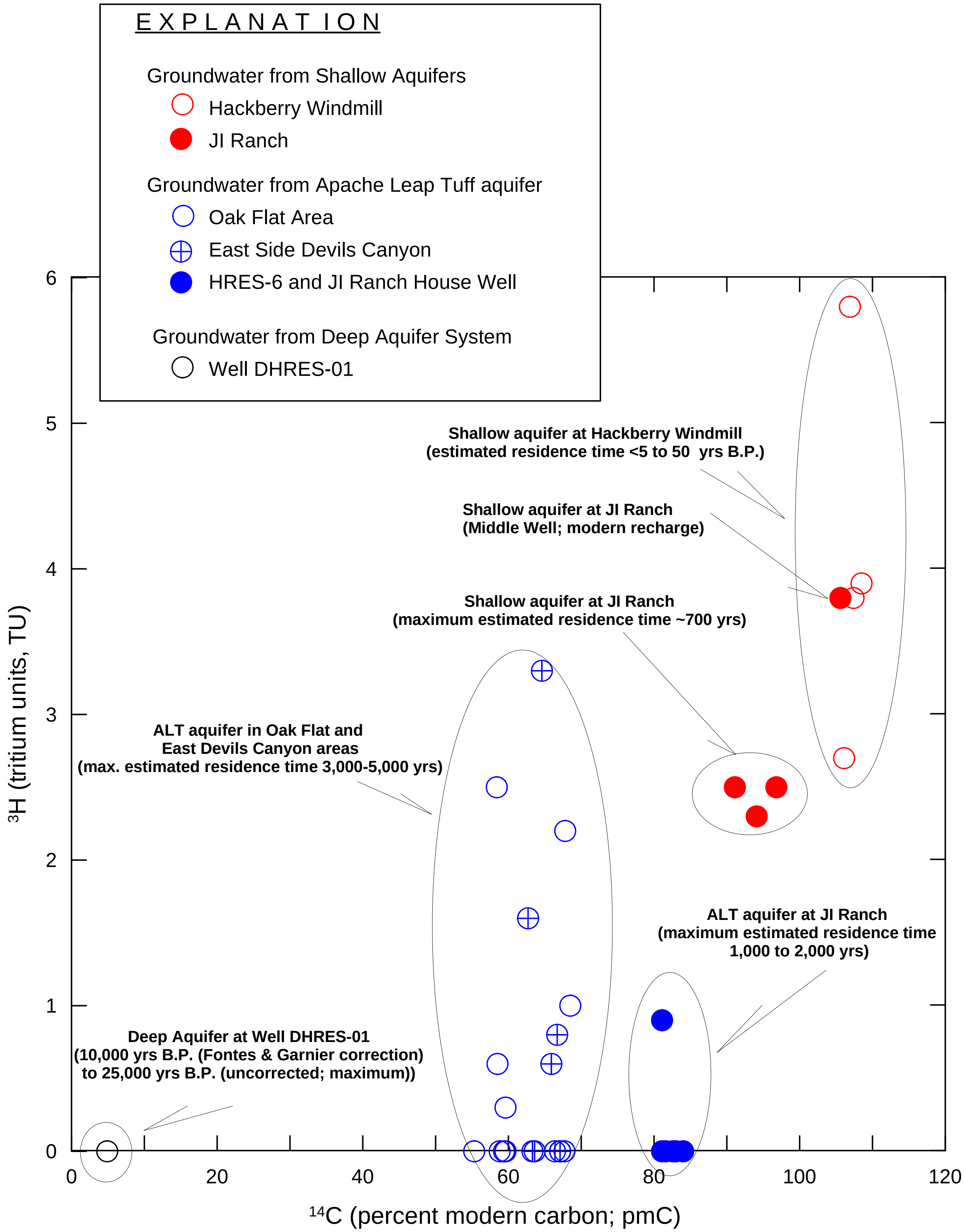

FIGURE 22. ^{3}**H AND** ^{14}**C FOR GROUNDWATER SAMPLES OBTAINED IN THE UPPER QUEEN CREEK/DEVILS CANYON STUDY AREA, RESOLUTION PROJECT**

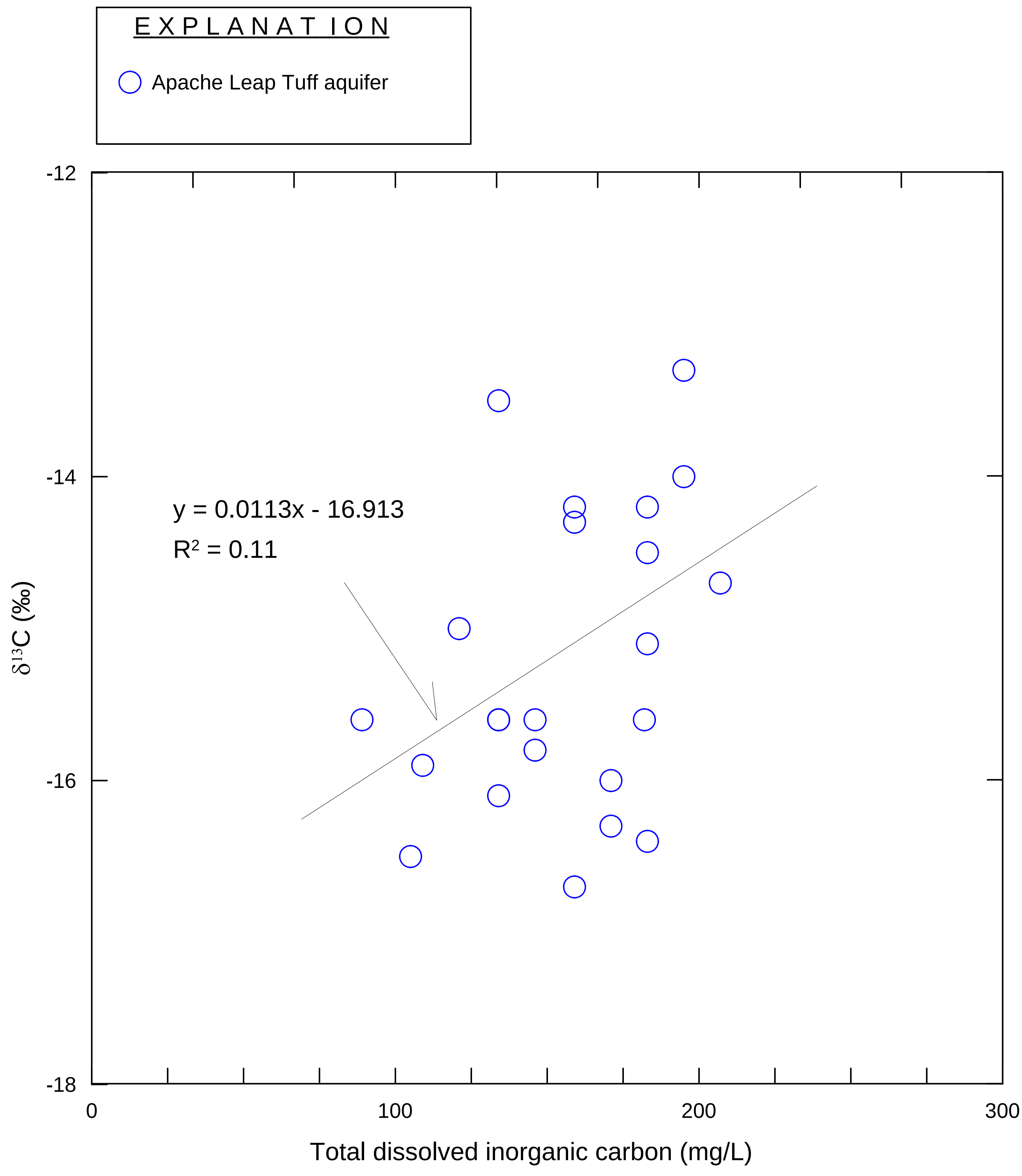

FIGURE 23. CORRELATION BETWEEN δ^{13}C AND TOTAL DISSOLVED INORGANIC CARBON CONCENTRATION IN APACHE LEAP TUFF AQUIFER RESOLUTION PROJECT

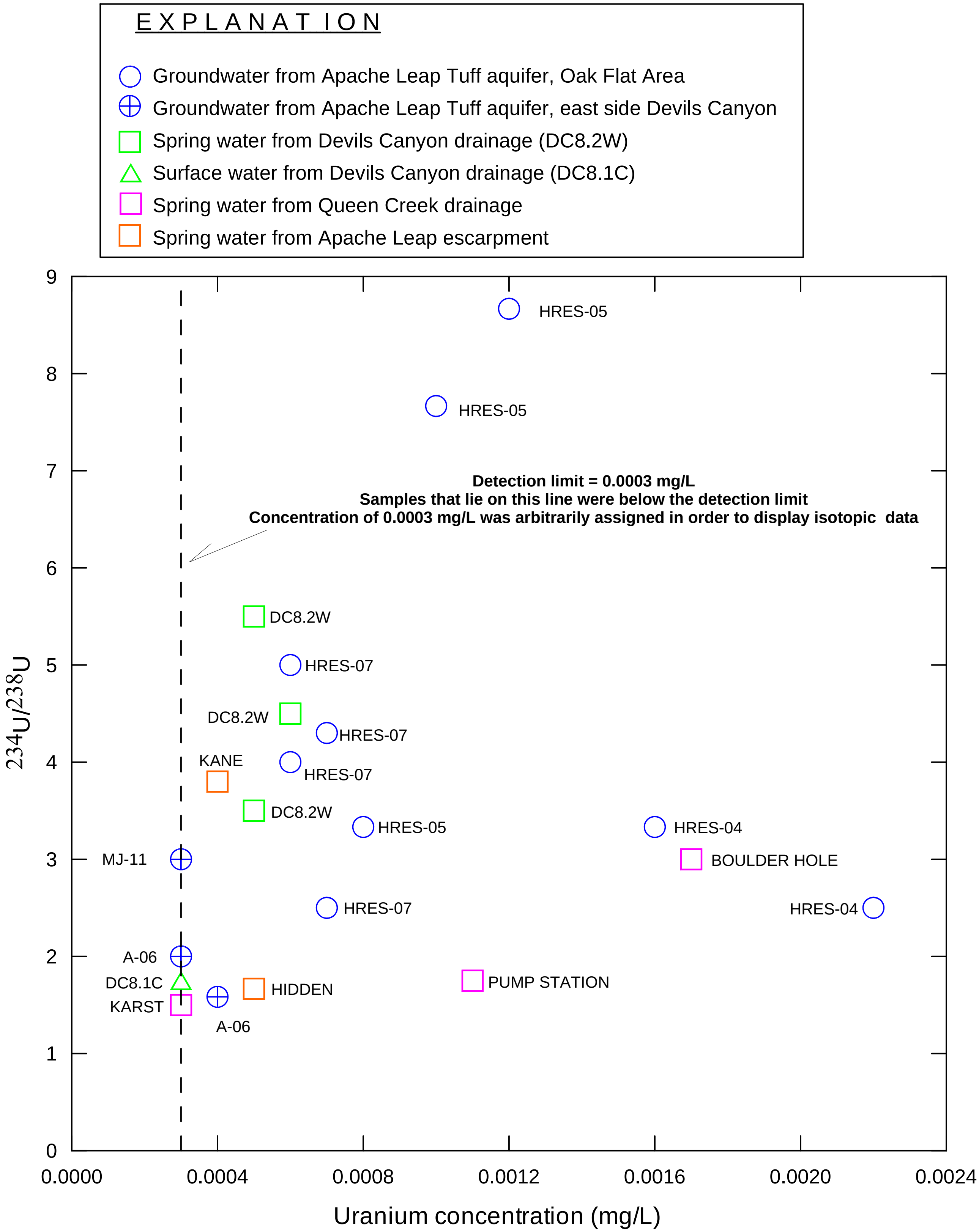

FIGURE 24. $^{234}U/^{238}U$ **vs. URANIUM CONCENTRATION FOR 2008 GROUNDWATER AND 2008 Q3 SURFACE WATER AND SPRING SAMPLES SAMPLES OBTAINED IN THE UPPER QUEEN CREEK/DEVILS CANYON STUDY AREA, RESOLUTION PROJECT**

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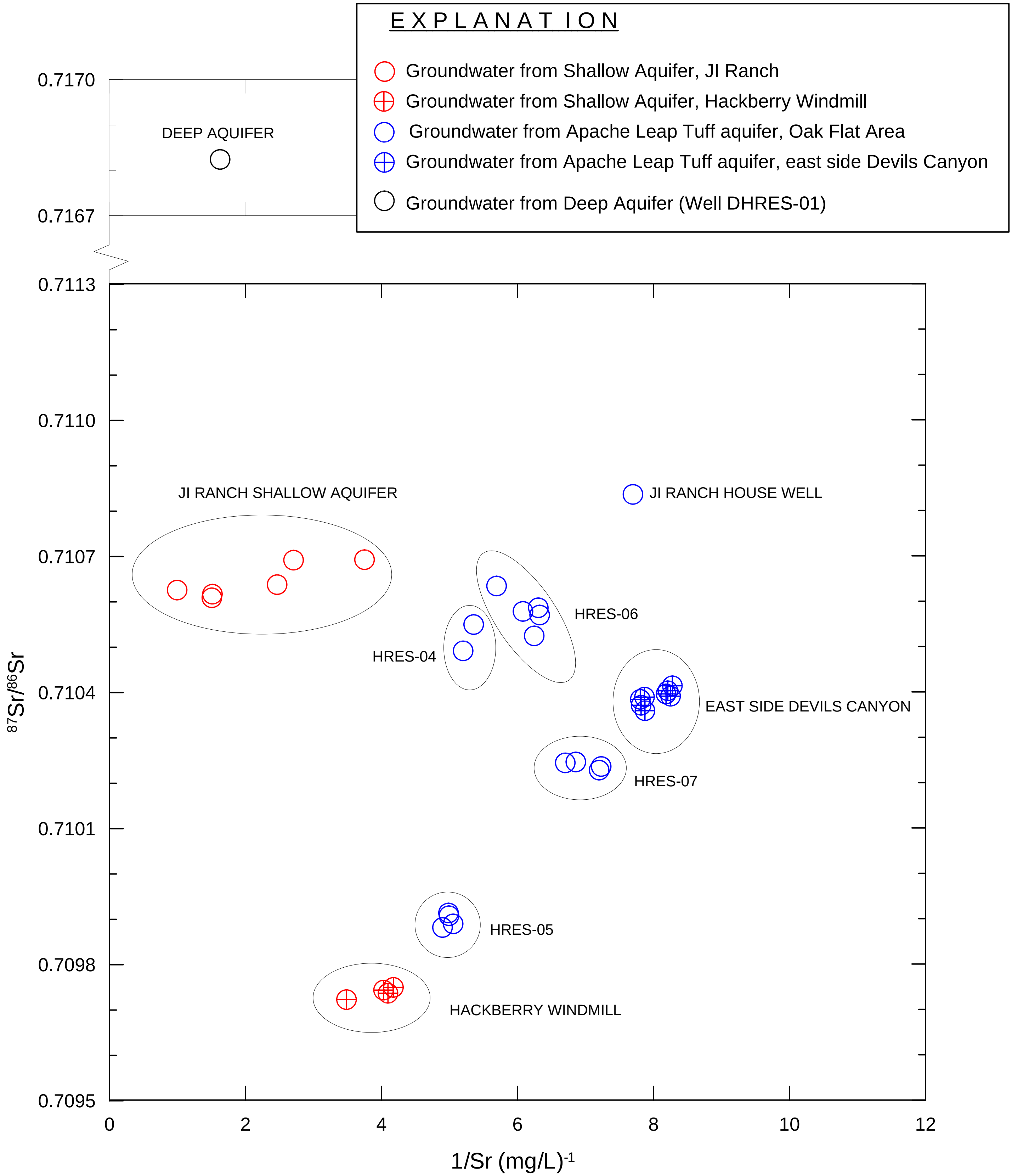

FIGURE 25. **$^{87}Sr/^{86}Sr$ vs. STRONTIUM FROM 2008 GROUNDWATER SAMPLES OBTAINED IN THE UPPER QUEEN CREEK/DEVILS CANYON STUDY AREA, RESOLUTION PROJECT**

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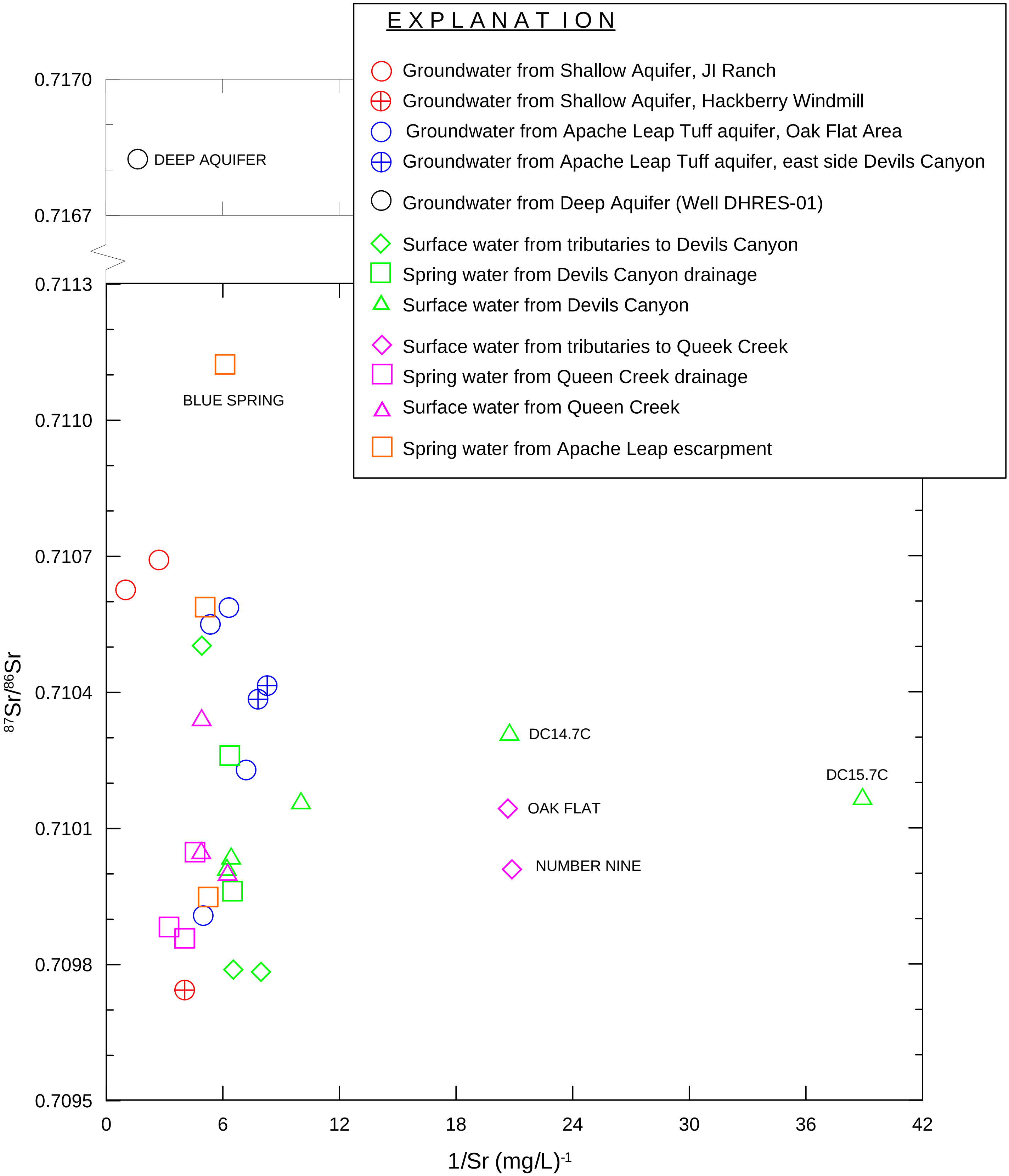
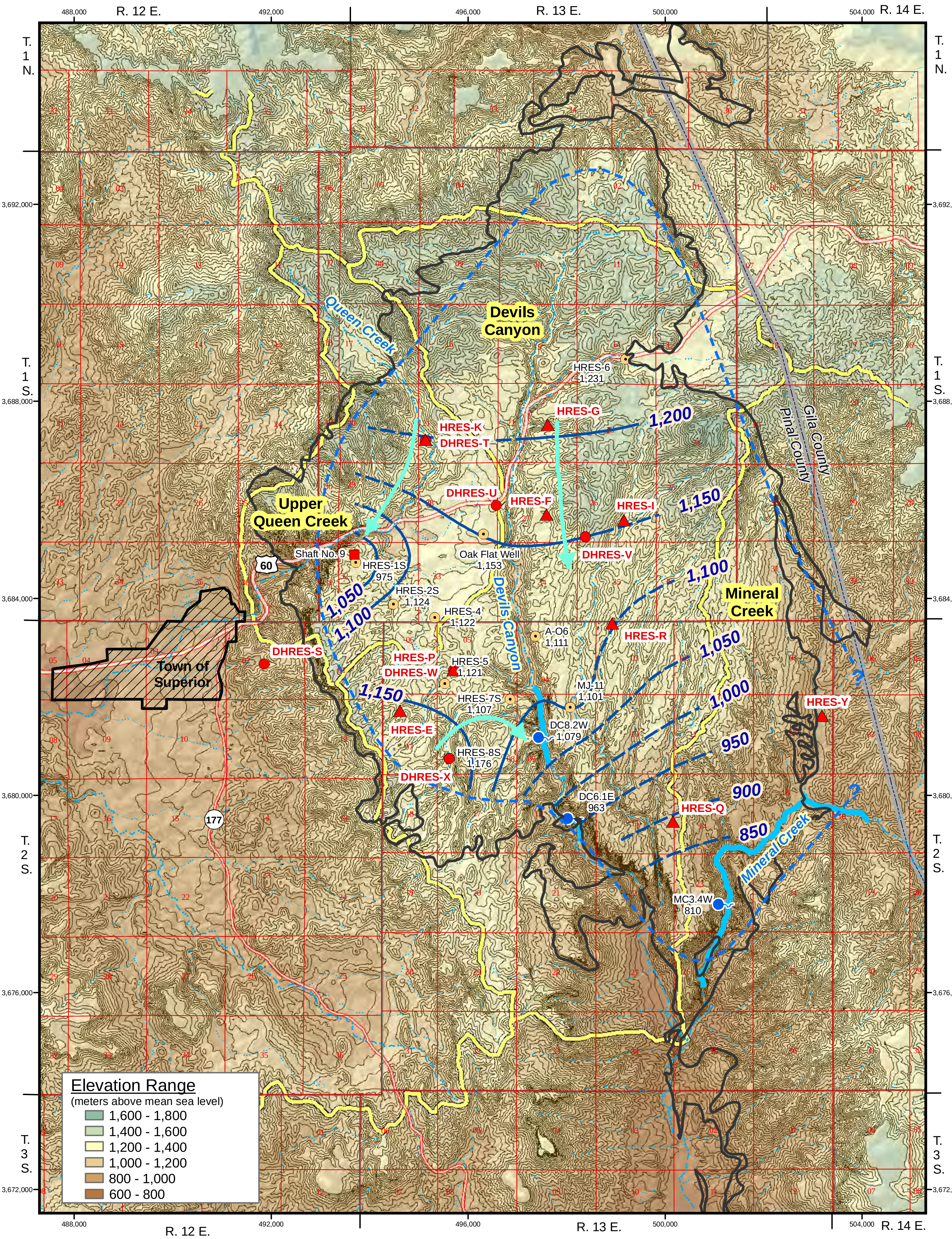


FIGURE 26. **$^{87}Sr/^{86}Sr$ vs. STRONTIUM FROM 2008 Q3 GROUNDWATER, SURFACE WATER, AND SPRING SAMPLES OBTAINED IN THE UPPER QUEEN CREEK/DEVILS CANYON STUDY AREA, RESOLUTION PROJECT**



EXPLANATION

- HRES-8S 1,176 — Well and Identifier; Water Level Elevation, in meters, December 2008
- Spring
- Shaft
- Proposed Deep Hydrologic Test Well
- Proposed ALT Aquifer Test Well
- Perennial Reach
- Approximate Extent of Apache Leap Tuff Aquifer
- Extent of Outcrop of Apache Leap Tuff
- Watershed Boundary
- -1,050- Contour of Equal Groundwater Elevation (dashed where projected)
- Direction of Groundwater Movement

N

0 2,000

Meters

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PROPOSED WELL LOCATIONS

UPPER QUEEN CREEK/
DEVILS CANYON STUDY AREA

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FIGURE 27

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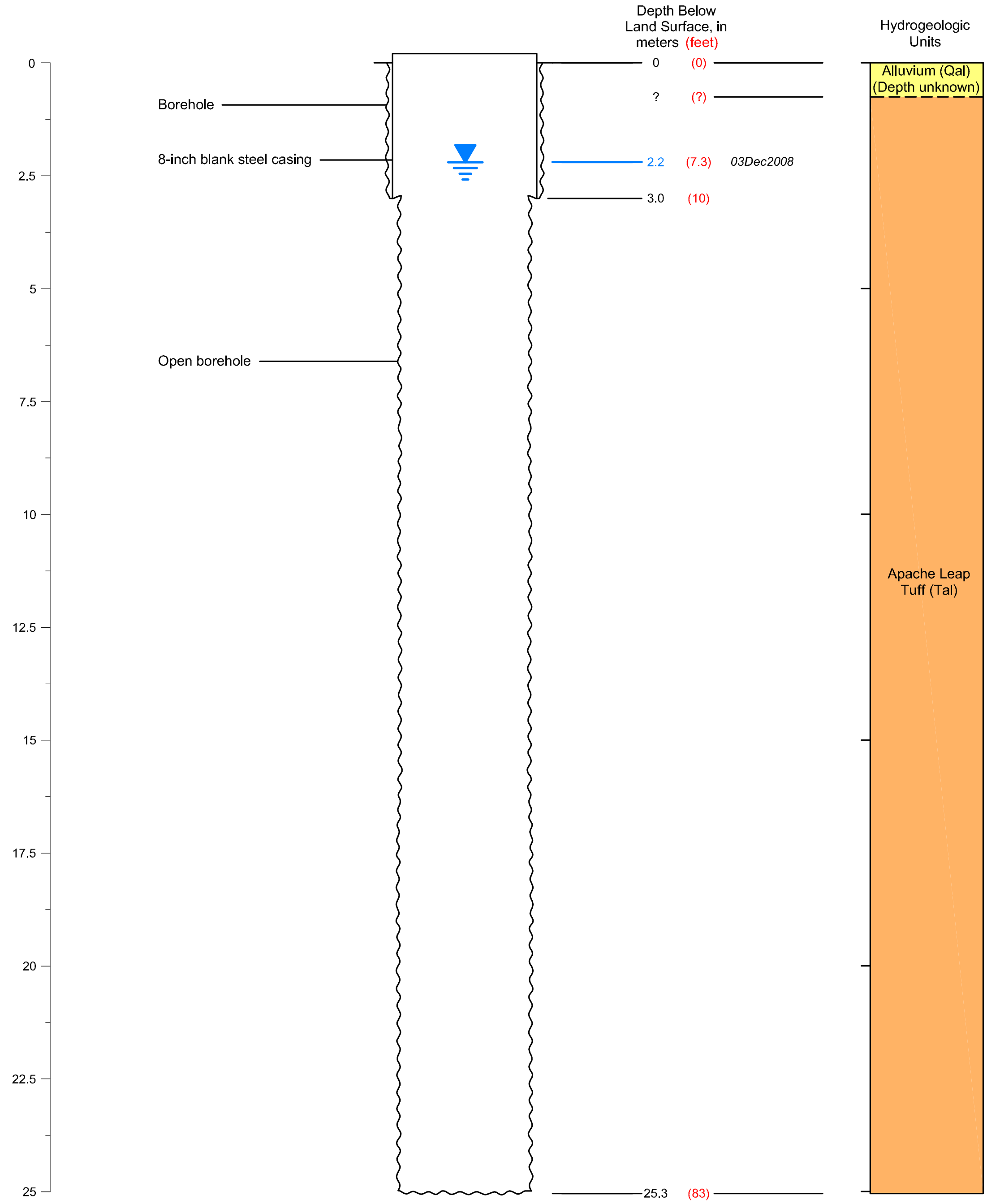
APPENDIX A

SCHEMATIC DIAGRAMS OF WELL CONSTRUCTION



EXPLANATION

Non-pumping Water Level

CADASTRAL: (D-1-13) 14dbd	ADWR NO: 55-609685
NORTHING: 3688841.135	EASTING: 499376.980
LAND SURFACE ELEVATION: 1352.05	
DATUM: NAD 27 HORIZONTAL: UTM 12 VERTICAL: NGVD 29 METERS	

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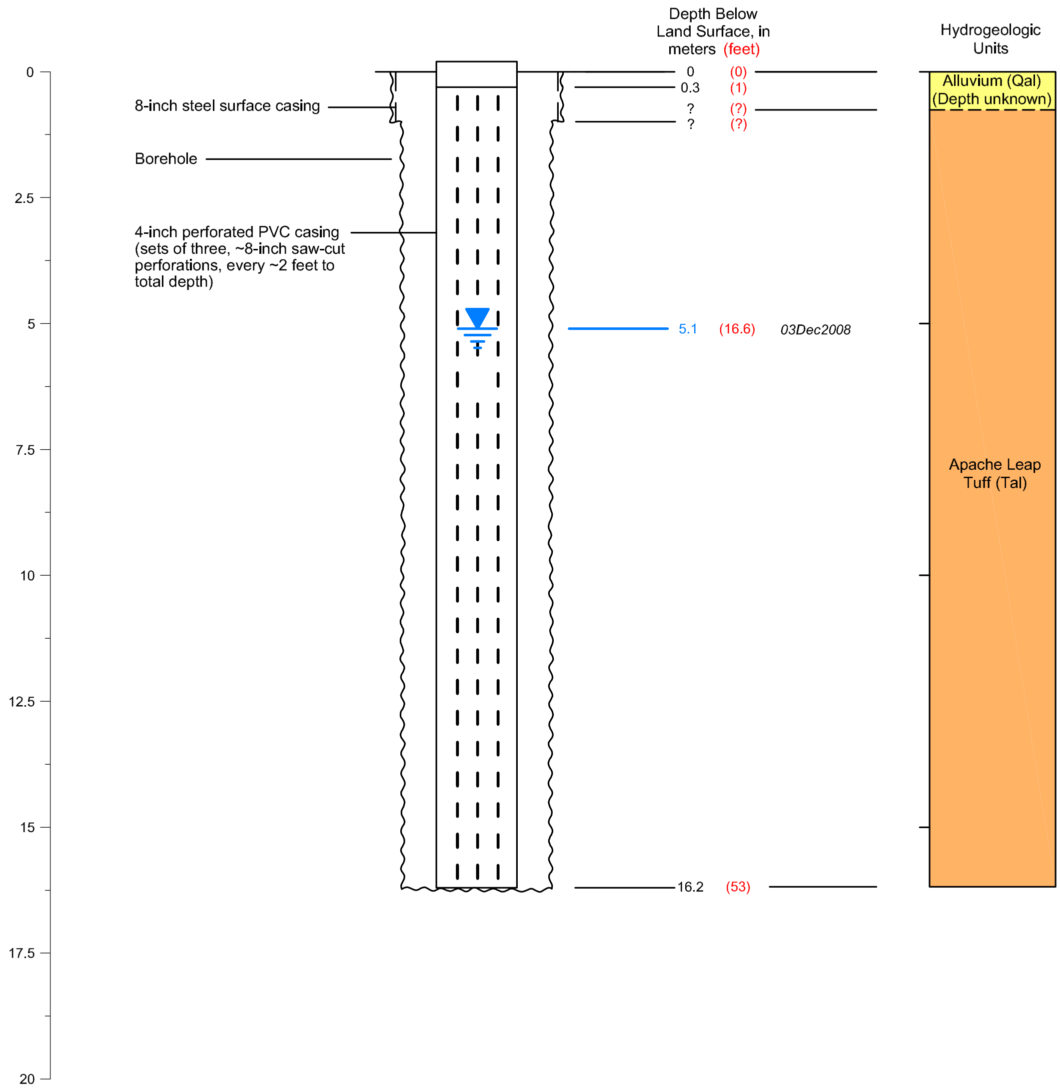
CORRAL WELL
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-1

605\WellSchematics_2009\14dbd_CorralWell_Rev2/17Feb2010



EXPLANATION

Non-pumping Water Level

CADASTRAL: (D-1-13) 14dbd	ADWR NO: None	**MIDDLE WELL** SCHEMATIC DIAGRAM OF WELL CONSTRUCTION
NORTHING: 3688777.760	EASTING: 499349.387	
LAND SURFACE ELEVATION: 1354.21		Version: February 16, 2010
DATUM: NAD 27 HORIZONTAL: UTM 12 VERTICAL: NGVD 29 METERS		FIGURE A-2

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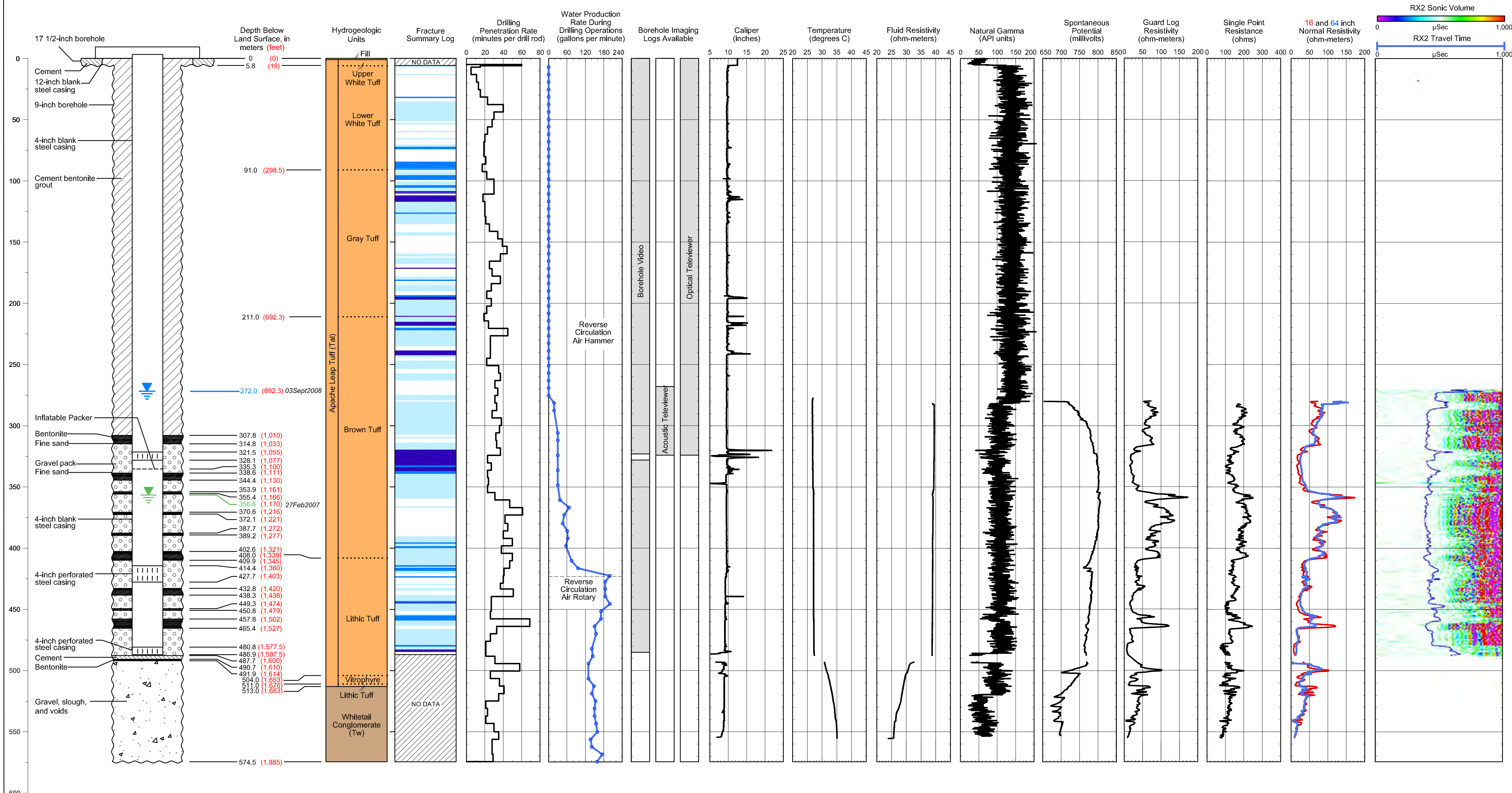
605\WellSchematics_2009\14dbd_MiddleWell_Rev2\16Feb2010



CADASTRAL: (D-1-13) 32bca	ADWR NO: 55-201852
NORTHING: 3684732.337	EASTING: 493714.748
LAND SURFACE ELEVATION: 1271.66	
DATUM: NAD 27 HORIZONTAL: UTM 12 VERTICAL: NGVD 29 METERS	

EXPLANATION

- No Fracturing Evident
- Minor Fracturing
- Moderate Fracturing
- Major Fracturing
- Shallow Non-pumping Water Level
- Deep Non-pumping Water Level

Resolution Copper Mining

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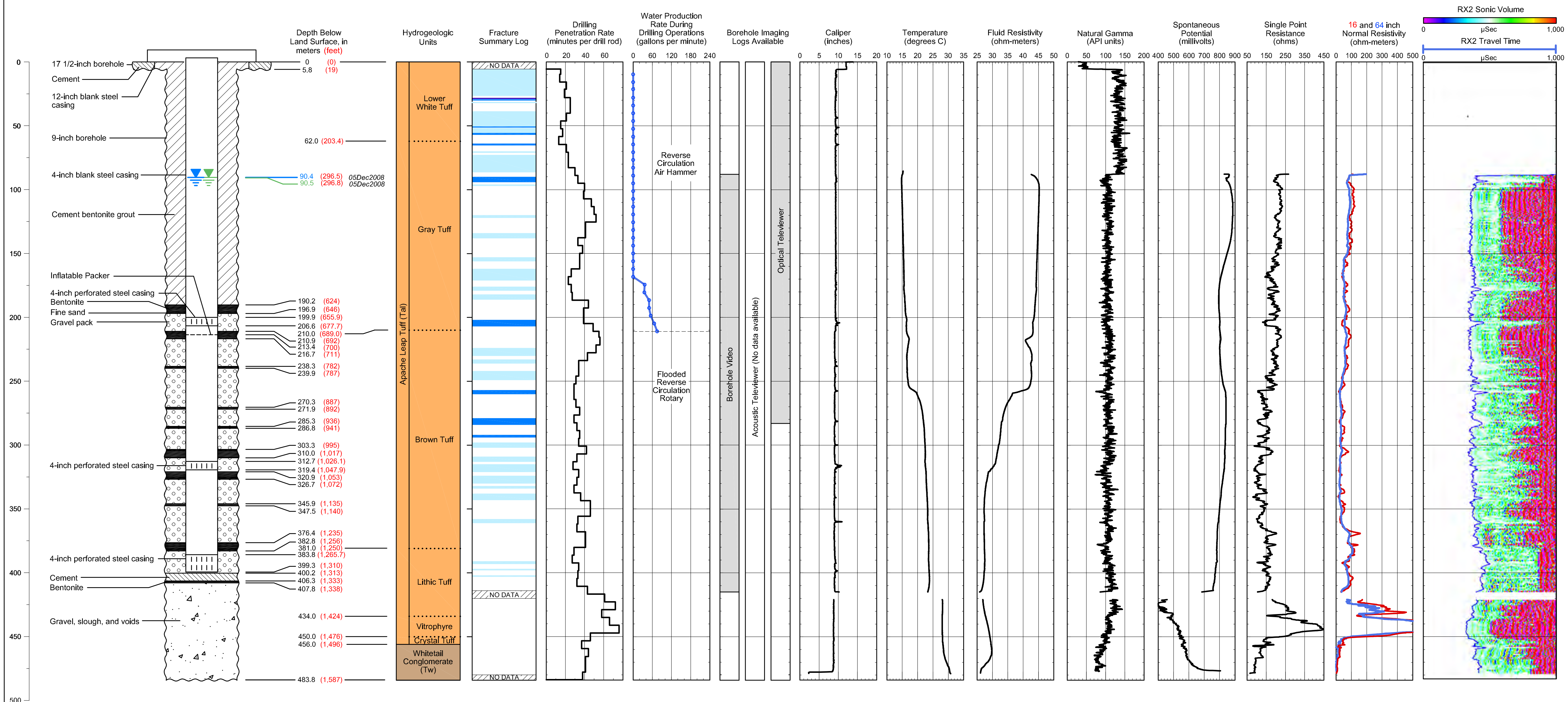
HRES-01
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-3

605\WellSchematics_2009\HRES-1-WS-LOGS-Rev4/17Feb2010



CADASTRAL: (D-1-13) 32dca	ADWR NO: 55-201850
NORTHING: 3683886.304	EASTING: 494479.323
LAND SURFACE ELEVATION: 1214.34	

DATUM: NAD 27
HORIZONTAL: UTM 12
VERTICAL: NGVD 29 METERS

EXPLANATION

- No Fracturing Evident
- Minor Fracturing
- Moderate Fracturing
- Major Fracturing
- Shallow Non-pumping Water Level
- Deep Non-pumping Water Level

Resolution Copper Mining

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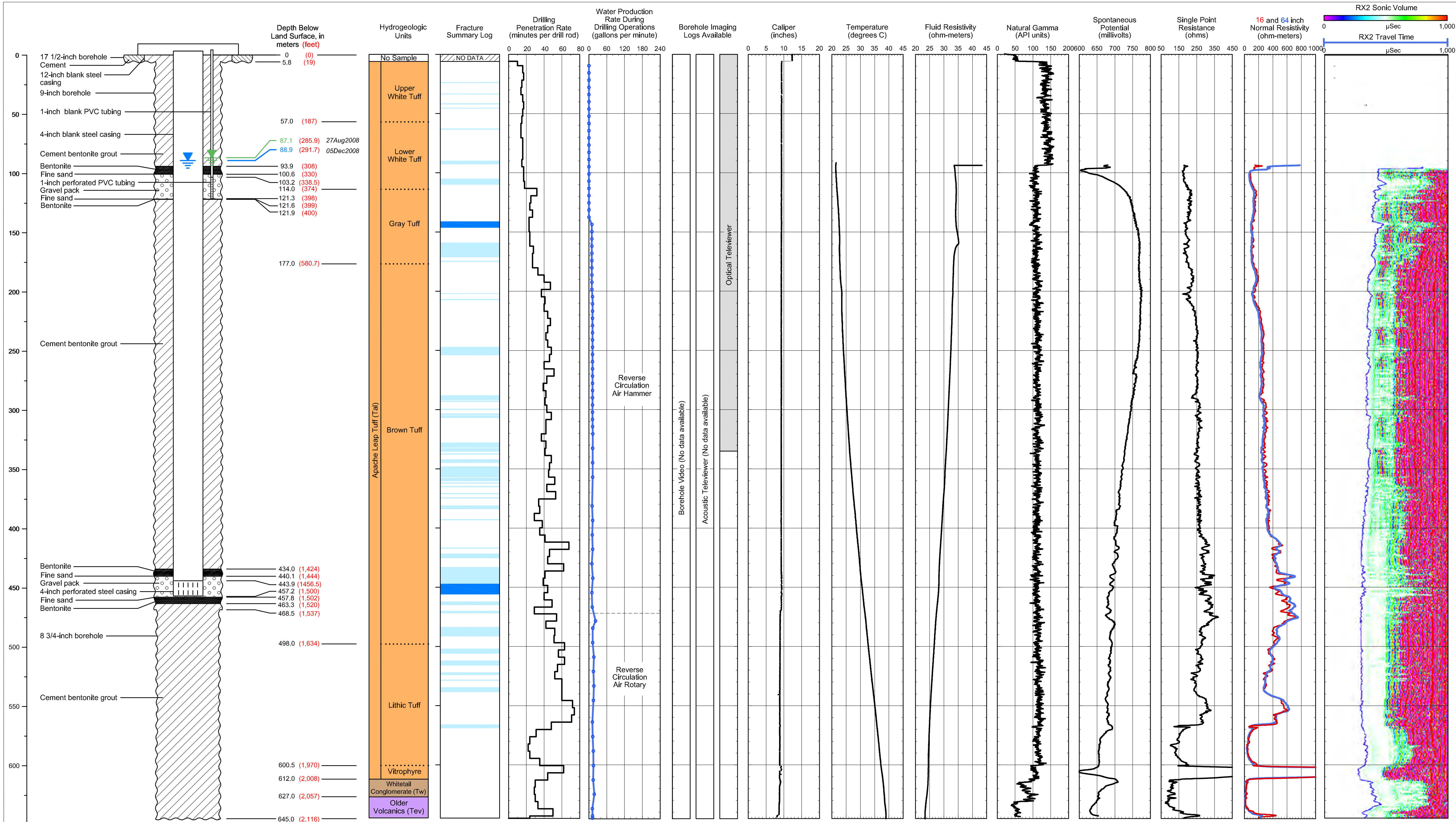
HRES-02
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-4

605\WellSchematics_2009\HRES-2-WS-LOGS-Rev4/17Feb2010



CADASTRAL: (D-1-13) 28ddb	ADWR NO: 55-201851
NORTHING: 3685328.404	EASTING: 496381.896
LAND SURFACE ELEVATION: 1241.39	
DATUM: NAD 27 HORIZONTAL: UTM 12 VERTICAL: NGVD 29 METERS	

EXPLANATION

- No Fracturing Evident
- Minor Fracturing
- Moderate Fracturing
- Major Fracturing
- Shallow Non-pumping Water Level
- Deep Non-pumping Water Level

Resolution Copper Mining

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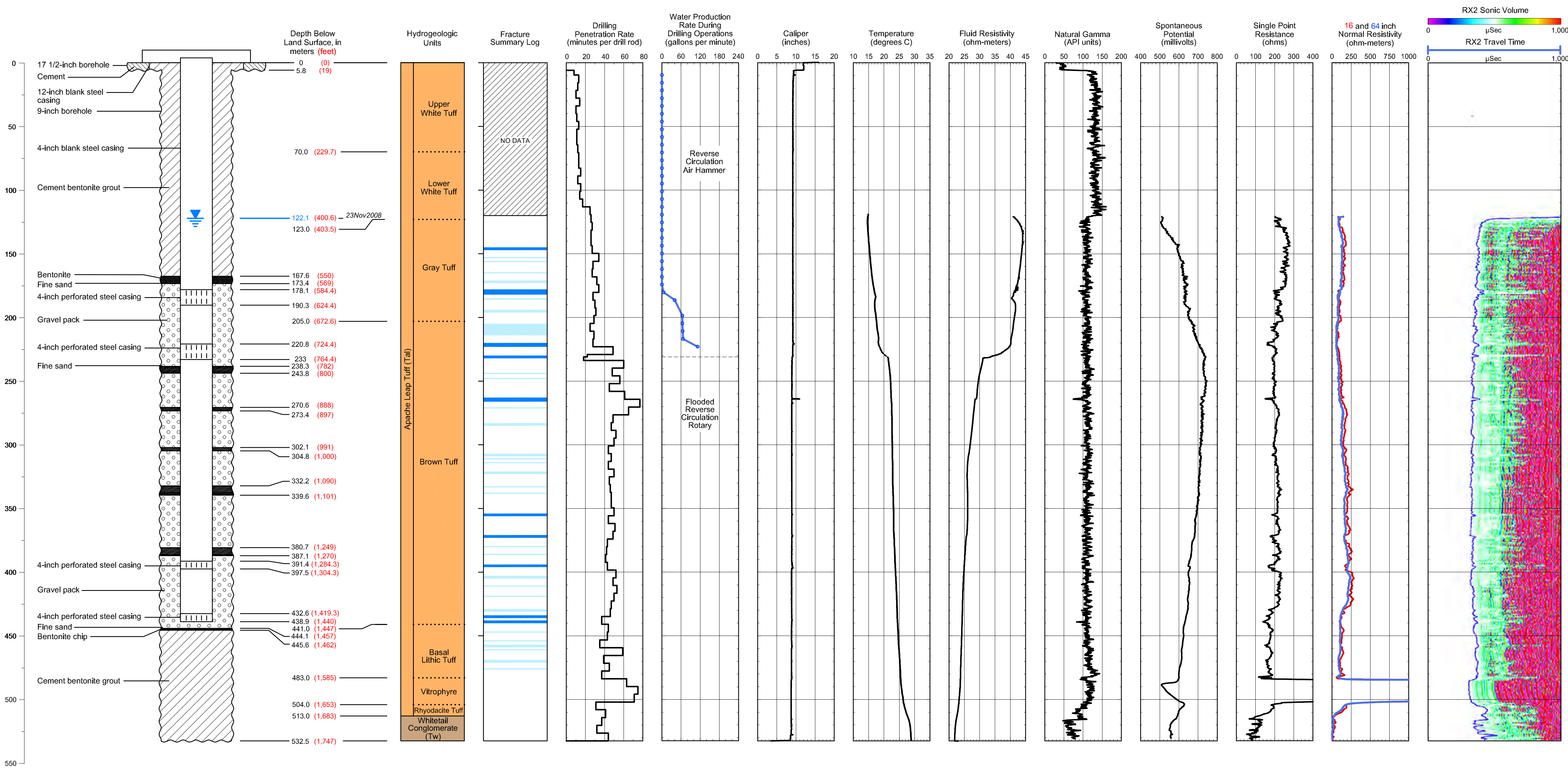
HRES-03
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-5

605\WellSchematics_2009\HRES-3-WS-LOGS-Rev3\17Feb2010



CADASTRAL: (D-1-13) 33ccd	ADWR NO: 55-201849
NORTHING: 3683616.170	EASTING: 495322.295
LAND SURFACE ELEVATION: 1243.49	
DATUM: NAD 27 HORIZONTAL: UTM 12 VERTICAL: NGVD 29 METERS	

EXPLANATION

- No Fracturing Evident
- Minor Fracturing
- Moderate Fracturing
- Major Fracturing
- Non-pumping Water Level

Resolution Copper Mining

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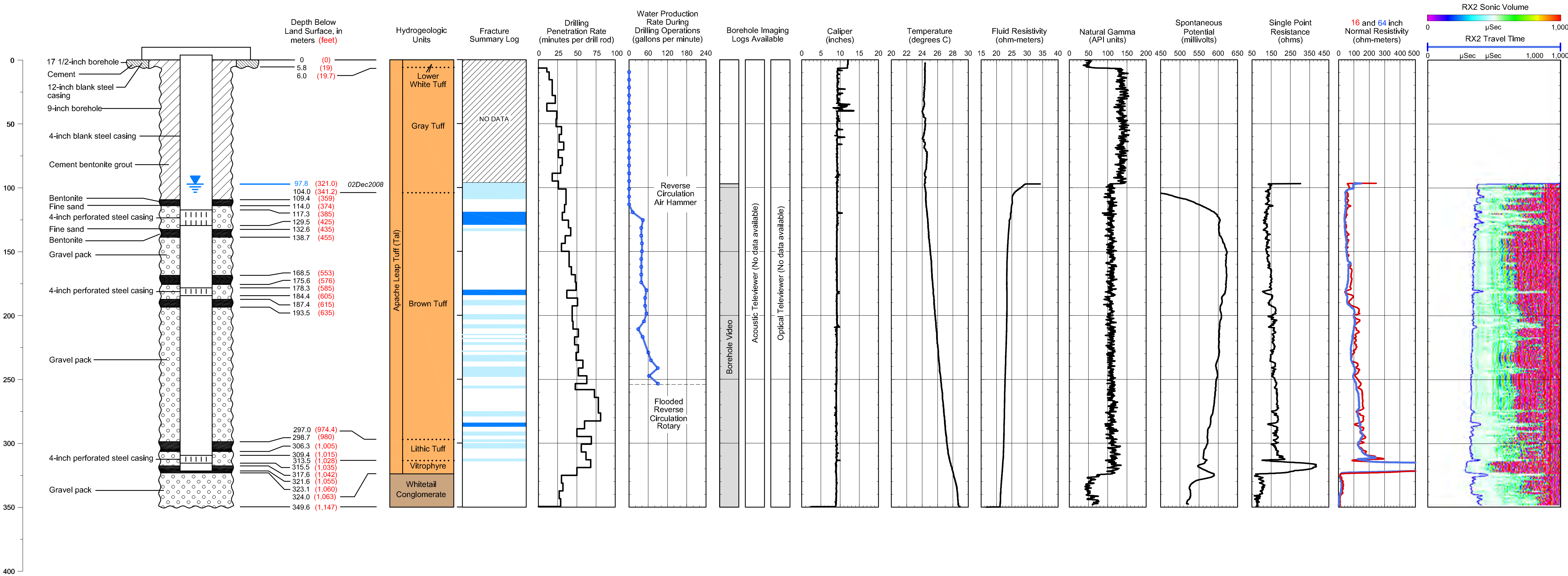
HRES-04
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-6

605\WellSchematics_2009\HRES-4-WS-LOGS-Rev3\17Feb2010



CADASTRAL: (D-2-13) 05ccb	ADWR NO: 55-201848
NORTHING: 3682274.632	EASTING: 495523.291
LAND SURFACE ELEVATION: 1218.30	

DATUM: NAD 27
HORIZONTAL: UTM 12
VERTICAL: NGVD 29 METERS

EXPLANATION

- No Fracturing Evident
- Minor Fracturing
- Moderate Fracturing
- Major Fracturing
- Non-pumping Water Level

Resolution Copper Mining

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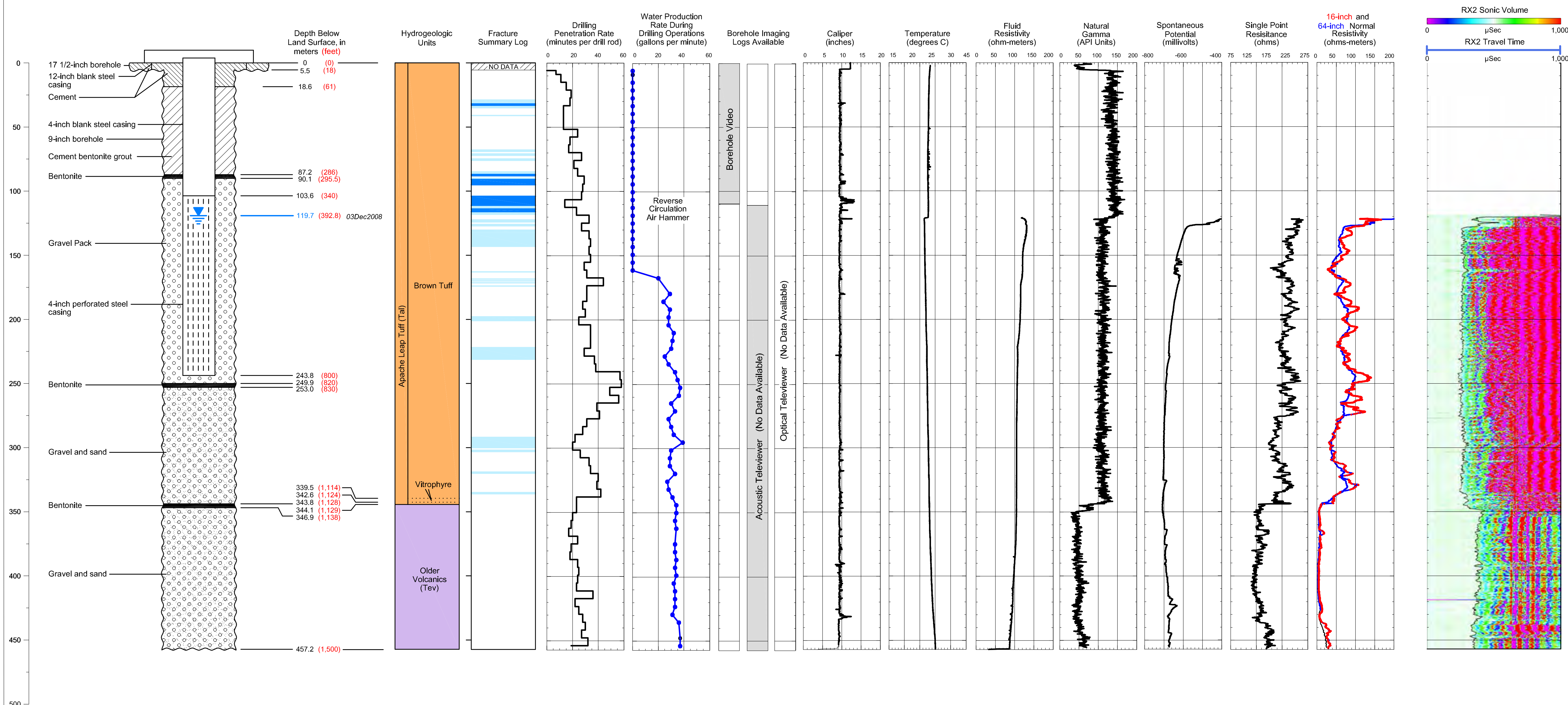
HRES-05
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-7

605\WellSchematics_2009\HRES-5-WS-LOGS-Rev3/17Feb2010



CADASTRAL: (D-1-13) 14dbc	ADWR NO: 55-214967
NORTHING: 3688855.460	EASTING: 499198.671
LAND SURFACE ELEVATION: 1350.36	

DATUM: NAD 27
HORIZONTAL: UTM 12
VERTICAL: NGVD 29 METERS

EXPLANATION

- No Fracturing Evident
- Minor Fracturing
- Moderate Fracturing
- Major Fracturing
- Non-pumping Water Level

Resolution Copper Mining

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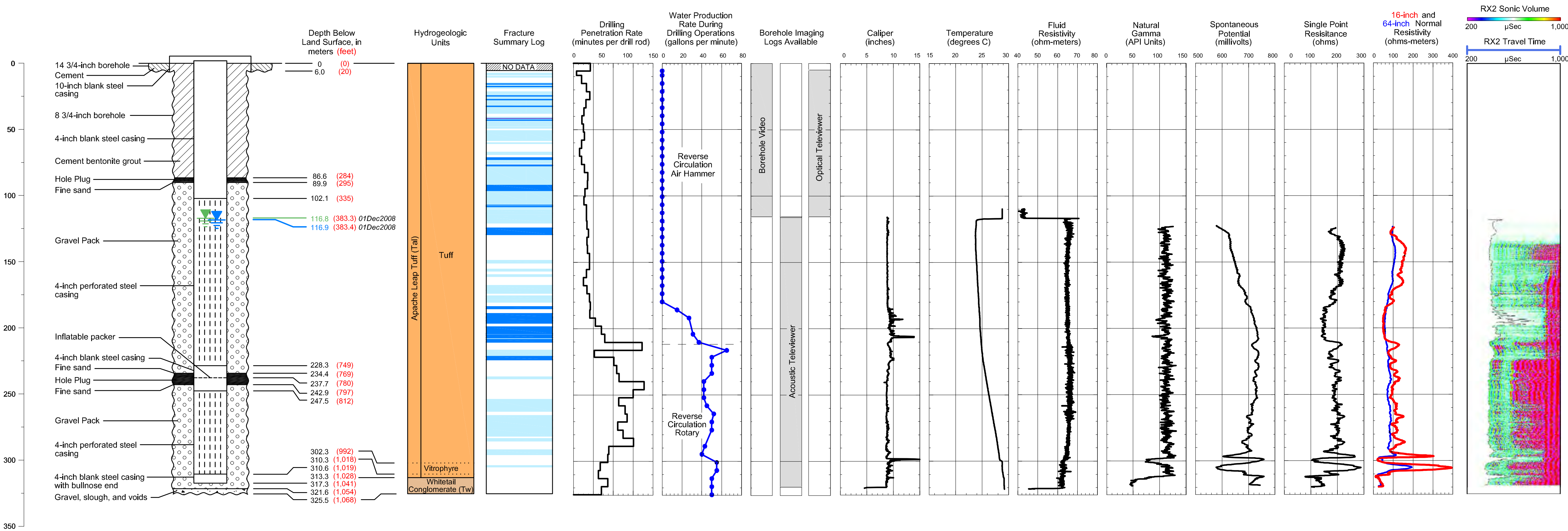
HRES-06
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-8

605\WellSchematics_2009\HRES-6-WS-LOGS-Rev2/17Feb2010



CADASTRAL: (D-2-13) 08aaa	ADWR NO: 55-907947
NORTHING: 3681952.962	EASTING: 496851.233
LAND SURFACE ELEVATION: 1223.31	
DATUM: NAD 27 HORIZONTAL: UTM 12 VERTICAL: NGVD 29 METERS	

EXPLANATION

- No Fracturing Evident
- Minor Fracturing
- Moderate Fracturing
- Major Fracturing
- Shallow Non-pumping Water Level
- Deep Non-pumping Water Level

Resolution Copper Mining

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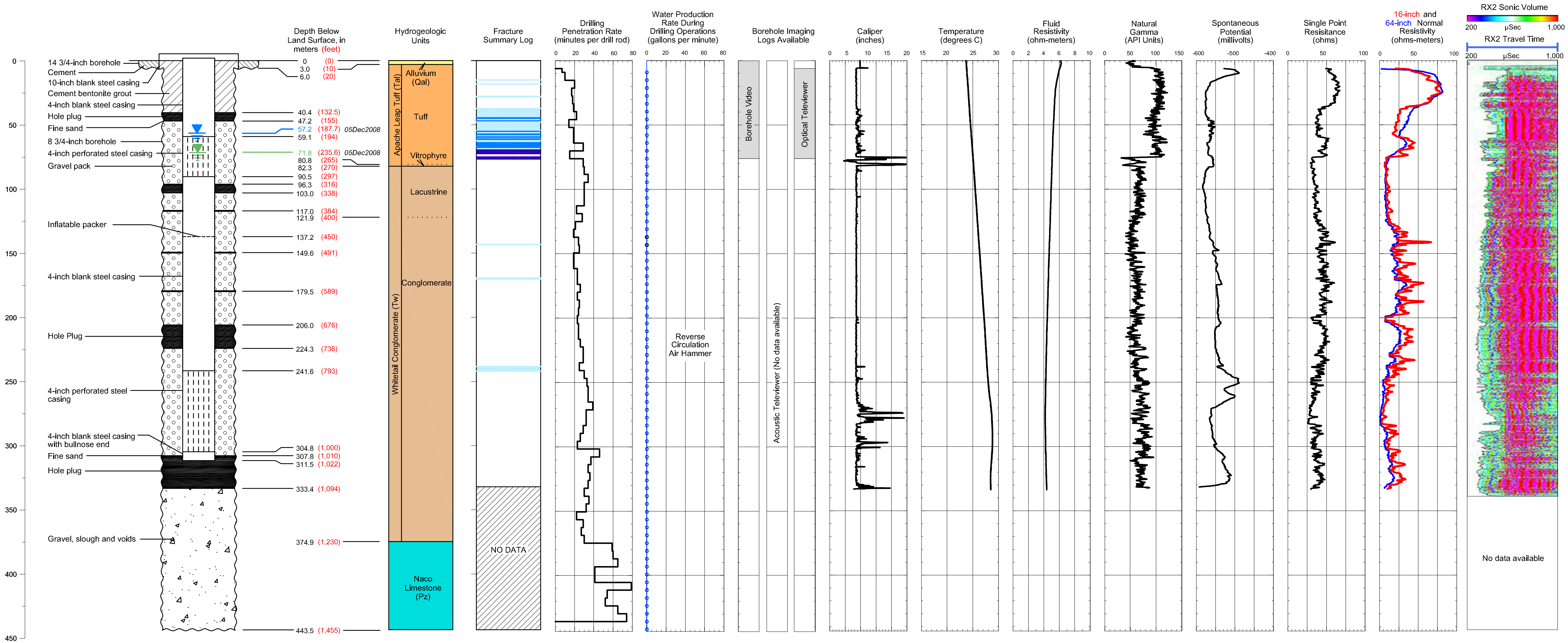
HRES-07
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-9

605\WellSchematics_2009\HRES-7-WS-LOGS-Rev2/17Feb2010



CADASTRAL: (D-2-13) 08cbb	ADWR NO: 55-907946
NORTHING: 3680752.809	EASTING: 495620.021
LAND SURFACE ELEVATION: 1232.70	

DATUM: NAD 27
HORIZONTAL: UTM 12
VERTICAL: NGVD 29 METERS

EXPLANATION

- No Fracturing Evident
- Minor Fracturing
- Moderate Fracturing
- Major Fracturing
- Shallow Non-pumping Water Level
- Deep Non-pumping Water Level

Resolution Copper Mining

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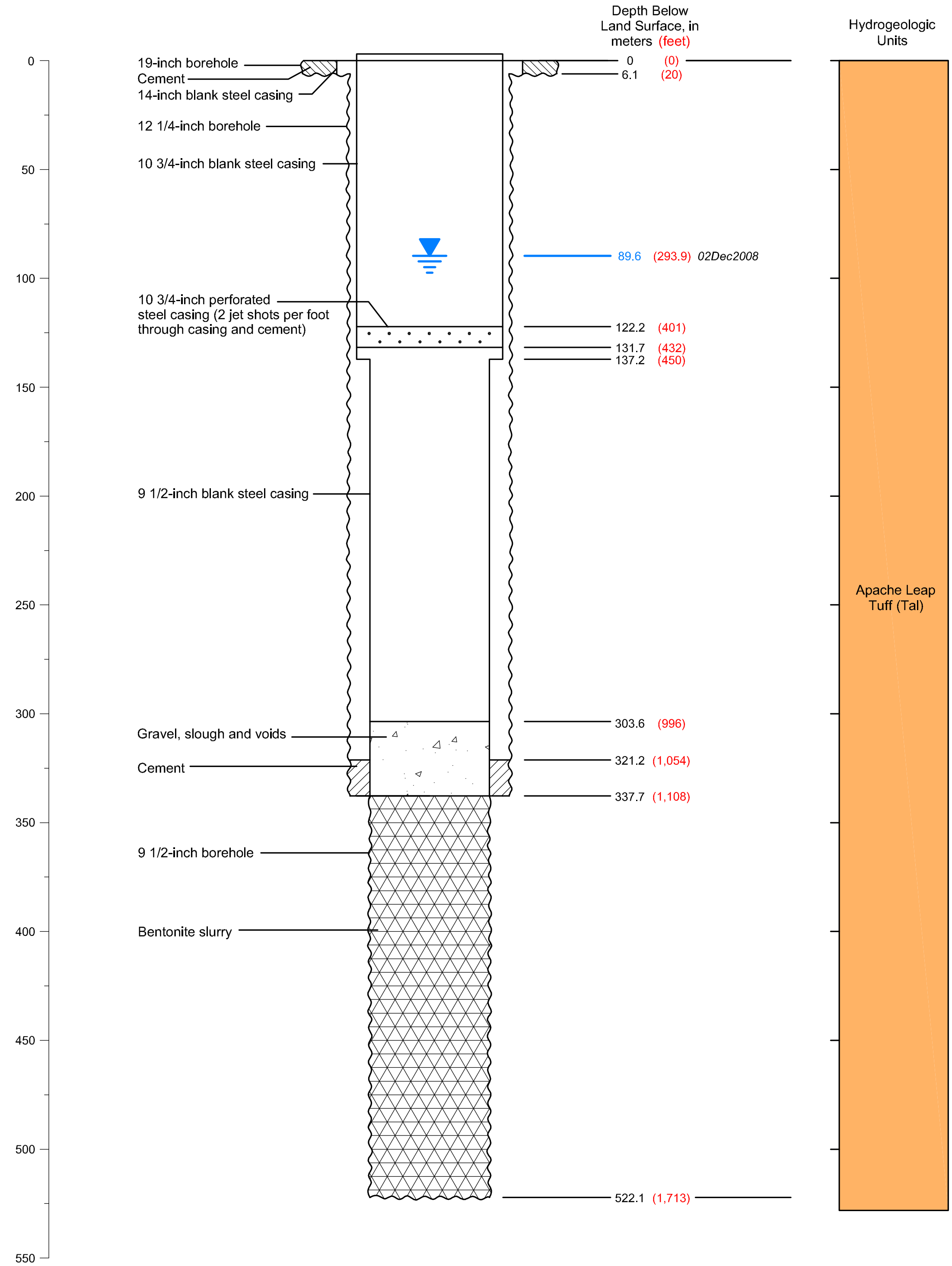
HRES-08
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-10

605\WellSchematics_2009\HRES-8-WS-LOGS-Rev2/17Feb2010



EXPLANATION

Non-pumping Water Level

CADASTRAL: (D-1-13) 29dcc	ADWR NO: 55-526592
NORTHING: 3685360.326	EASTING: 496371.669
LAND SURFACE ELEVATION: 1241.77	

DATUM: NAD 27
HORIZONTAL: UTM 12
VERTICAL: NGVD 29 METERS

Resolution Copper Mining

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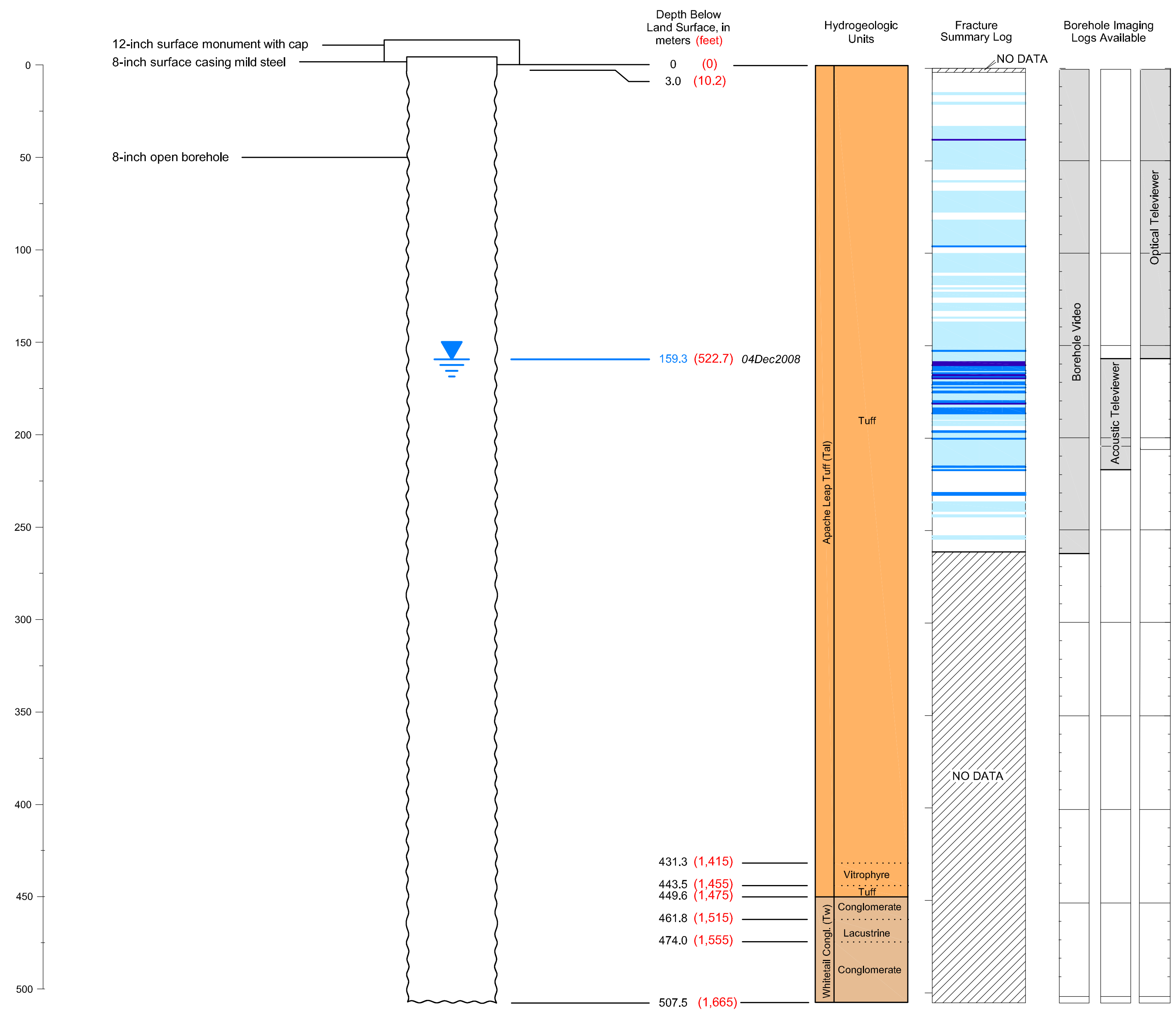
OAK FLAT WELL
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-11



CADASTRAL: (D-2-13) 04bbd	ADWR NO: 55-615241
NORTHING: 3683231.668	EASTING: 497365.707
LAND SURFACE ELEVATION: 1269.61	

DATUM: NAD 27
HORIZONTAL: UTM 12
VERTICAL: NGVD 29 METERS

EXPLANATION

- No Fracturing Evident
- Minor Fracturing
- Moderate Fracturing
- Major Fracturing
- Non-pumping Water Level

Resolution Copper Mining

MONTGOMERY & ASSOCIATES
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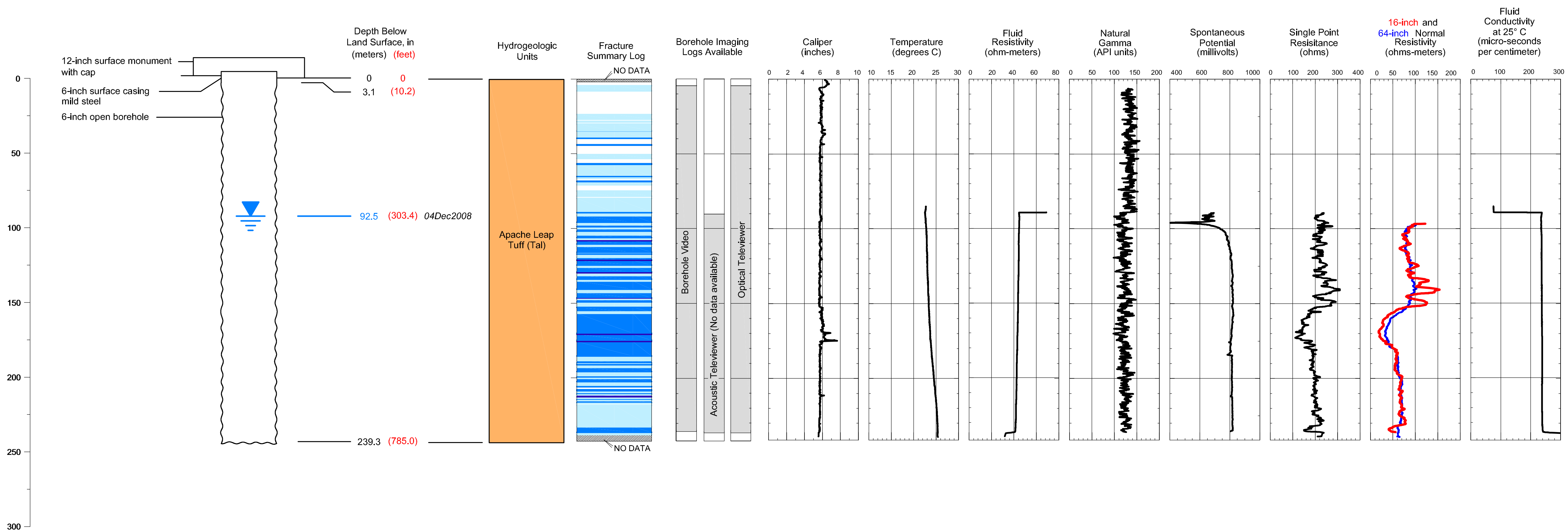
A-06
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-12

605\WellSchematics_2009\04bbd_A06-ws-LOGS-Rev3/17Feb2010



CADASTRAL: (D-2-13) 09abd	ADWR NO: 55-615246
NORTHING: 3681789.236	EASTING: 498075.785
LAND SURFACE ELEVATION: 1193.07	
DATUM: NAD 27 HORIZONTAL: UTM 12 VERTICAL: NGVD 29 METERS	

EXPLANATION

- No Fracturing Evident
- Minor Fracturing
- Moderate Fracturing
- Major Fracturing
- Non-pumping Water Level

Resolution Copper Mining

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MJ-11
SCHEMATIC DIAGRAM OF WELL CONSTRUCTION

Version: February 17, 2010

FIGURE A-13

605\WellSchematics_2009\MJ-11_ws-LOGSrev2/17Feb2010

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APPENDIX B

WATER LEVEL HYDROGRAPHS

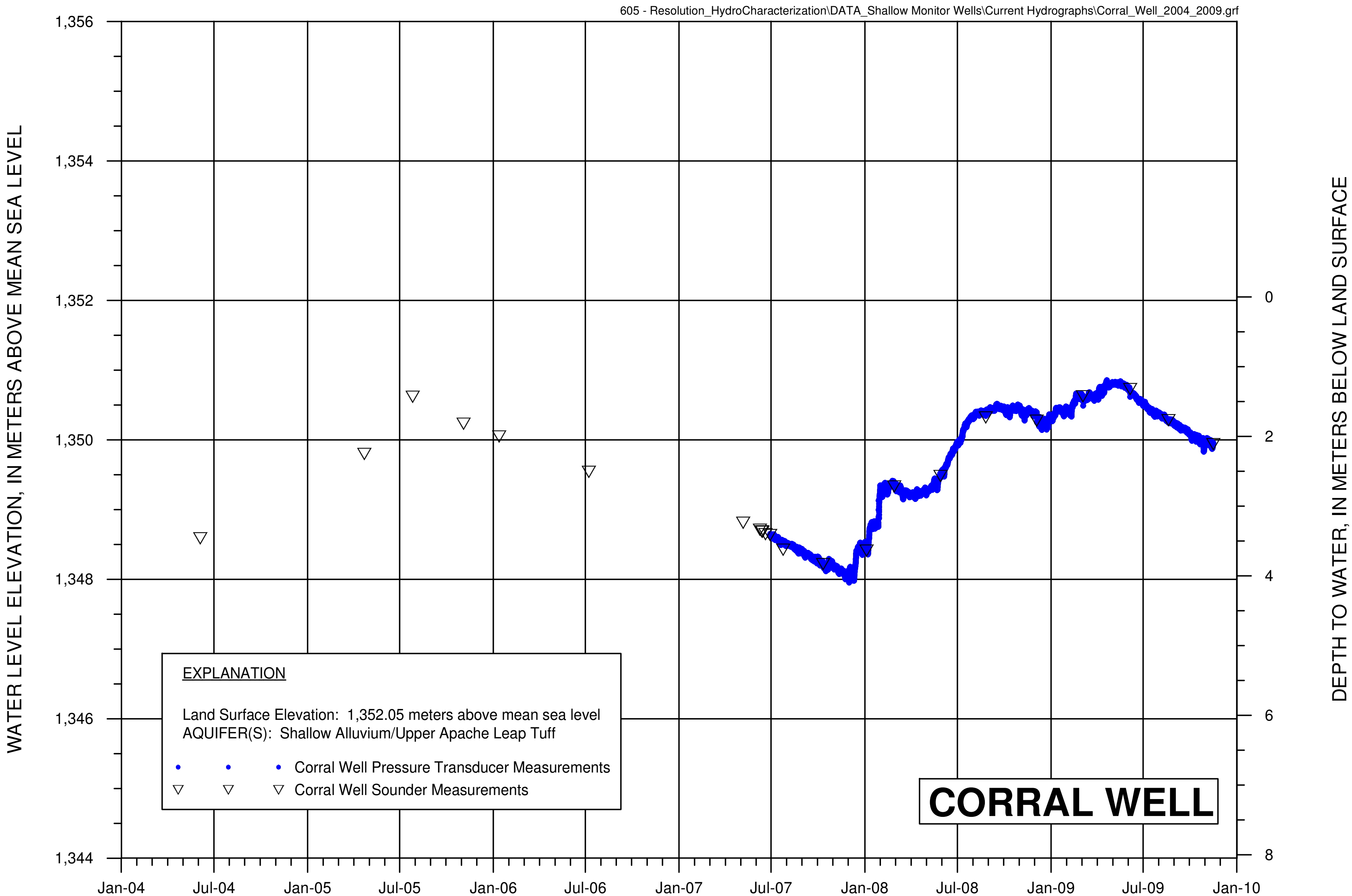

FIGURE B-1. WATER LEVEL HYDROGRAPH FOR CORRAL WELL, YEARS 2004 THROUGH 2009, JI RANCH, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

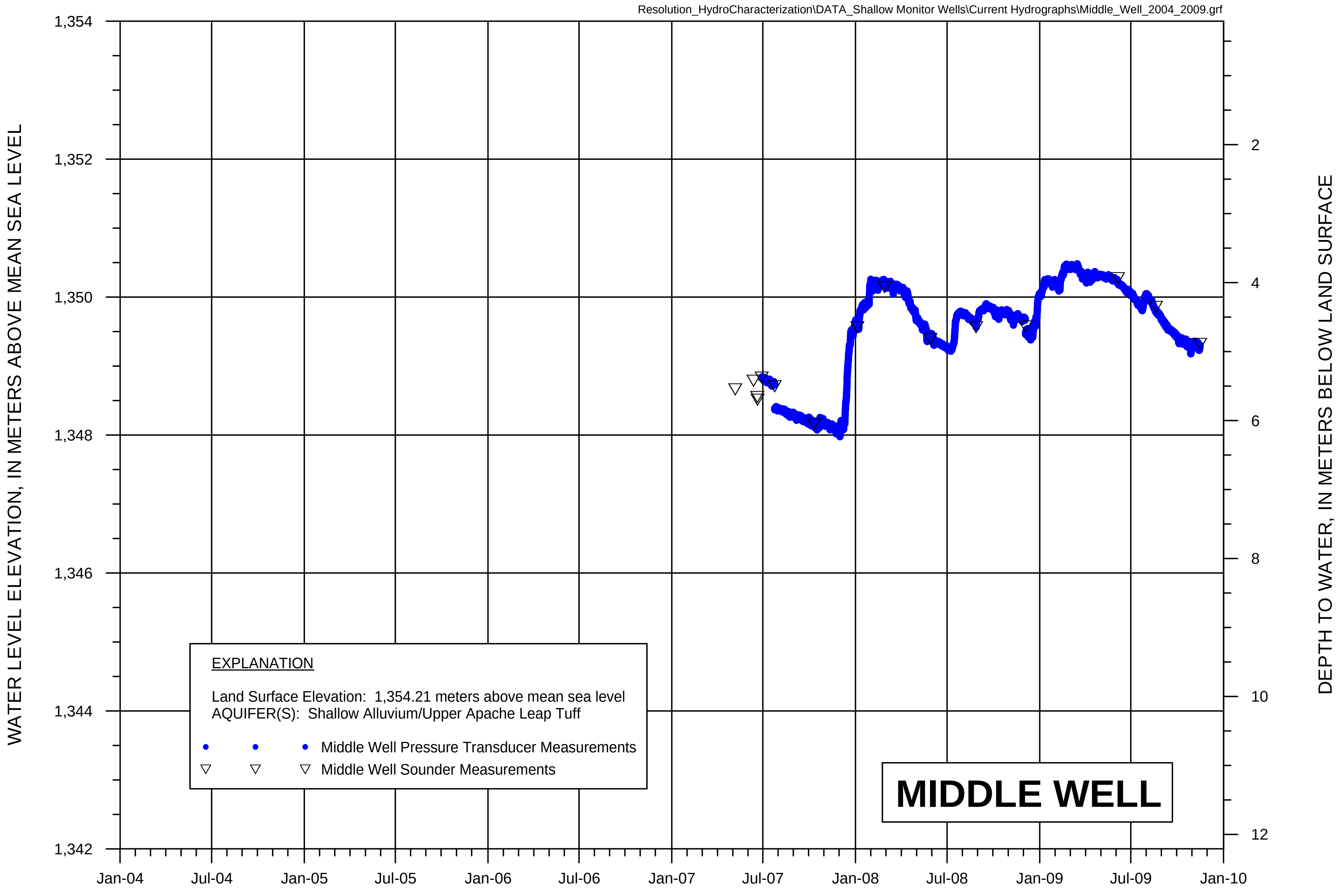

FIGURE B-2. WATER LEVEL HYDROGRAPH FOR MIDDLE WELL, YEARS 2004 THROUGH 2009, JI RANCH, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

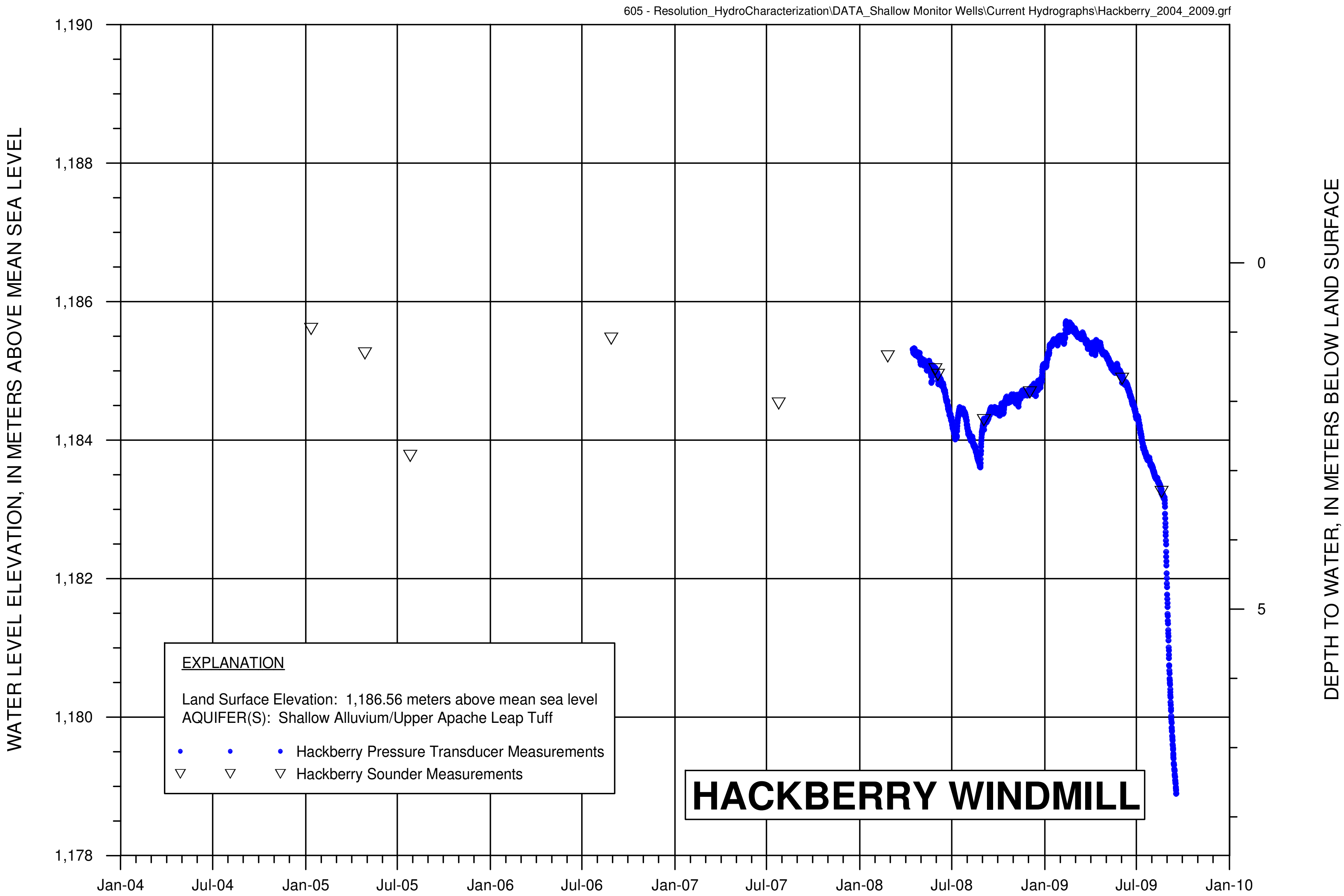

FIGURE B-3. WATER LEVEL HYDROGRAPH FOR HACKBERRY WINDMILL, YEARS 2004 THROUGH 2009, HACKBERRY CANYON, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

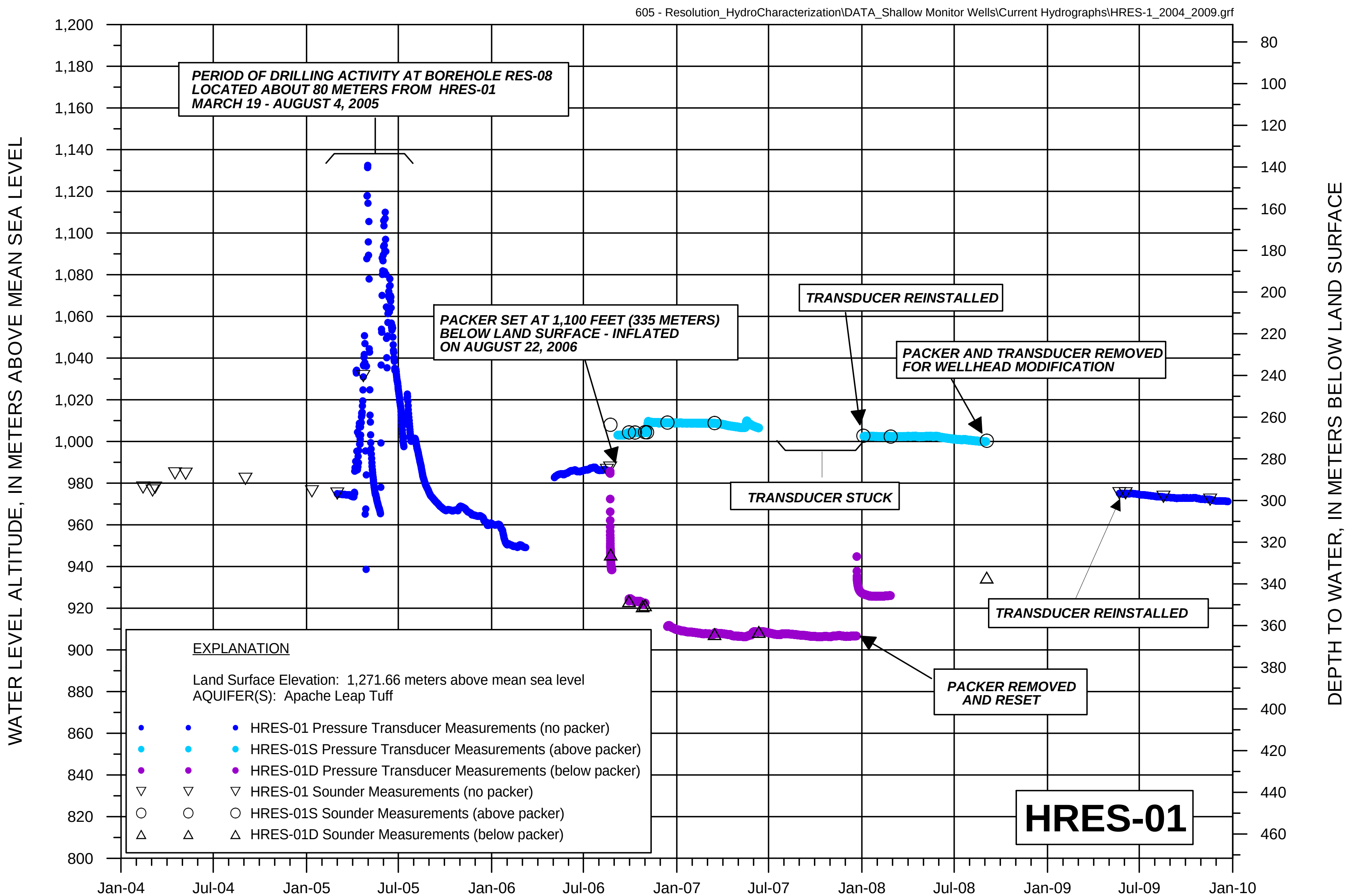

FIGURE B-4. WATER LEVEL HYDROGRAPH FOR HYDROLOGIC TEST WELL HRES-01, YEARS 2004 THROUGH 2009, OAK FLAT AREA, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

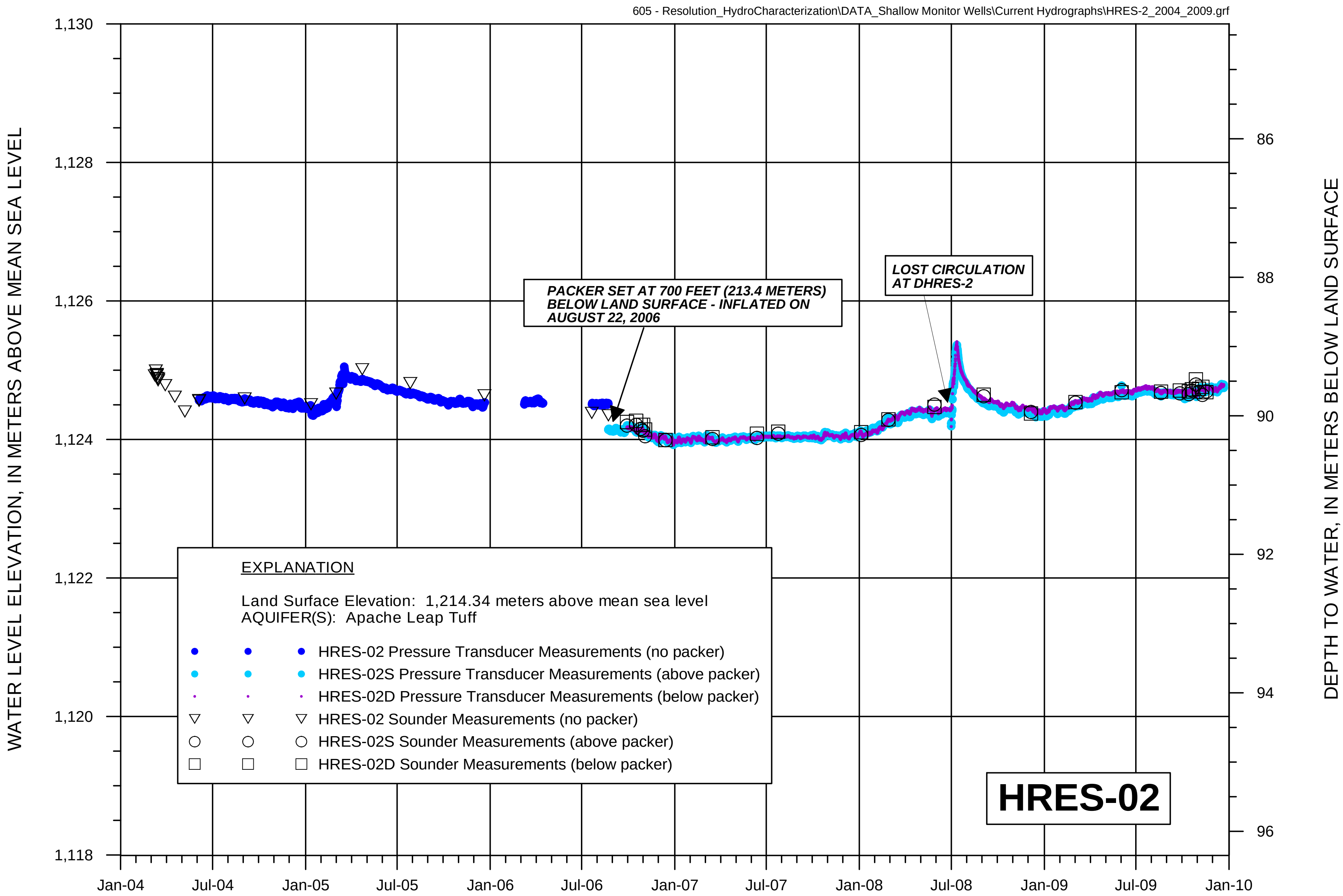

FIGURE B-5. WATER LEVEL HYDROGRAPH FOR HYDROLOGIC TEST WELL HRES-02, YEARS 2004 THROUGH 2009, OAK FLAT AREA, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

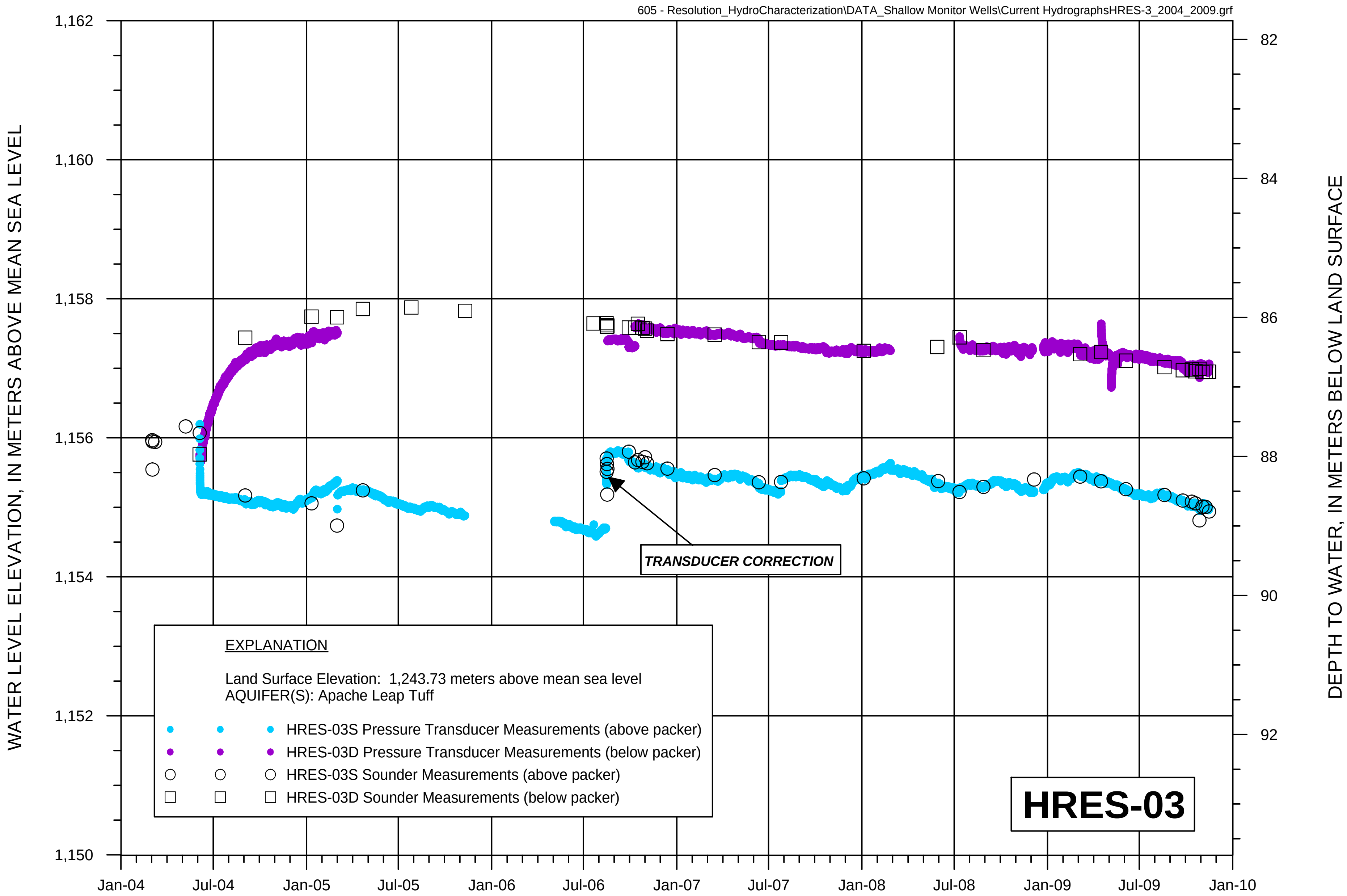

FIGURE B-6. WATER LEVEL HYDROGRAPH FOR HYDROLOGIC TEST WELL HRES-03, YEARS 2004 THROUGH 2009, OAK FLAT AREA, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

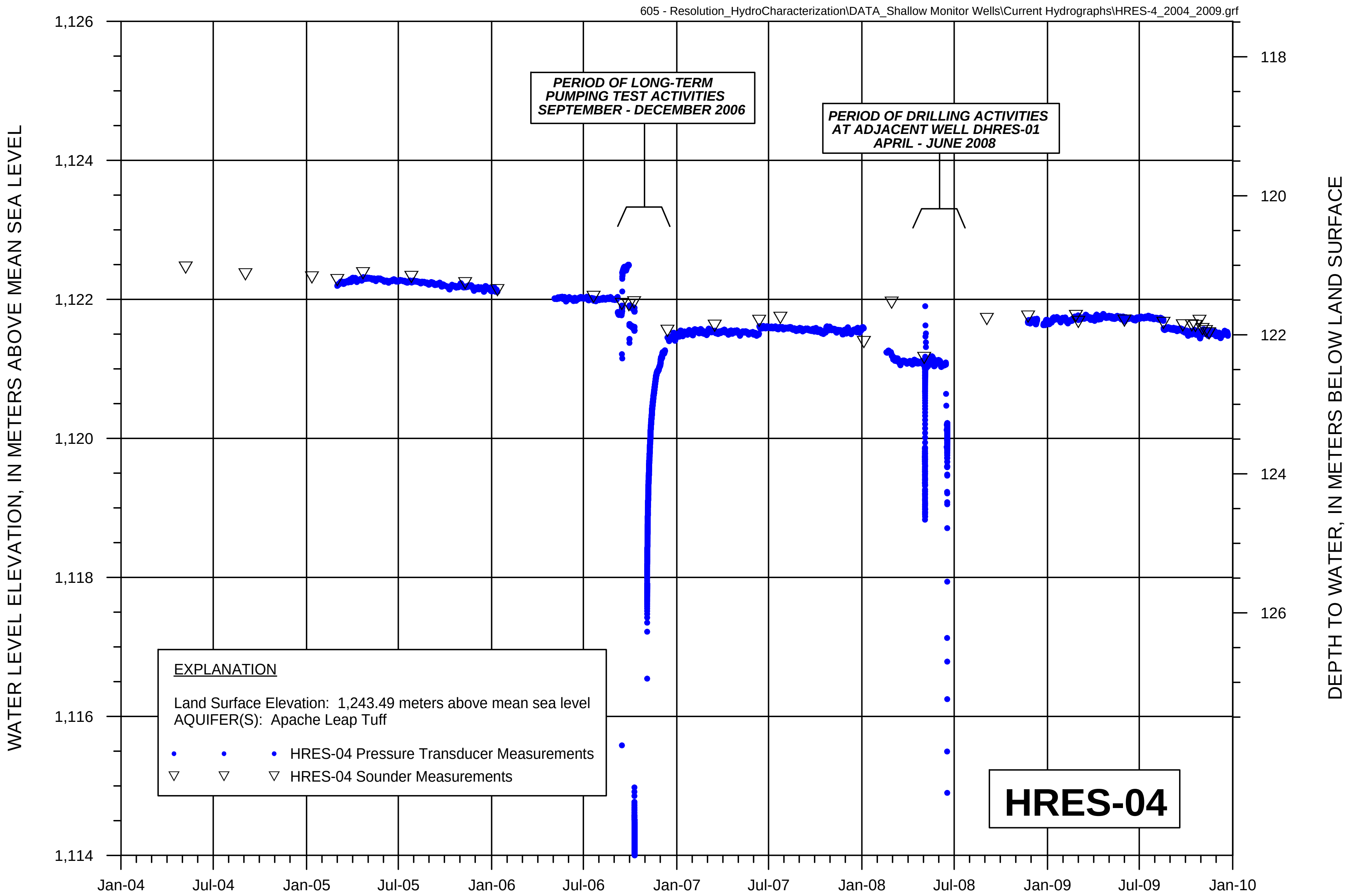

FIGURE B-7. WATER LEVEL HYDROGRAPH FOR HYDROLOGIC TEST WELL HRES-04, YEARS 2004 THROUGH 2009, OAK FLAT AREA, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

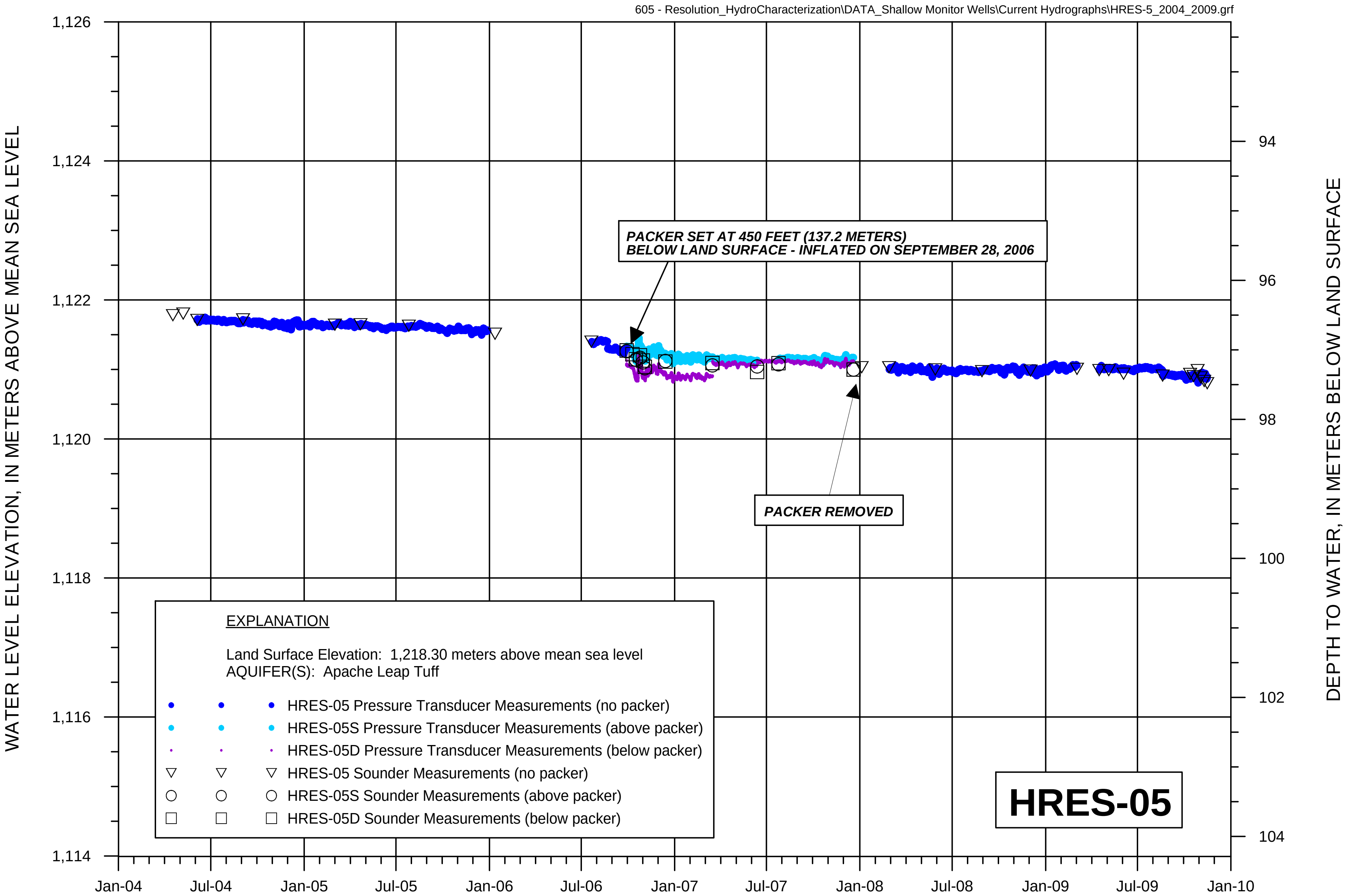

FIGURE B-8. WATER LEVEL HYDROGRAPH FOR HYDROLOGIC TEST WELL HRES-05, YEARS 2004 THROUGH 2009, OAK FLAT AREA, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

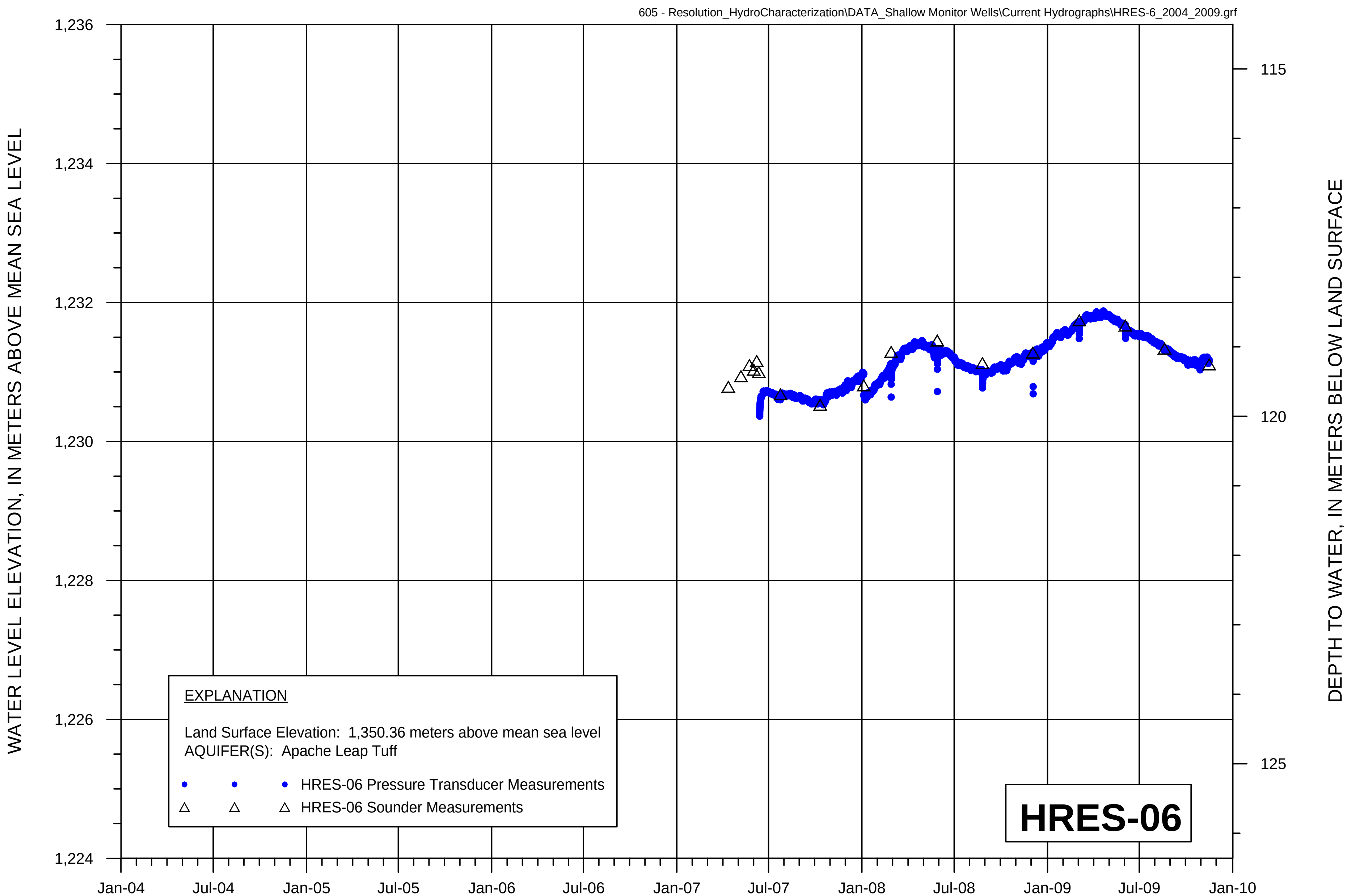

FIGURE B-9. WATER LEVEL HYDROGRAPH FOR HYDROLOGIC TEST WELL HRES-06, YEARS 2004 THROUGH 2009, JI RANCH, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

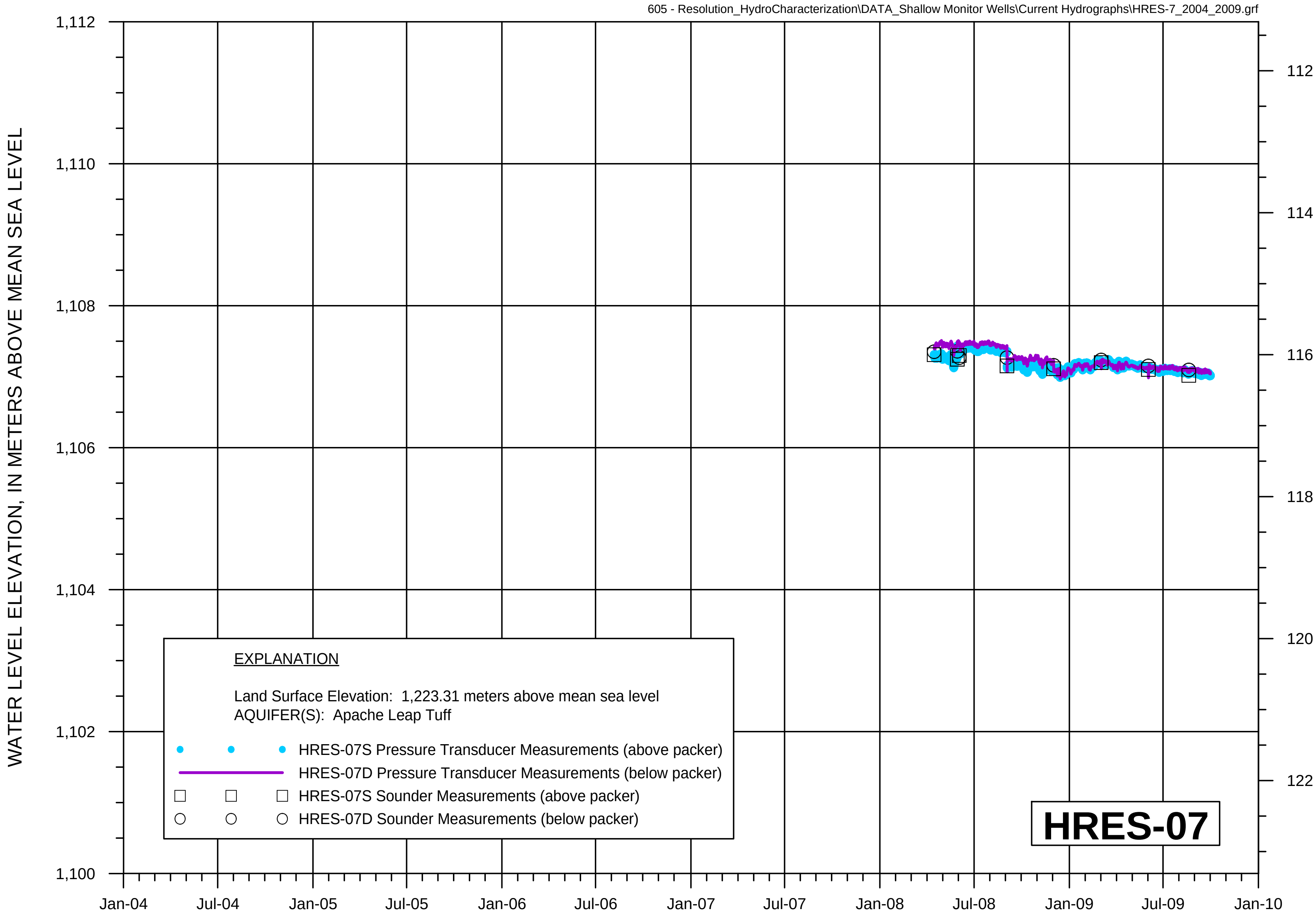

FIGURE B-10. WATER LEVEL HYDROGRAPH FOR HYDROLOGIC TEST WELL HRES-07, YEARS 2004 THROUGH 2009, OAK FLAT AREA, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

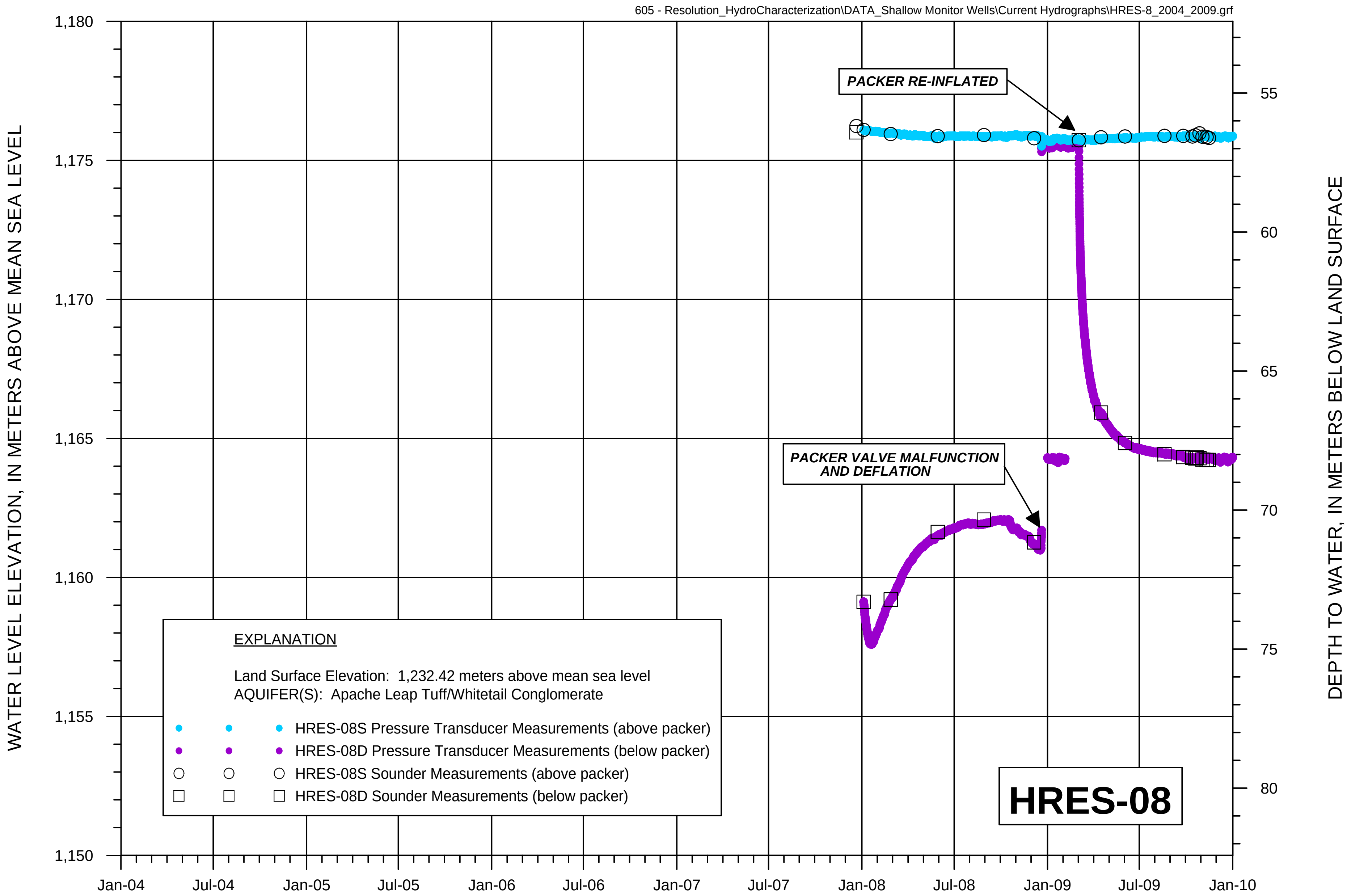

FIGURE B-11. WATER LEVEL HYDROGRAPH FOR HYDROLOGIC TEST WELL HRES-08, YEARS 2004 THROUGH 2009, HACKBERRY CANYON, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

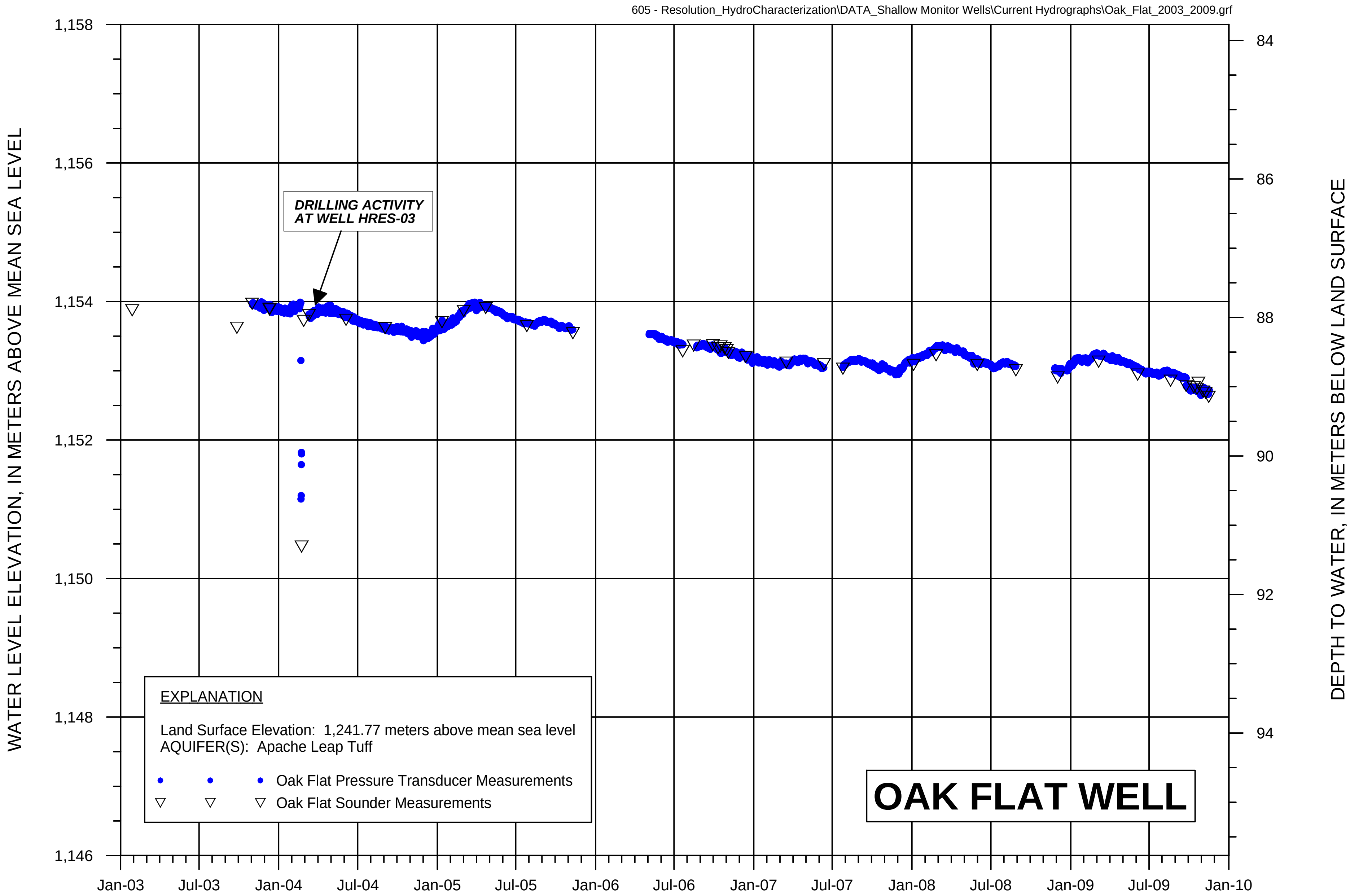

FIGURE B-12. WATER LEVEL HYDROGRAPH FOR OAK FLAT WELL, YEARS 2003 THROUGH 2009, OAK FLAT AREA, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

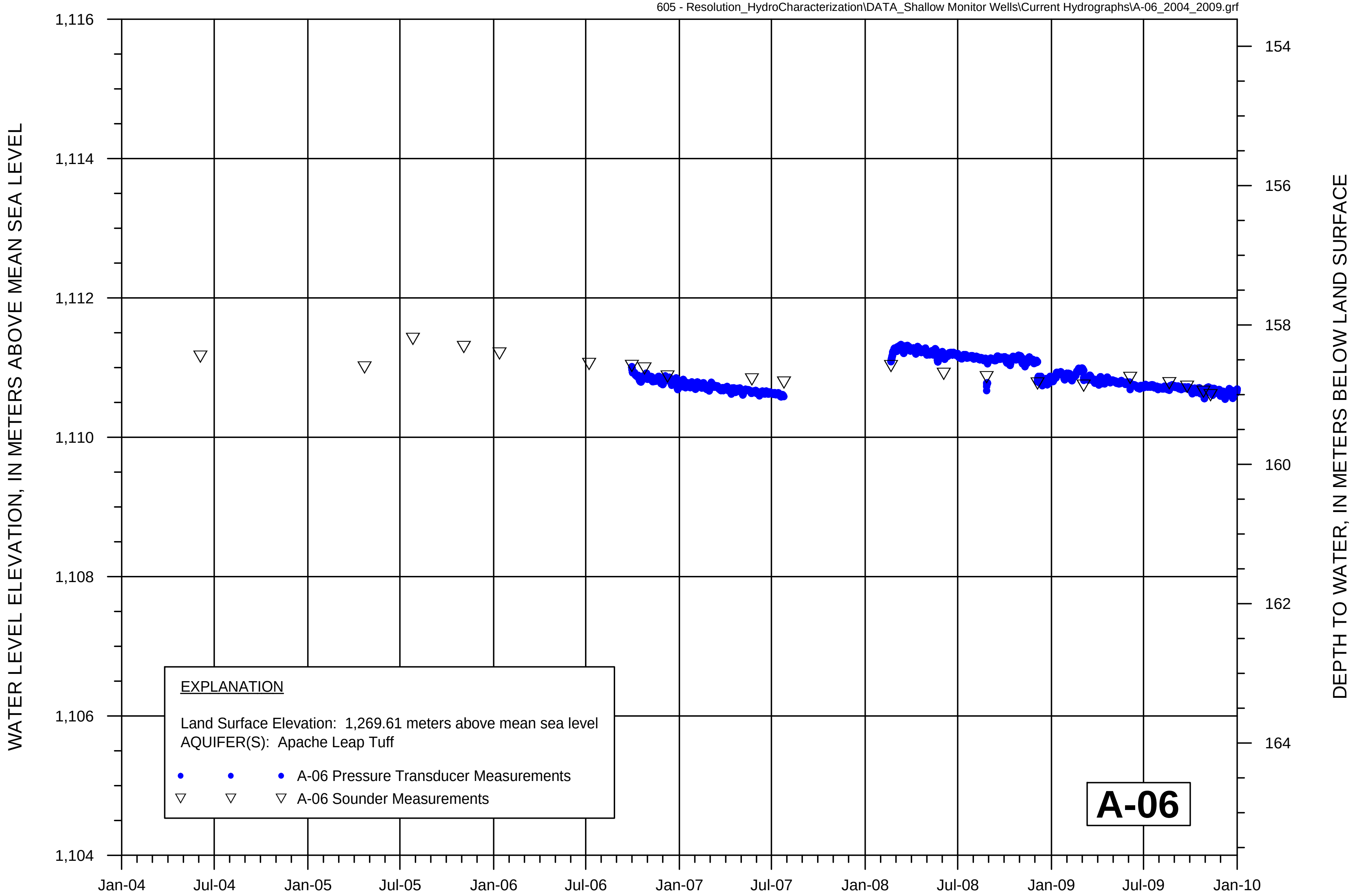

FIGURE B-13. WATER LEVEL HYDROGRAPH FOR WELL A-06, YEARS 2004 THROUGH 2009
EAST DEVIL'S CANYON WATERSHED, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

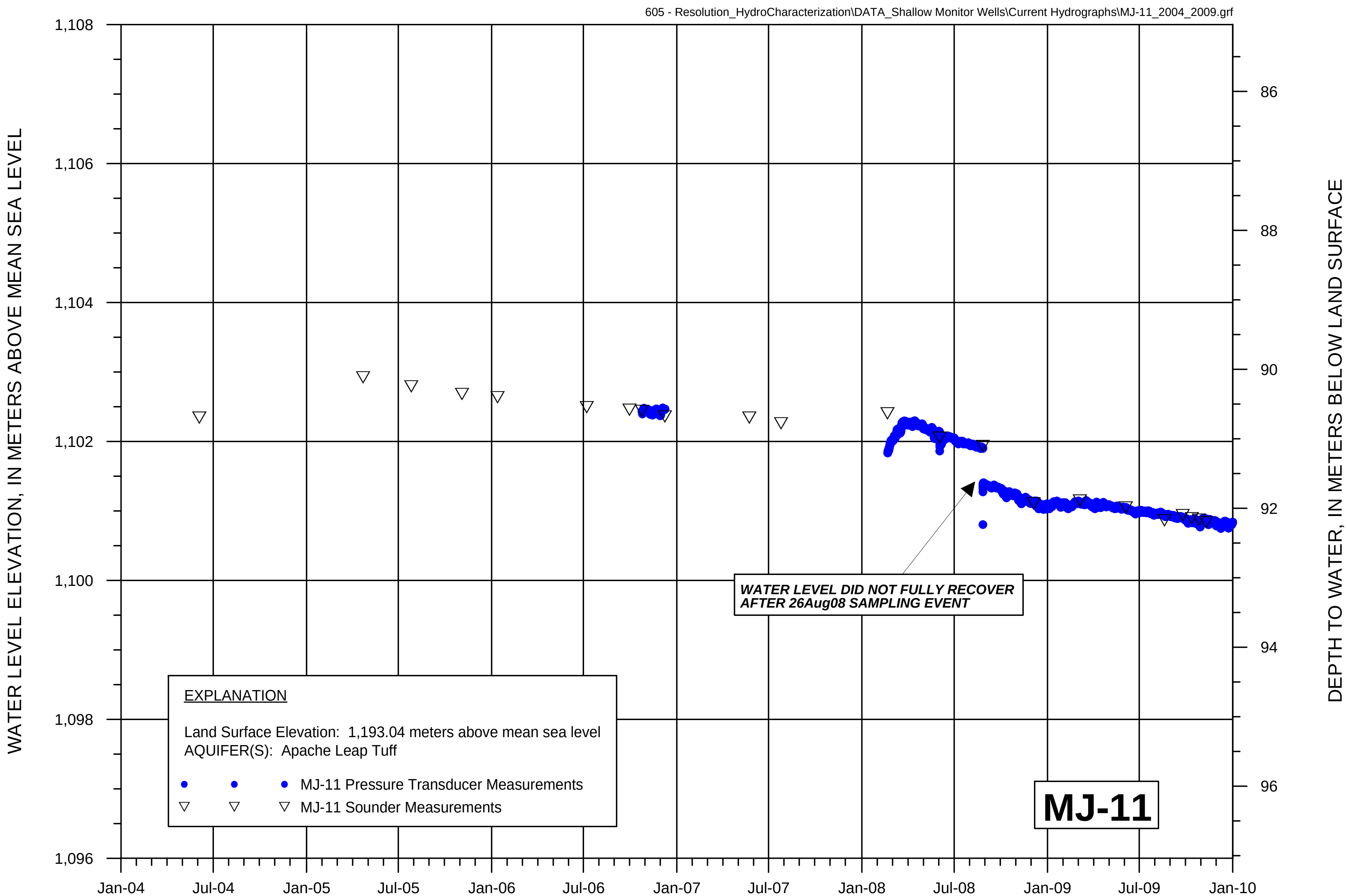

FIGURE B-14. WATER LEVEL HYDROGRAPH FOR WELL MJ-11, YEARS 2004 THROUGH 2009
EAST DEVIL'S CANYON WATERSHED, PINAL COUNTY, ARIZONA

MONTGOMERY & ASSOCIATES

605\DATA_Shallow Monitor Wells\Current Hydrographs\FigB15_WL_HYD_RES2-4_Shaft9_3_1998_2009_G4.grf

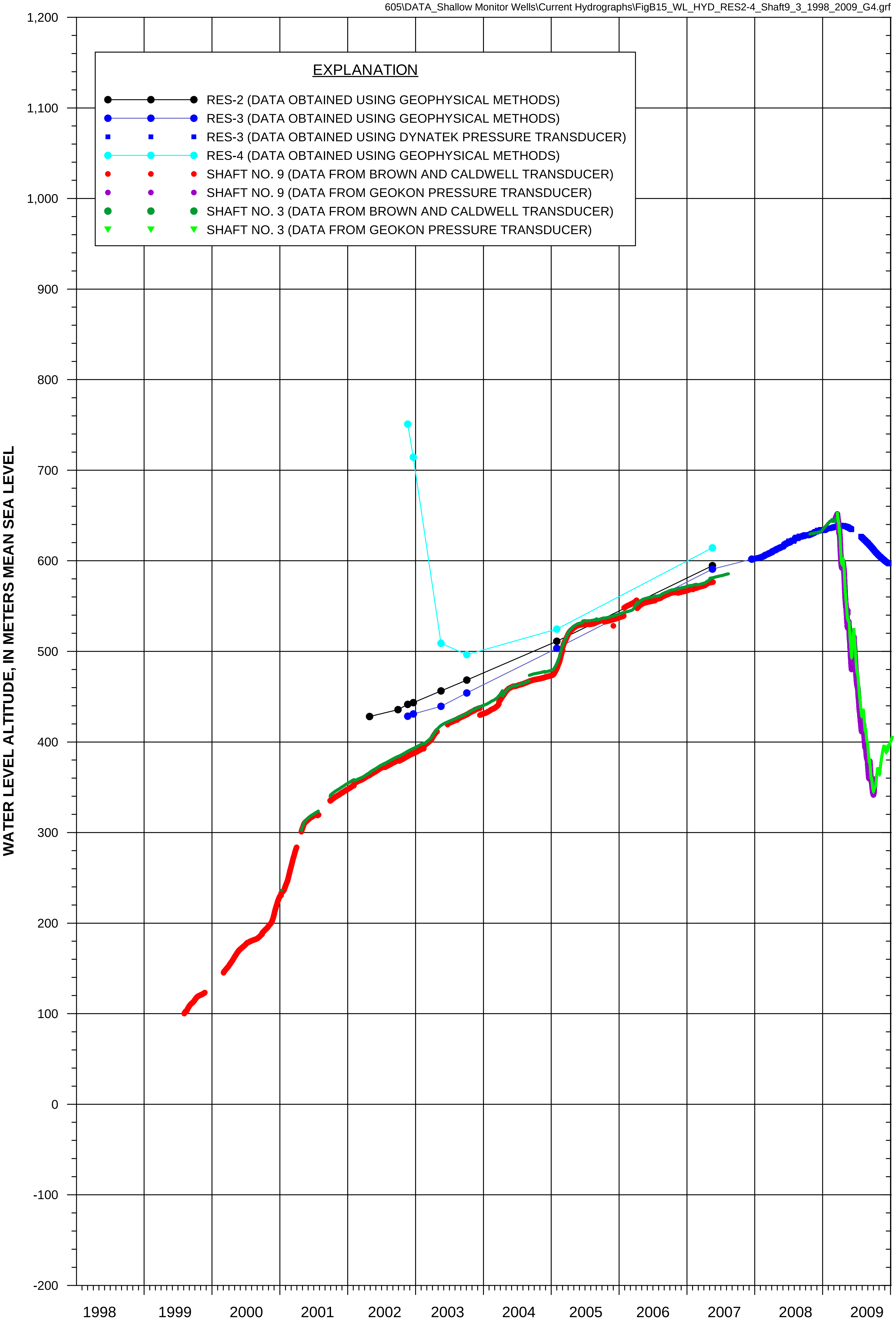

FIGURE B-15. WATER LEVEL HYDROGRAPH FOR DEEP GROUNDWATER SYSTEM AT EXPLORATION BOREHOLES RES-2, RES-3, AND RES-4, AND SHAFTS NO. 9 AND NO. 3, RESOLUTION PROJECT

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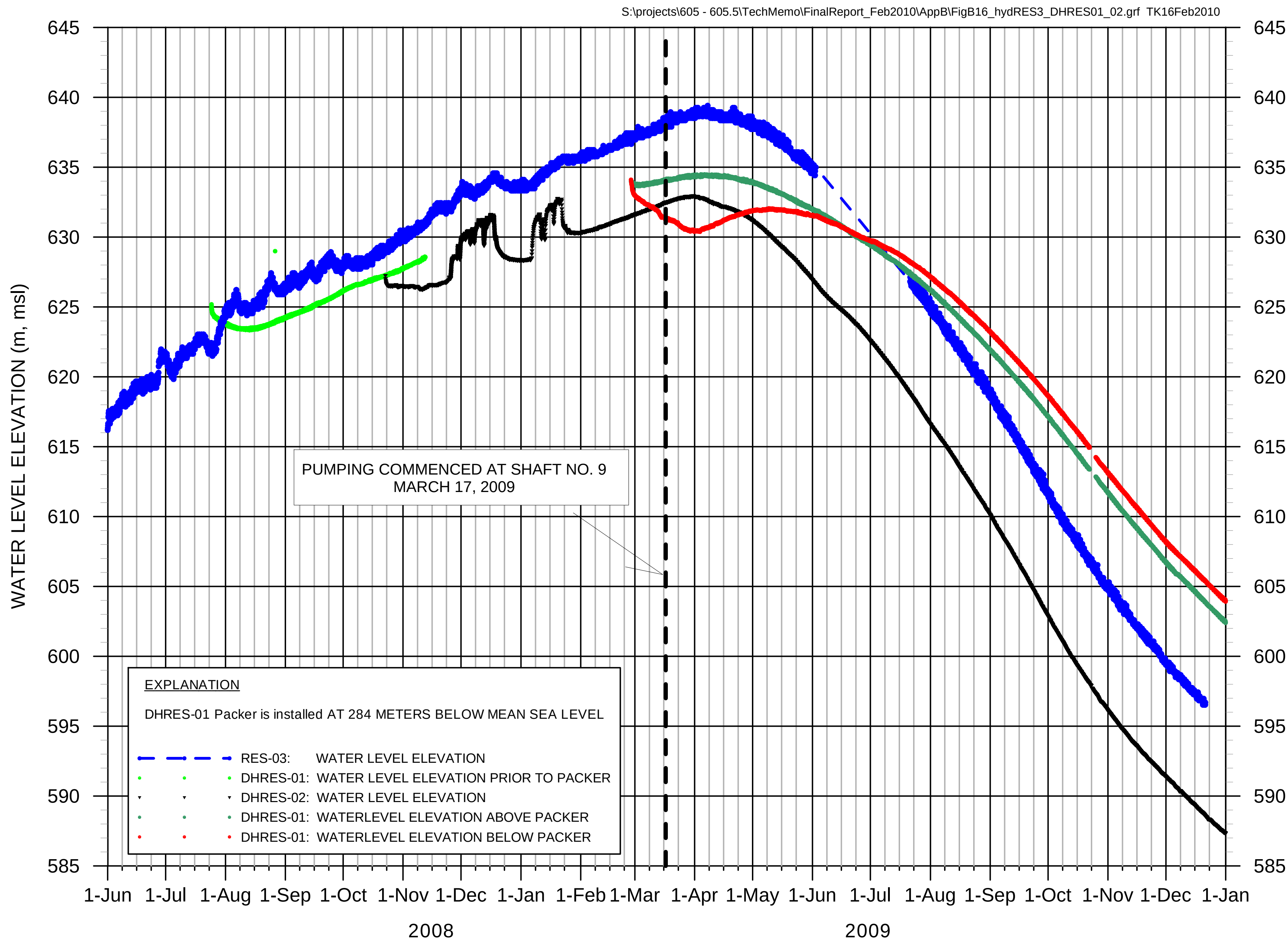

FIGURE B-16. WATER LEVEL HYDROGRAPHS FOR DEEP GROUNDWATER SYSTEM AT DHRES-01, DHRES-02, AND RES-03, RESOLUTION PROJECT

MONTGOMERY & ASSOCIATES

APPENDIX C

WATER LEVEL DATA

TABLE C-1. SUMMARY OF WATER LEVEL DATA IN OAK FLAT AREA, GROUNDWATER MONITORING PROGRAM RESOLUTION COPPER MINING LLC, PINAL COUNTY, ARIZONA

WELL IDENTIFIER	WELL COORDINATES[a]		LAND SURFACE ELEVATION	MEASURING POINT ELEVATION	DATE MEASURED	DEPTH TO WATER	DEPTH TO WATER	WATER LEVEL ELEVATION
	Easting	Northing	(m, amsl)[b]	(m, amsl)		(m, bmp)[c]	(ft, bmp)[d]	(m, amsl)
SHALLOW AQUIFER WELLS								
MIDDLE WELL	499,349	3,688,778	1,354.21	1,354.63	7-May-2007	5.97	19.59	1,348.66
					12-Jun-2007	5.85	19.18	1,348.78
					19-Jun-2007	6.08	19.95	1,348.55
					20-Jun-2007	6.12	20.08	1,348.51
					28-Jun-2007	5.80	19.03	1,348.83
					24-Jul-2007	5.93	19.44	1,348.70
					10-Oct-2007	6.47	21.23	1,348.16
					4-Jan-2008	5.07	16.64	1,349.56
					27-Feb-2008	4.49	14.73	1,350.14
					28-May-2008	5.24	17.20	1,349.39
					27-Aug-2008	5.07	16.64	1,349.56
					3-Dec-2008	5.06	16.60	1,349.57
					5-Jun-2009	4.36	14.30	1,350.27
CORRAL WELL	499,377	3,688,841	1,352.05	1,352.396	4-Jun-2004	3.81	12.50	1,348.59
					22-Apr-2005	2.60	8.53	1,349.80
					26-Jul-2005	1.78	5.84	1,350.62
					3-Nov-2005	2.17	7.10	1,350.23
					12-Jan-2006	2.35	7.71	1,350.05
					7-Jul-2006	2.86	9.37	1,349.54
					7-May-2007	3.59	11.77	1,348.81
					8-Jun-2007	3.69	12.10	1,348.71
					12-Jun-2007	3.71	12.18	1,348.68
					13-Jun-2007	3.72	12.20	1,348.68
					19-Jun-2007	3.75	12.30	1,348.65
					28-Jun-2007	3.76	12.35	1,348.63
					24-Jul-2007	3.97	13.04	1,348.42
				1,352.50	10-Oct-2007	4.28	14.05	1,348.22
					4-Jan-2008	4.09	13.41	1,348.41
					27-Feb-2008	3.17	10.39	1,349.33
					28-May-2008	3.02	9.90	1,349.48
					25-Aug-2008	2.18	7.14	1,350.32
					3-Dec-2008	2.23	7.30	1,350.27
					4-Mar-2009	1.87	6.15	1,350.63
					5-Jun-2009	1.77	5.81	1,350.73
HACKBERRY WINDMILL	496,326	3,681,544	1,186.44	1,186.52	29-Jan-2003	11.10	36.42	1,175.42
					11-Jan-2005	0.92	3.01	1,185.60
					28-Apr-2005	1.27	4.17	1,185.25
					26-Jul-2005	2.75	9.02	1,183.77
					27-Aug-2006	1.06	3.47	1,185.46
					24-Jul-2007	1.99	6.54	1,184.53
					25-Feb-2008	1.32	4.32	1,185.20
				1,187.12	29-May-2008	2.10	6.89	1,185.02
					3-Jun-2008	2.18	7.15	1,184.94
					2-Sep-2008	2.83	9.30	1,184.29
					2-Dec-2008	2.44	7.99	1,184.68
					2-Jun-2009	2.24	7.34	1,184.88
APACHE LEAP TUFF AQUIFER WELLS								
HRES-01	493,715	3,684,732	1,271.66	1,271.66	13-Feb-2004	294.43	965.96	977.23
					3-Mar-2004	295.83	970.58	975.82
					8-Mar-2004	294.48	966.15	977.17
					16-Apr-2004	287.68	943.82	983.98
					7-May-2004	287.80	944.26	983.86
					2-Sep-2004	290.24	952.28	981.42
					11-Jan-2005	296.26	972.03	975.40
					2-Mar-2005	297.32	975.52	974.33
					22-Apr-2005	240.99	790.67	1,030.67
					16-Aug-2006	285.98	938.25	985.68
					22-Aug-2006	284.88	934.64	986.78
				1,272.60	22-May-2009	297.47	975.94	975.14
					3-Jun-2009	297.56	976.23	975.04

TABLE C-1. SUMMARY OF WATER LEVEL DATA IN OAK FLAT AREA, GROUNDWATER MONITORING PROGRAM
RESOLUTION COPPER MINING LLC, PINAL COUNTY, ARIZONA

WELL IDENTIFIER	WELL COORDINATES[a]		LAND SURFACE ELEVATION	MEASURING POINT ELEVATION	DATE MEASURED	DEPTH TO WATER	DEPTH TO WATER	WATER LEVEL ELEVATION
	Easting	Northing	(m, amsl)[b]	(m, amsl)		(m, bmp)[c]	(ft, bmp)[d]	(m, amsl)
HRES-01S	493,715	3,684,732	1271.656	1,272.34	23-Aug-2006	264.32	867.18	1,008.03
					28-Sep-2006	267.99	879.23	1,004.35
					10-Oct-2006	268.08	879.54	1,004.26
					30-Oct-2006	267.88	878.88	1,004.46
					3-Nov-2006	267.96	879.14	1,004.38
					13-Dec-2006	263.29	863.80	1,009.06
					16-Mar-2007	263.44	864.32	1,008.90
					4-Jan-2008	269.61	884.55	1,002.73
					26-Feb-2008	270.03	885.93	1,002.31
					3-Sep-2008	271.98	892.32	1,000.36
HRES-01D	493,715	3,684,732	1271.656	1,272.36	23-Aug-2006	326.52	1,071.25	945.84
					28-Sep-2006	348.90	1,144.67	923.46
					25-Oct-2006	351.37	1,152.79	920.99
					30-Oct-2006	350.86	1,151.10	921.50
					13-Aug-2006	361.17	1,184.94	911.19
					16-Mar-2007	364.69	1,196.50	907.67
					11-Jun-2007	363.65	1,193.08	908.71
					24-Jul-2007	365.11	1,197.88	907.25
					3-Sep-2008	337.55	1,107.44	934.81
HRES-02	494,479	3,683,886	1,214.344	1,214.87	8-Mar-2004	89.95	295.11	1,124.92
					10-Mar-2004	89.88	294.88	1,124.99
					12-Mar-2004	89.93	295.05	1,124.94
					12-Mar-2004	89.95	295.10	1,124.92
					12-Mar-2004	89.95	295.10	1,124.92
					12-Mar-2004	89.93	295.05	1,124.94
					13-Mar-2004	89.99	295.23	1,124.88
					15-Mar-2004	90.02	295.35	1,124.85
					15-Mar-2004	90.00	295.27	1,124.87
					29-Mar-2004	90.09	295.58	1,124.78
					17-Apr-2004	90.26	296.12	1,124.61
					7-May-2004	90.47	296.82	1,124.40
					4-Jun-2004	90.31	296.28	1,124.56
					4-Jun-2004	90.32	296.31	1,124.55
					2-Sep-2004	90.29	296.21	1,124.59
					11-Jan-2005	90.37	296.47	1,124.50
					2-Mar-2005	90.22	295.98	1,124.66
					22-Apr-2005	89.86	294.82	1,125.01
					26-Jul-2005	90.06	295.48	1,124.81
					21-Jul-2006	90.49	296.89	1,124.38
					22-Aug-2006	90.53	297.00	1,124.34
HRES-02S	494,479	3,683,886	1,214.344	1,214.79	28-Sep-2006	90.59	297.20	1,124.20
					16-Oct-2006	90.57	297.16	1,124.22
					25-Oct-2006	90.63	297.35	1,124.16
					30-Oct-2006	90.66	297.44	1,124.13
					3-Nov-2006	90.74	297.70	1,124.05
					13-Dec-2006	90.80	297.89	1,123.99
					16-Mar-2007	90.78	297.83	1,124.01
					12-Jun-2007	90.76	297.78	1,124.03
					24-Jul-2007	90.70	297.58	1,124.09
					4-Jan-2008	90.72	297.64	1,124.07
					27-Feb-2008	90.50	296.93	1,124.29
					28-May-2008	90.28	296.20	1,124.51
					2-Sep-2008	90.16	295.81	1,124.63
					5-Dec-2008	90.39	296.55	1,124.40
					3-Mar-2009	90.25	296.11	1,124.54
					2-Jun-2009	90.07	295.52	1,124.72

TABLE C-1. SUMMARY OF WATER LEVEL DATA IN OAK FLAT AREA, GROUNDWATER MONITORING PROGRAM
RESOLUTION COPPER MINING LLC, PINAL COUNTY, ARIZONA

WELL IDENTIFIER	WELL COORDINATES[a]		LAND SURFACE ELEVATION	MEASURING POINT ELEVATION	DATE MEASURED	DEPTH TO WATER	DEPTH TO WATER	WATER LEVEL ELEVATION
	Easting	Northing	(m, amsl)[b]	(m, amsl)		(m, bmp)[c]	(ft, bmp)[d]	(m, amsl)
HRES-02D	494,479	3,683,886	1,214.344	1,214.84	28-Sep-2006	90.59	297.20	1,124.25
					16-Oct-2006	90.57	297.14	1,124.27
					25-Oct-2006	90.63	297.33	1,124.21
					30-Oct-2006	90.63	297.33	1,124.21
					3-Nov-2006	90.69	297.55	1,124.14
					13-Dec-2006	90.85	298.05	1,123.99
					16-Mar-2007	90.81	297.92	1,124.03
					12-Jun-2007	90.75	297.75	1,124.08
					24-Jul-2007	90.73	297.66	1,124.11
					4-Jan-2008	90.73	297.68	1,124.11
					27-Feb-2008	90.55	297.07	1,124.29
					28-May-2008	90.37	296.48	1,124.47
					2-Sep-2008	90.19	295.90	1,124.65
					5-Dec-2008	90.46	296.79	1,124.38
					3-Mar-2009	90.30	296.25	1,124.54
					2-Jun-2009	90.16	295.79	1,124.68
HRES-03S	496,382	3,685,328	1,243.728	1,244.33	2-Mar-2004	88.36	289.89	1,155.97
					3-Mar-2004	88.38	289.95	1,155.95
					3-Mar-2004	88.78	291.28	1,155.55
					8-Mar-2004	88.39	289.98	1,155.94
					7-May-2004	88.16	289.24	1,156.17
					4-Jun-2004	88.26	289.55	1,156.07
					2-Sep-2004	89.16	292.50	1,155.18
					11-Jan-2005	89.27	292.87	1,155.06
					2-Mar-2005	89.59	293.92	1,154.74
					22-Apr-2005	89.08	292.26	1,155.25
					26-Jul-2005	88.37	289.94	1,155.96
					15-Aug-2006	88.62	290.76	1,155.71
					15-Aug-2006	88.82	291.39	1,155.51
					16-Aug-2006	88.70	291.02	1,155.63
					16-Aug-2006	89.14	292.46	1,155.19
					17-Aug-2006	88.77	291.25	1,155.56
					28-Sep-2006	88.53	290.44	1,155.80
					10-Oct-2006	88.68	290.94	1,155.65
					16-Oct-2006	88.64	290.83	1,155.69
					25-Oct-2006	88.67	290.92	1,155.66
					30-Oct-2006	88.61	290.70	1,155.72
					3-Nov-2006	88.69	290.98	1,155.64
					13-Dec-2006	88.77	291.23	1,155.56
					16-Mar-2007	88.86	291.54	1,155.47
					11-Jun-2007	88.97	291.88	1,155.36
					25-Jul-2007	88.96	291.87	1,155.37
					4-Jan-2008	88.91	291.69	1,155.42
					30-May-2008	88.95	291.82	1,155.38
					11-Jul-2008	89.11	292.34	1,155.22
					27-Aug-2008	89.03	292.10	1,155.30
					5-Dec-2008	88.93	291.75	1,155.40
					6-Mar-2009	88.88	291.61	1,155.45
					16-Apr-2009	88.95	291.84	1,155.38
					4-Jun-2009	89.07	292.21	1,155.26
HRES-03D	496,382	3,685,328	1,243.728	1,244.40	3-Mar-2004	135.04	443.03	1,109.36
					3-Mar-2004	135.00	442.90	1,109.40
					4-Mar-2004	120.95	396.83	1,123.45
					8-Mar-2004	104.61	343.20	1,139.79
					8-Mar-2004	104.59	343.15	1,139.81
					8-Mar-2004	104.32	342.24	1,140.08
					7-May-2004	92.11	302.19	1,152.29
					4-Jun-2004	88.64	290.82	1,155.76
					2-Sep-2004	86.97	285.31	1,157.44
					11-Jan-2005	86.66	284.31	1,157.74
					2-Mar-2005	86.67	284.35	1,157.73
					22-Apr-2005	86.55	283.95	1,157.85
					26-Jul-2005	86.53	283.88	1,157.87
					21-Jul-2006	86.76	284.64	1,157.64
					15-Aug-2006	86.76	284.63	1,157.64

MONTGOMERY & ASSOCIATES

TABLE C-1. SUMMARY OF WATER LEVEL DATA IN OAK FLAT AREA, GROUNDWATER MONITORING PROGRAM
RESOLUTION COPPER MINING LLC, PINAL COUNTY, ARIZONA

WELL IDENTIFIER	WELL COORDINATES[a]		LAND SURFACE ELEVATION	MEASURING POINT ELEVATION	DATE MEASURED	DEPTH TO WATER	DEPTH TO WATER	WATER LEVEL ELEVATION
	Easting	Northing	(m, amsl)[b]	(m, amsl)		(m, bmp)[c]	(ft, bmp)[d]	(m, amsl)
HRES-03D (continued)	496,382	3,685,328	1,243.728	1,244.40	16-Aug-2006	86.81	284.80	1,157.59
					16-Aug-2006	86.79	284.73	1,157.61
					17-Aug-2006	86.80	284.78	1,157.60
					28-Sep-2006	86.82	284.83	1,157.58
					10-Oct-2006	86.82	284.84	1,157.58
					16-Oct-2006	86.76	284.66	1,157.64
					25-Oct-2006	86.82	284.85	1,157.58
					30-Oct-2006	86.83	284.89	1,157.57
					3-Nov-2006	86.86	284.98	1,157.54
					13-Dec-2006	86.91	285.15	1,157.49
					16-Mar-2007	86.92	285.17	1,157.48
					11-Jun-2007	87.03	285.52	1,157.37
					25-Jul-2007	87.03	285.54	1,157.37
					4-Jan-2008	87.15	285.94	1,157.25
					28-May-2008	87.10	285.75	1,157.30
					11-Jul-2008	86.96	285.30	1,157.44
					27-Aug-2008	87.14	285.90	1,157.26
					6-Mar-2009	87.20	286.09	1,157.20
					16-Apr-2009	87.17	285.99	1,157.23
					4-Jun-2009	87.29	286.40	1,157.11
Oak Flat Well	496,379	3,685,341	1,241.67	1,242.40	28-Jan-2003	88.63	290.77	1,153.77
					26-Sep-2003	88.88	291.60	1,153.52
					31-Oct-2003	88.53	290.46	1,153.87
					10-Dec-2003	88.61	290.73	1,153.79
					10-Dec-2003	88.60	290.69	1,153.80
					22-Feb-2004	92.04	301.96	1,150.36
					23-Feb-2004	94.61	310.40	1,147.79
					27-Feb-2004	88.78	291.27	1,153.62
					10-Mar-2004	88.69	290.99	1,153.71
					4-Jun-2004	88.76	291.22	1,153.64
					2-Sep-2004	88.88	291.61	1,153.52
					11-Jan-2005	88.80	291.33	1,153.60
					2-Mar-2005	88.64	290.80	1,153.76
					22-Apr-2005	88.60	290.66	1,153.81
					26-Jul-2005	88.86	291.52	1,153.55
					21-Jul-2006	89.22	292.71	1,153.18
					15-Aug-2006	89.14	292.44	1,153.26
					28-Sep-2006	89.13	292.42	1,153.27
					10-Oct-2006	89.17	292.56	1,153.23
					16-Oct-2006	89.15	292.48	1,153.25
					25-Oct-2006	89.18	292.57	1,153.22
					30-Oct-2006	89.20	292.66	1,153.20
					3-Nov-2006	89.24	292.79	1,153.16
					13-Dec-2006	89.30	292.98	1,153.10
					16-Mar-2007	89.38	293.25	1,153.02
					11-Jun-2007	89.41	293.33	1,152.99
					25-Jul-2007	89.47	293.54	1,152.93
					4-Jan-2008	89.41	293.35	1,152.99
					25-Feb-2008	89.28	292.90	1,153.12
					30-May-2008	89.42	293.36	1,152.98
					27-Aug-2008	89.49	293.61	1,152.91
					2-Dec-2008	89.60	293.95	1,152.80
					6-Mar-2009	89.37	293.20	1,153.03
					4-Jun-2009	89.55	293.81	1,152.85

TABLE C-1. SUMMARY OF WATER LEVEL DATA IN OAK FLAT AREA, GROUNDWATER MONITORING PROGRAM RESOLUTION COPPER MINING LLC, PINAL COUNTY, ARIZONA

WELL IDENTIFIER	WELL COORDINATES[a]		LAND SURFACE ELEVATION	MEASURING POINT ELEVATION	DATE MEASURED	DEPTH TO WATER	DEPTH TO WATER	WATER LEVEL ELEVATION
	Easting	Northing	(m, amsl)[b]	(m, amsl)		(m, bmp)[c]	(ft, bmp)[d]	(m, amsl)
HRES-04	495,322	3,683,616	1,243.492	1,243.86	7-May-2004	121.40	398.29	1,122.46
					2-Sep-2004	121.50	398.61	1,122.36
					11-Jan-2005	121.54	398.75	1,122.32
					2-Mar-2005	121.58	398.88	1,122.28
					22-Apr-2005	121.48	398.55	1,122.38
					26-Jul-2005	121.54	398.73	1,122.33
					12-Jan-2006	121.73	399.36	1,122.14
					21-Jul-2006	121.82	399.67	1,122.04
					14-Sep-2006	121.92	400.01	1,121.94
					28-Sep-2006	121.94	400.07	1,121.92
					9-Oct-2006	121.90	399.93	1,121.96
					13-Dec-2006	122.31	401.28	1,121.55
					16-Mar-2007	122.24	401.04	1,121.62
					12-Jun-2007	122.17	400.81	1,121.69
					24-Jul-2007	122.12	400.67	1,121.74
					4-Jan-2008	122.47	401.81	1,121.39
					28-Feb-2008	121.90	399.95	1,121.96
					2-May-2008	122.70	402.56	1,121.16
					3-Sep-2008	122.14	400.72	1,121.72
					23-Nov-2008	122.11	400.61	1,121.75
					26-Feb-2009	122.10	400.58	1,121.76
					2-Mar-2009	122.18	400.86	1,121.68
					1-Jun-2009	122.16	400.80	1,121.70
HRES-05	495,523	3,682,275	1,218.296	1,218.89	17-Apr-2004	97.11	318.60	1,121.78
					7-May-2004	97.09	318.52	1,121.81
					4-Jun-2004	97.18	318.82	1,121.71
					2-Sep-2004	97.17	318.80	1,121.72
					2-Mar-2005	97.25	319.04	1,121.64
					22-Apr-2005	97.24	319.02	1,121.65
					26-Jul-2005	97.26	319.10	1,121.63
					12-Jan-2006	97.38	319.47	1,121.52
					21-Jul-2006	97.49	319.85	1,121.40
				1,218.81	4-Jan-2008	97.78	320.80	1,121.03
					27-Feb-2008	97.78	320.80	1,121.03
					28-May-2008	97.81	320.91	1,121.00
					28-Aug-2008	97.84	320.99	1,120.97
					2-Dec-2008	97.83	320.96	1,120.98
					3-Mar-2009	97.80	320.88	1,121.01
					16-Apr-2009	97.82	320.94	1,120.99
					5-May-2009	97.82	320.94	1,120.99
					3-Jun-2009	97.87	321.11	1,120.94
HRES-05S	495,523	3,682,275	1,218.296	1,218.85	28-Sep-2006	97.59	320.17	1,121.26
					16-Oct-2006	97.71	320.57	1,121.14
					24-Oct-2006	97.68	320.48	1,121.17
					30-Oct-2006	97.75	320.70	1,121.10
					3-Nov-2006	97.83	320.98	1,121.02
					13-Dec-2006	97.73	320.63	1,121.12
					16-Mar-2007	97.79	320.84	1,121.06
					12-Jun-2007	97.81	320.89	1,121.04
					24-Jul-2007	97.78	320.79	1,121.07
					19-Dec-2007	97.85	321.04	1,121.00
HRES-05D	495,523	3,682,275	1,218.296	1,218.89	28-Sep-2006	97.61	320.25	1,121.28
					10-Oct-2006	97.67	320.43	1,121.22
					16-Oct-2006	97.74	320.67	1,121.15
					24-Oct-2006	97.68	320.48	1,121.21
					30-Oct-2006	97.76	320.73	1,121.13
					3-Nov-2006	97.85	321.03	1,121.04
					13-Dec-2006	97.77	320.78	1,121.12
					16-Mar-2007	97.80	320.85	1,121.09
					12-Jun-2007	97.92	321.27	1,120.97
					24-Jul-2007	97.80	320.86	1,121.09
					19-Dec-2007	97.89	321.16	1,121.00

TABLE C-1. SUMMARY OF WATER LEVEL DATA IN OAK FLAT AREA, GROUNDWATER MONITORING PROGRAM
RESOLUTION COPPER MINING LLC, PINAL COUNTY, ARIZONA

WELL IDENTIFIER	WELL COORDINATES[a]		LAND SURFACE ELEVATION	MEASURING POINT ELEVATION	DATE MEASURED	DEPTH TO WATER	DEPTH TO WATER	WATER LEVEL ELEVATION
	Easting	Northing	(m, amsl)[b]	(m, amsl)		(m, bmp)[c]	(ft, bmp)[d]	(m, amsl)
HRES-06	499,199	3,688,855	1,350.364	1,351.004	12-Apr-2007	120.21	394.40	1,230.79
					7-May-2007	120.06	393.90	1,230.94
					24-May-2007	119.90	393.37	1,231.10
					1-Jun-2007	119.97	393.59	1,231.04
					7-Jun-2007	119.84	393.18	1,231.16
					11-Jun-2007	120.00	393.70	1,231.00
					24-Jul-2007	120.32	394.75	1,230.68
					10-Oct-2007	120.47	395.25	1,230.53
					4-Jan-2008	120.19	394.33	1,230.81
					27-Feb-2008	119.71	392.75	1,231.29
					28-May-2008	119.55	392.21	1,231.46
					25-Aug-2008	119.87	393.28	1,231.13
					3-Dec-2008	119.72	392.78	1,231.28
					4-Mar-2009	119.26	391.26	1,231.75
					3-Jun-2009	119.33	391.51	1,231.67
A-O6	497,366	3,683,232	1,269.61	1,269.61	3-Jun-2004	158.45	519.86	1,111.16
					22-Apr-2005	158.61	520.37	1,111.00
					26-Jul-2005	158.20	519.02	1,111.41
					3-Nov-2005	158.32	519.40	1,111.30
					12-Jan-2006	158.41	519.71	1,111.20
					7-Jul-2006	158.56	520.20	1,111.05
					29-Sep-2006	158.59	520.30	1,111.02
					24-Oct-2006	158.62	520.42	1,110.99
					8-Dec-2006	158.74	520.80	1,110.87
					23-May-2007	158.78	520.94	1,110.83
					25-Jul-2007	158.83	521.08	1,110.78
				1,270.09	22-Sep-2007			
					20-Feb-2008	159.07	521.88	1,111.02
					3-Jun-2008	159.18	522.25	1,110.91
					26-Aug-2008	159.23	522.40	1,110.86
					4-Dec-2008	159.32	522.70	1,110.77
					5-Mar-2009	159.35	522.81	1,110.74
					4-Jun-2009	159.24	522.44	1,110.85
MJ-11	498,076	3,681,789	1,193.09	1,193.52	3-Jun-2004	91.12	298.95	1,102.40
					22-Apr-2005	90.54	297.05	1,102.98
					26-Jul-2005	90.67	297.49	1,102.85
					3-Nov-2005	90.78	297.85	1,102.74
					12-Jan-2006	90.83	297.98	1,102.69
					7-Jul-2006	90.97	298.46	1,102.55
					29-Sep-2006	91.01	298.58	1,102.51
					24-Oct-2006	91.03	298.64	1,102.49
					8-Dec-2006	91.10	298.90	1,102.42
					23-May-2007	91.12	298.95	1,102.40
					25-Jul-2007	91.20	299.22	1,102.32
				1,193.64	20-Feb-2008	91.18	299.15	1,102.46
					2-Jun-2008	91.53	300.30	1,102.11
					26-Aug-2008	91.65	300.69	1,101.99
					4-Dec-2008	92.48	303.40	1,101.16
					5-Mar-2009	92.44	303.27	1,101.20
					4-Jun-2009	92.54	303.60	1,101.10
HRES-07S	496,851	3,681,953	1,223.31	1,223.97	14-Apr-2008	116.66	382.75	1,107.31
					29-May-2008	116.73	382.96	1,107.24
					2-Jun-2008	116.67	382.79	1,107.30
					2-Sep-2008	116.82	383.27	1,107.15
					1-Dec-2008	116.86	383.40	1,107.11
					3-Mar-2009	116.78	383.12	1,107.19
					2-Jun-2009	116.87	383.43	1,107.10

TABLE C-1. SUMMARY OF WATER LEVEL DATA IN OAK FLAT AREA, GROUNDWATER MONITORING PROGRAM RESOLUTION COPPER MINING LLC, PINAL COUNTY, ARIZONA

WELL IDENTIFIER	WELL COORDINATES[a]		LAND SURFACE ELEVATION	MEASURING POINT ELEVATION	DATE MEASURED	DEPTH TO WATER	DEPTH TO WATER	WATER LEVEL ELEVATION
	Easting	Northing	(m, amsl)[b]	(m, amsl)		(m, bmp)[c]	(ft, bmp)[d]	(m, amsl)
HRES-07D	496,851	3,681,953	1,223.31	1,223.99	14-Apr-2008	116.64	382.67	1,107.35
					29-May-2008	116.63	382.65	1,107.36
					2-Jun-2008	116.72	382.95	1,107.27
					2-Sep-2008	116.72	382.95	1,107.27
					1-Dec-2008	116.83	383.30	1,107.16
					3-Mar-2009	116.75	383.05	1,107.24
					2-Jun-2009	116.84	383.33	1,107.15
HRES-08S	495,620	3,680,753	1232.42	1,233.01	21-Dec-2007	56.78	186.27	1,176.23
					4-Jan-2008	56.92	186.73	1,176.09
					26-Feb-2008	57.06	187.22	1,175.95
					29-May-2008	57.14	187.46	1,175.87
					28-Aug-2008	57.10	187.33	1,175.91
					5-Dec-2008	57.21	187.71	1,175.80
					3-Mar-2009	57.29	187.95	1,175.72
					16-Apr-2009	57.18	187.59	1,175.83
					2-Jun-2009	57.15	187.50	1,175.86
HRES-08D	495,620	3,680,753	1,232.42	1,233.08	21-Dec-2007	57.06	187.22	1,176.02
					4-Jan-2008	73.95	242.63	1,159.13
					26-Feb-2008	73.87	242.36	1,159.21
					29-May-2008	71.44	234.38	1,161.64
					28-Aug-2008	70.99	232.92	1,162.09
					5-Dec-2008	71.81	235.60	1,161.27
					3-Mar-2009	57.35	188.15	1,175.73
					16-Apr-2009	67.14	220.29	1,165.94
					2-Jun-2009	68.24	223.89	1,164.84
DEEP AQUIFER WELLS								
RES-02				1,229.07	27-Apr-2002			428.07
					27-Sep-2002			435.67
					18-Nov-2002			441.47
					18-Dec-2002			443.37
					16-May-2003			456.27
					2-Oct-2003			468.27
					28-Jan-2005			511.18
					15-May-2007			594.67
RES-03				1,214.75	18-Nov-2002			428.35
					18-Dec-2002			430.85
					16-May-2003			439.25
					2-Oct-2003			454.05
					28-Jan-2005			503.39
					15-May-2007			590.75
RES-04				1,211.10	18-Nov-2002			750.90
					18-Dec-2002			714.30
					16-May-2003			508.90
					2-Oct-2003			496.40
					28-Jan-2005			524.64
					15-May-2007			614.30
					3-Jul-2007			605.20

[a] Universal Transverse Mercator (UTM), North American Datum 1927, Zone 12 East
[b] m, amsl = meters above mean sea level
[c] m, bmp = meters below measuring point
[d] ft, bmp = feet below measuring point

APPENDIX D

HYDROCHEMICAL DATA

TABLE D-1. SUMMARY OF COMMON CONSTITUENTS AND ROUTINE PARAMETERS FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

			COMMON CONSTITUENTS[a] (mg/L)[b]													ROUTINE PARAMETERS: FIELD			ROUTINE PARAMETERS: LABORATORY		
SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	SiO_2	Br	F	$NO_3 + NO_2$ (as N)	TDS	TEMP (°C)[c]	pH	EC (µS/cm)[d]	pH	EC (µS/cm)	ANALYTICAL LABORATORY[e]
GROUNDWATER (SHALLOW AQUIFERS)																					
Hackberry Windmill Well	WM-ALU	17-Jun-86	28.2	5.15	7.0	2.6	3.52	---	117	25.9	31.9	---	0.45	<0.14	135	20.0	*6.50*	240	---	---	TA
Hackberry Windmill Well	RESE-1000263	27-Feb-08	40	8.0	16	3.1	15	<2.0	121	35	30	<0.50	<0.40	2.4	230	14.9	6.61	328	---	---	TA
Hackberry Windmill Well	RESE-1003011	3-Jun-08	33	6.4	11	2.5	8.5	<6.0	113	25	34	<0.50	<0.40	<0.20	190	16.8	*6.47*	268	6.78	270	TA
Hackberry Windmill Well	RESE-1003019	2-Sep-08	36	6.7	11	3.1	9.3	<6.0	134	28	40	<0.50	<0.40	<0.30	200	20.7	6.66	279	6.83	280	TA
Hackberry Windmill Well (duplicate)	RESE-1003020	2-Sep-08	35	7.0	12	3.3	9.3	<6.0	134	28	39	<0.50	<0.40	<0.30	170	20.7	6.66	279	7.19	280	TA
Hackberry Windmill Well	RESE-1003024	2-Dec-08	36	7.0	11	3.0	8.8	<6.0	134	20	39	<0.50	<0.40	<0.20	190	20.2	*6.41*	270	6.81	280	TA
Hackberry Windmill Well	RESE-1003033	3-Mar-09	37	6.8	12	2.5	14	<6.0	122	36	31	<0.50	<0.40	1.2	200	17.1	*6.40*	313	7.28	310	TA
Hackberry Windmill Well (SVL dup)	RESE-1003033	3-Mar-09	---	---	---	---	14	---	---	37.6	---	0.112	<0.100	---	---	17.1	*6.40*	313	---	---	SVL
Hackberry Windmill Well	RESE-1003042	2-Jun-09	33	6.4	11	2.7	7.7	<6.0	134	25	35	<0.50	<0.40	<0.30	150	17.6	*6.43*	271	7.31	260	TA
Hackberry Windmill Well (SVL dup)	RESE-1003042	2-Jun-09	---	---	---	---	8.23	---	---	25.8	---	0.108	<0.100	---	---	17.6	*6.43*	271	---	---	SVL
JI Ranch Corral Well	RESE-1000302	21-Jun-07	110	23	46	2.1	49	<5.0	63	*390*	40	<0.50	0.11	<0.20	*730*	16.0	*5.88*	990	---	---	TA
JI Ranch Corral Well	RESE-1003005	29-May-08	85	17	48	<2.0	51	<6.0	17.1	*260*	37	<0.50	<0.40	**16**	*620*	15.0	*5.51*	787	*5.54*	780	TA
JI Ranch Corral Well	RESE-1003014	25-Aug-08	130	26	55	2.1	57	<6.0	29	*450*	39	<0.50	<0.40	<0.20	*750*	17.0	*5.66*	1020	*5.81*	1100	TA
JI Ranch Corral Well	RESE-1003029	3-Dec-08	85	19	45	<2.0	51	<6.0	13.4	*290*	38	<0.50	<0.40	<0.20	*550*	14.4	*5.49*	778	*5.65*	780	TA
JI Ranch Corral Well	RESE-1003038	4-Mar-09	86	16	41	3.3	46	<6.0	79.3	240	38	<0.50	<0.40	4.7	*530*	13.6	*6.02*	776	6.83	760	TA
JI Ranch Corral Well (SVL dup)	RESE-1003038	4-Mar-09	---	---	---	---	39.8	---	---	229	---	0.16	0.143	---	---	13.6	*6.02*	776	---	---	SVL
JI Ranch Corral Well	RESE-1003047	5-Jun-09	64	13	41	2	40	<6.0	81.7	190	41	<0.50	<0.40	<0.30	400	15.8	*5.94*	614	6.91	600	TA
JI Ranch Corral Well (SVL dup)	RESE-1003047	5-Jun-09	---	---	---	---	40.2	---	---	177	---	0.252	<0.100	---	---	15.8	*5.94*	614	---	---	SVL
JI Ranch Middle Well	RESE-1003006	30-May-08	30	7.1	16	<2.0	25	<6.0	57.3	58	36	<0.50	<0.40	0.44	240	17.0	*6.16*	300	6.54	300	TA
JI Ranch Middle Well	RESE-1003017	27-Aug-08	43	10	22	<2.0	27	<6.0	61	100	36	<0.50	<0.40	0.36	270	17.1	*6.26*	377	*6.32*	420	TA
JI Ranch Middle Well	RESE-1003028	3-Dec-08	47	12	45	<2.0	26	<6.0	74	120	39	<0.50	<0.40	<0.20	310	17.7	*6.50*	494	6.60	470	TA
JI Ranch Middle Well	RESE-1003037	4-Mar-09	43	9.9	22	<2.0	29	<6.0	74	100	35	<0.50	<0.40	0.78	290	17.1	*6.38*	444	7.20	420	TA
JI Ranch Middle Well (SVL dup)	RESE-1003037	4-Mar-09	---	---	---	---	26	---	---	100	---	0.198	0.109	---	---	17.1	*6.38*	444	---	---	SVL
JI Ranch Middle Well	RESE-1003048	5-Jun-09	54	13	29	<2.0	35	<6.0	84.2	170	37	<0.50	<0.40	0.46	350	17.8	*6.21*	563	7.07	530	TA
JI Ranch Middle Well (SVL dup)	RESE-1003048	5-Jun-09	---	---	---	---	30.4	---	---	122	---	0.136	<0.100	---	---	17.8	*6.21*	563	---	---	SVL

TABLE D-1. SUMMARY OF COMMON CONSTITUENTS AND ROUTINE PARAMETERS FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	COMMON CONSTITUENTS[a] (mg/L)[b]													ROUTINE PARAMETERS					ANALYTICAL LABORATORY[e]
																FIELD			LABORATORY		
			Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	SiO_2	Br	F	$NO_3 + NO_2$ (as N)	TDS	TEMP (°C)[c]	pH	EC (µS/cm)[d]	pH	EC (µS/cm)	
GROUNDWATER (APACHE LEAP TUFF AQUIFER)																					
JI Ranch House Well	RESE-1000303	21-Jun-07	26	3.8	17	2.0	7.3	<5.0	122	7.3	59	<0.50	0.27	1.1	190	22.8	6.80	232	---	---	TA
Oak Flat Well	RESE-1001301	16-Aug-06	25	4	31	1.0	14	24.0	92	6.8	88	--	0.36	1.3	240	23.0	---	---	*8.86*	270	TA
Well A-06	RESE-1000255	24-Sep-07	29	4.8	25	1.1	4.6	<5.0	183	2.9	71	<0.50	0.35	0.37	210	25.9	7.13	268	---	---	TA
Well A-06 (duplicate)	RESE-1000256	24-Sep-07	30	5.0	24	1.0	4.6	<5.0	183	2.8	73	<0.50	0.35	0.36	210	25.9	7.13	268	---	---	TA
Well A-06	RESE-1003008	2-Jun-08	28	4.8	23	<2.0	4.4	<6.0	146	2.4	69	<0.50	<0.40	0.27	220	26.2	7.17	264	7.42	260	TA
Well A-06	RESE-1003016	28-Aug-08	29	4.8	24	<2.0	4.5	<6.0	171	3.2	72	<0.50	<0.40	0.32	180	26.0	7.23	267	7.29	280	TA
Well A-06	RESE-1003030	4-Dec-08	28	4.8	22	<2.0	4.9	<6.0	171	3.3	71	<0.50	0.41	0.29	220	25.5	7.39	264	7.41	270	TA
A-06	RESE-1003039	5-Mar-09	26	4.4	22	<2.0	4.6	<6.0	171	3	68	<0.50	0.75	0.30	190	25.1	7.28	265	7.73	260	TA
A-06 (SVL dup)	RESE-1003039	5-Mar-09	---	---	---	---	4.76	---	---	3.1	---	<0.100	0.25	---	---	25.1	7.28	265	---	---	SVL
A-06	RESE-1003046	4-Jun-09	28	4.7	24	<2.0	4.8	<6.0	171	2.9	70	<0.50	0.73	0.38	190	26.3	7.22	268	7.88	260	TA
A-06 (SVL dup)	RESE-1003046	4-Jun-09	---	---	---	---	4.73	---	---	3.04	---	<0.100	0.22	---	---	26.3	7.22	268	---	---	SVL
Well HRES-01	HRES-1d; open borehole test	8-Feb-04	14	0.77	55	0.72	5.7	<5.0	158.6	7.9	56	---	0.56	1.00	300	14.6	8.12	308	8.38	300	DM
Well HRES-01	RESE-1001102	15-Mar-04	8.75	0.815	52.2	<1.0	5.64	<1.0	155	6.82	55.0	---	0.29	0.840	205	26.2	8.34	259	8.30	269	DM
Well HRES-01	RESE-1001103	18-Mar-04	7.41	0.722	54.8	<1.0	5.70	<1.0	155	6.80	54.4	---	0.31	0.810	196	26.9	8.42	259	8.31	270	DM
Well HRES-02	HRES-2; open borehole test	18-Feb-04	27	4.7	33	<1.0	6.5	<5.0	158.6	15	59	---	0.46	0.97	250	22.1	8.37	302	8.29	290	DM
Well HRES-02	RESE-1001105	6-Apr-04	21.3	4.76	33.8	<1.0	7.42	<1.0	144	13.6	60.7	---	0.4	0.94	206	23.8	8.03	269	8.01	285	DM
Well HRES-02	RESE-1001108	8-Apr-04	2.3	0.177	66.3	<1.0	7.46	42	119	7.97	44.8	---	0.68	0.88	192	25.4	*9.30*	322	*9.23*	304	DM
Well HRES-02	RESE-1001109	10-Apr-04	1.89	0.047	69.3	<1.0	6.64	44	131	8.31	47.6	---	0.76	0.89	211	22.6	*9.36*	333	*9.21*	324	DM
Well HRES-03	HRES-3AL; open borehole test	25-Feb-04	32	6.7	25	7.2	13	<5.0	146	8.4	74	---	0.40	2.4	270	20.8	8.14	297	8.29	290	DM
Well HRES-03	RESE-1001111	16-Apr-04	1.16	0.041	55.7	<1.0	6.8	73	74	7.16	6.98	---	1.05	<0.020	155	24.2	*10.17*	515	*9.79*	293	DM
Well HRES-04	HRES-4AL; open borehole test	3-Mar-04	27	4.0	37	1.1	6.8	<5.0	171	11	56	---	0.50	0.62	230	23.1	8.31	306	8.36	320	DM
Well HRES-04	RESE-1001110	15-Apr-04	29	4.31	30.9	<1.0	8.45	<1.0	182	9.25	56.1	---	0.41	0.36	217	---	---	---	7.9	321	DM
Well HRES-04	4531	3-Nov-06	28	4.3	27	<1.0	5.9	<5.0	159	5.0	68	---	0.46	2.6	210	27.1	6.72	298	7.83	260	
Well HRES-04	RESE-1001114	18-Jan-08	32	4.6	31	0.95	5.7	<5.0	183	4.9	67	<0.50	0.37	0.33	200	25.6	7.87	299	7.99	300	TA
Well HRES-04	RESE-1003021	3-Sep-08	27	4.5	34	<2.0	5.8	<6.0	183	6.1	66	<0.50	0.42	0.49	190	28.2	7.28	290	7.83	280	TA
Well HRES-04	RESE-1003031	2-Mar-09	27	4.0	29	<2.0	5.6	<6.0	183	5.6	63	<0.50	0.71	0.51	210	27.7	7.54	292	7.99	290	TA
Well HRES-04 (SVL dup)	RESE-1003031	2-Mar-09	---	---	---	---	5.76	---	---	5.8	---	<0.100	0.26	---	---	27.7	7.54	292	---	---	SVL
Well HRES-04	RESE-1003040	1-Jun-09	27	4.2	31	<2.0	5.5	<6.0	183	5.4	63	<0.50	0.46	0.54	180	28.4	7.59	294	8.10	280	TA
Well HRES-04 (SVL dup)	RESE-1003040	1-Jun-09	---	---	---	---	5.61	---	---	5.6	---	<0.100	0.21	---	---	28.4	7.59	294	---	---	SVL

MONTGOMERY & ASSOCIATES

TABLE D-1. SUMMARY OF COMMON CONSTITUENTS AND ROUTINE PARAMETERS FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	COMMON CONSTITUENTS[a] (mg/L)[b]													ROUTINE PARAMETERS					ANALYTICAL LABORATORY[e]
																FIELD			LABORATORY		
			Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	SiO_2	Br	F	$NO_3 + NO_2$ (as N)	TDS	TEMP (°C)[c]	pH	EC (µS/cm)[d]	pH	EC (µS/cm)	
GROUNDWATER (APACHE LEAP TUFF AQUIFER) - continued																					
Well HRES-05	HRES-5AL; open borehole test	10-Mar-04	35	5.8	29	1.3	5.1	<5.0	195	2.7	68	---	0.40	0.53	240	22.5	8.24	309	8.35	330	DM
Well HRES-05	RESE-1001104	2-Apr-04	38.8	6.74	28.5	1.1	5.96	<1.0	210	3.89	67.4	---	0.32	0.65	240	21.3	7.64	329	7.66	351	DM
Well HRES-05	RESE-1000264	27-Feb-08	35	6.6	27	<2.0	5.8	<2.0	195	3.4	66	<0.50	0.46	0.81	210	23.3	7.49	320	---	---	TA
Well HRES-05	RESE-1003001	28-May-08	37	6.7	26	<2.0	5.1	<6.0	195	2.1	66	<0.50	<0.40	0.56	250	24.9	7.34	330	7.73	320	TA
Well HRES-05	RESE-1003012	25-Aug-08	38	6.8	27	<2.0	4.7	<6.0	183	2.0	70	<0.50	<0.40	0.57	230	25.3	7.37	321	7.64	330	TA
Well HRES-05	RESE-1003025	2-Dec-08	36	6.8	25	<2.0	4.9	<6.0	207	2.1	69	<0.50	0.44	0.56	220	24.2	7.64	326	7.62	330	TA
Well HRES-05	RESE-1003034	3-Mar-09	34	6.1	24	<2.0	4.7	<6.0	207	2.1	64	<0.50	0.73	0.55	230	24.3	7.53	325	7.96	310	TA
Well HRES-5 (SVL dup)	RESE-1003034	3-Mar-09	---	---	---	---	4.88	---	---	2.2	---	<0.100	0.25	---	---	24.3	7.53	325	---	---	SVL
Well HRES-05	RESE-1003043	3-Jun-09	37	6.5	26	<2.0	4.8	<6.0	207	2.1	68	<0.50	0.66	0.59	190	24.5	7.39	328	8.01	310	TA
Well HRES-05 (SVL dup)	RESE-1003043	3-Jun-09	---	---	---	---	4.95	---	---	2.3	---	<0.100	0.23	---	---	24.5	7.39	328	---	---	SVL
Well HRES-06	RESE-1000301	12-Jun-07	26	4.3	19	1.6	8.1	<5.0	134	14	55	<0.50	0.32	0.27	200	19.7	6.72	261	---	---	TA
Well HRES-06	RESE-1000265	27-Feb-08	26	4.4	18	<2.0	7.6	<2.0	121	14	54	<0.50	<0.40	0.52	180	19.1	7.27	243	---	---	TA
Well HRES-06 (duplicate)	RESE-1000266	27-Feb-08	27	4.4	18	<2.0	7.6	<2.0	121	14	55	<0.50	<0.40	0.54	180	19.1	7.27	243	---	---	TA
Well HRES-06	RESE-1003003	28-May-08	27	4.4	18	<2.0	7.1	<6.0	105	14	55	<0.50	<0.40	0.26	200	20.3	6.51	245	7.20	240	TA
Well HRES-06	RESE-1003013	25-Aug-08	30	4.7	19	<2.0	6.9	<6.0	89	14	60	<0.50	<0.40	0.26	170	21.2	7.74	262	7.16	250	TA
Well HRES-06	RESE-1003026	3-Dec-08	28	4.6	17	<2.0	6.7	<6.0	134	13	56	<0.50	<0.40	0.25	180	20.9	6.51	253	7.18	250	TA
Well HRES-06 (duplicate)	RESE-1003027	3-Dec-08	28	4.5	17	<2.0	6.9	<6.0	134	14	57	<0.50	<0.40	0.26	220	20.9	6.51	253	7.27	250	TA
Well HRES-06	RESE-1003035	4-Mar-09	25	4.0	16	<2.0	6.8	<6.0	134	14	53	<0.50	0.60	0.26	180	20.4	7.00	241	7.61	240	TA
Well HRES-06 (SVL dup)	RESE-1003035	4-Mar-09	---	---	---	---	7.24	---	---	14.7	---	<0.100	0.14	---	---	20.4	7.00	241	---	---	SVL
Well HRES-06 duplicate	RESE-1003036	4-Mar-09	25	4.1	17	<2.0	6.9	<6.0	134	14	55	<0.50	0.57	0.26	180	20.4	7.00	241	7.63	240	TA
Well HRES-06 duplicate (SVL dup)	RESE-1003036	4-Mar-09	---	---	---	---	7.24	---	---	14.7	---	<0.100	0.14	---	---	20.4	7.00	241	---	---	SVL
Well HRES-06	RESE-1003044	3-Jun-09	26	4.2	18	<2.0	6.8	<6.0	134	14	55	<0.50	0.52	<0.30	140	20.6	6.99	244	7.63	240	TA
Well HRES-06 (SVL dup)	RESE-1003044	3-Jun-09	---	---	---	---	7.14	---	---	14.5	---	<0.100	0.13	---	---	20.6	6.99	244	---	---	SVL
Well HRES-06 duplicate	RESE-1003045	3-Jun-09	27	4.3	18	<2.0	7	<6.0	134	14	56	<0.50	0.57	<0.30	170	20.6	6.99	244	7.60	240	TA
Well HRES-06 duplicate (SVL dup)	RESE-1003045	3-Jun-09	---	---	---	---	7.15	---	---	14.7	---	0.121	0.13	---	---	20.6	6.99	244	---	---	SVL
Well HRES-07	RESE-1000262	26-Feb-08	27	4.7	27	<2.0	6.7	<2.0	159	5.8	62	<0.50	0.46	0.89	210	23.2	7.50	278	---	---	TA
Well HRES-07	RESE-1003009	3-Jun-08	27	4.7	26	<2.0	5.6	<6.0	134	4.7	60	<0.50	<0.40	0.62	220	24.0	7.32	271	7.61	270	TA
Well HRES-07 (duplicate)	RESE-1003010	3-Jun-08	26	4.4	24	<2.0	5.6	<6.0	146	4.7	57	<0.50	<0.40	0.62	230	24.0	7.32	271	7.63	270	TA
Well HRES-07	RESE-1003018	2-Sep-08	27	4.8	27	<2.0	5.7	<6.0	159	4.4	62	<0.50	<0.40	0.58	190	24.0	7.16	272	7.76	260	TA
Well HRES-07	RESE-1003022	1-Dec-08	29	4.8	24	<2.0	5.6	<6.0	171	4.3	61	<0.50	0.44	0.61	200	23.7	7.31	271	7.43	280	TA
Well HRES-07	RESE-1003032	3-Mar-09	27	4.2	23	<2.0	5.5	<6.0	171	4.2	59	<0.50	0.60	0.59	190	25.3	7.25	269	7.88	260	TA
Well HRES-07 (SVL dup)	RESE-1003032	3-Mar-09	---	---	---	---	5.68	---	---	4.46	---	<0.100	0.25	---	---	25.3	7.25	269	---	---	SVL
Well HRES-07	RESE-1003041	2-Jun-09	28	4.5	25	<2.0	5.5	<6.0	171	4.3	61	<0.50	0.65	0.62	160	23.9	7.02	275	7.92	260	TA
Well HRES-07 (SVL dup)	RESE-1003041	2-Jun-09	---	---	---	---	5.67	---	---	4.49	---	0.1	0.25	---	---	23.9	7.02	275	---	---	SVL

TABLE D-1. SUMMARY OF COMMON CONSTITUENTS AND ROUTINE PARAMETERS FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	COMMON CONSTITUENTS[a] (mg/L)[b]													ROUTINE PARAMETERS: FIELD			ROUTINE PARAMETERS: LABORATORY		ANALYTICAL LABORATORY[e]
			Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	SiO_2	Br	F	$NO_3 + NO_2$ (as N)	TDS	TEMP (°C)[c]	pH	EC (µS/cm)[d]	pH	EC (µS/cm)	
GROUNDWATER (APACHE LEAP TUFF AQUIFER) - continued																					
Well MJ-11	RESE-1000257	28-Sep-07	27	4.6	22	0.97	4.4	<5.0	159	3.4	71	<0.50	0.34	0.41	190	23.7	7.09	249	---	---	TA
Well MJ-11	RESE-1000261	20-Feb-08	25	4.6	24	1.2	4.3	<5.0	146	3.0	71	<0.50	0.38	0.43	230	22.0	7.14	256	---	---	TA
Well MJ-11	RESE-1003007	2-Jun-08	26	4.6	22	<2.0	4.3	<6.0	134	3.2	71	<0.50	<0.40	0.46	220	23.3	7.17	248	7.39	250	TA
Well MJ-11	RESE-1003015	26-Aug-08	27	4.8	23	<2.0	4.3	<6.0	109	3.0	75	<0.50	<0.40	0.46	190	23.9	7.08	251	7.4	89	TA
GROUNDWATER (DEEP GROUNDWATER SYSTEM)																					
DHRES-01	RESE-112808	28-Nov-08	32	2.8	130	18	20	<6.0	281	160	44	<0.50	*3.2*	<0.20	*500*	68.7	7.2	865	7.91	810	TA
U.S. EPA National Primary Drinking Water Regulations			---	---	---	---	---	---	---	---	---	---	4.0	10	---	---	---	---	---	---	---
U.S. EPA National Secondary Drinking Water Regulations			---	---	---	---	250	---	---	250	---	---	2.0	---	500	---	6.5 to 8.5	---	6.5 to 8.5	---	---
Arizona Numeric Aquifer Water Quality Standards			---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Values in bold red are out of compliance with applicable primary water quality standards
Values in red italics are out of compliance with applicable secondary water quality standards

[a] Ca = Calcium; Mg = Magnesium; Na = Sodium; K = Potassium; Cl = Chloride
CO_3 = Carbonate; HCO_3 = Bicarbonate; SO_4 = Sulfate; SiO_2 = Silica; Br = Bromide
F = Fluoride; NO_3+NO_2 (as N) = Nitrate plus Nitrite, in equivalent milligrams of nitrogen per liter; TDS = Total dissolved solids; < = Less than reported detection limit

[b] mg/L = milligrams per liter
[c] TEMP (°C) = Temperature, in degrees Celsius
[d] EC (µS/cm) = Electrical conductivity in microsiemens per centimeter
[e] ANALYTICAL LABORATORY
TA = Test America, Phoenix, AZ
DM = Del Mar Analytical, Phoenix, AZ
SVL = SVL Analytical, Kellogg, ID

--- = not available, not applicable

TABLE D-2. SUMMARY OF TRACE CONSTITUENTS FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	TRACE CONSTITUENTS[a] (mg/L)[b]																						ANALYTICAL LABORATORY[c]
			Al	Sb	As	Ba	Be	B	Cd	Cr	Co	Cu	CN	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	S	Tl	Zn	
GROUNDWATER (SHALLOW AQUIFERS)																									
Hackberry Windmill	RESE-1000263	27-Feb-08	<0.20	<0.0030	<0.0010	0.11	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.020	<0.050	0.0011	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	0.082	TA
Hackberry Windmill	RESE-1003011	3-Jun-08	<0.20	<0.0030	<0.0010	0.094	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	<0.050	TA
Hackberry Windmill	RESE-1003019	2-Sep-08	<0.20	<0.0030	<0.0010	0.10	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.020	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	0.061	TA
Hackberry Windmill (duplicate)	RESE-1003020	2-Sep-08	<0.20	<0.0030	<0.0010	0.10	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.020	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	0.064	TA
Hackberry Windmill	RESE-1003024	2-Dec-08	<0.20	<0.0030	<0.0010	0.10	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	*0.51*	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.10	<0.0010	0.31	TA
Hackberry Windmill	RESE-1003033	3-Mar-09	<0.20	<0.0030	<0.0010	0.11	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	0.0018	<0.020	0.20	<0.0010	0.034	<0.00020	<0.0010	0.0028	<0.0020	<0.0010	<0.040	<0.0010	0.074	TA
Hackberry Windmill	RESE-1003042	2-Jun-09	<0.20	<0.0030	<0.0010	0.094	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	<0.0010	<0.020	0.27	<0.0010	0.048	<0.00020	<0.0010	0.0015	<0.0020	<0.0010	<0.040	<0.0010	0.095	TA
JI Ranch Corral Well	RESE-1000302	21-Jun-07	<0.050	<0.002	<0.001	0.033	<0.0020	<0.050	<0.001	<0.0050	0.036	<0.010	<0.0020	*30*	0.0073	*1.3*	---	<0.0020	0.019	<0.002	<0.001	<0.10	<0.001	0.60	TA
JI Ranch Corral Well	RESE-1003005	29-May-08	<0.20	<0.0030	0.0011	0.039	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	<0.0010	---	<0.00020	<0.010	0.019	0.013	<0.0010	<0.040	<0.0010	0.083	TA
JI Ranch Corral Well	RESE-1003014	25-Aug-08	<0.20	<0.0030	0.0015	0.048	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	<0.0010	---	<0.00020	<0.010	0.019	<0.0020	<0.0010	<0.040	<0.0010	0.36	TA
JI Ranch Corral Well	RESE-1003029	3-Dec-08	<0.20	<0.0030	<0.0010	0.027	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	*8.5*	<0.0010	---	<0.00020	<0.010	0.016	<0.0020	<0.0010	<0.10	<0.0010	0.093	TA
JI Ranch Corral Well	RESE-1003038	4-Mar-09	<0.20	<0.0030	0.0011	0.034	<0.0010	<0.20	<0.0010	<0.0010	0.012	0.0049	<0.020	*2.7*	<0.0010	*0.500*	<0.00020	<0.0010	0.014	<0.0020	<0.0010	<0.040	<0.0010	0.044	TA
JI Ranch Corral Well	RESE-1003047	5-Jun-09	<0.20	<0.0030	0.0016	0.034	<0.0010	<0.20	<0.0010	<0.0010	0.015	0.0047	<0.020	*4.1*	<0.0010	*0.520*	<0.00020	<0.0010	0.0084	<0.0020	<0.0010	<0.040	<0.0010	0.029	TA
JI Ranch Middle Well	RESE-1003006	30-May-08	<0.20	<0.0030	<0.0010	0.083	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	<0.050	TA
JI Ranch Middle Well	RESE-1003017	27-Aug-08	<0.20	<0.0030	0.0019	0.130	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	0.0011	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	<0.050	TA
JI Ranch Middle Well	RESE-1003028	3-Dec-08	<0.20	<0.0030	<0.0010	0.15	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	*12*	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.10	<0.0010	<0.050	TA
JI Ranch Middle Well	RESE-1003037	4-Mar-09	<0.20	<0.0030	<0.0010	0.13	<0.0010	<0.20	<0.0010	<0.0010	0.0029	0.0015	<0.020	*4.6*	<0.0010	*0.920*	<0.00020	<0.0010	0.0041	<0.0020	<0.0010	<0.040	<0.0010	<0.010	TA
JI Ranch Middle Well	RESE-1003048	5-Jun-09	<0.20	<0.0030	<0.0010	0.16	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	<0.0010	<0.020	*12*	<0.0010	*0.670*	<0.00020	<0.0010	0.0025	<0.0020	<0.0010	<0.040	<0.0010	<0.010	TA
GROUNDWATER (APACHE LEAP TUFF AQUIFER)																									
JI Ranch House Well	RESE-1000303	21-Jun-07	<0.050	<0.002	0.0017	0.022	<0.0020	<0.050	<0.001	<0.0050	<0.010	<0.010	<0.0020	<0.040	<0.001	<0.020	---	<0.0020	<0.010	<0.002	<0.001	<0.10	<0.001	<0.020	TA
Oak Flat Well	RESE-1001301	16-Aug-06	<0.50	<0.002	0.0031	0.025	<0.0040	<0.50	<0.0050	<0.010	<0.050	<0.020	---	<0.20	0.0014	*0.051*	<0.00020	<0.050	<0.050	<0.0020	<0.0050	---	<0.0010	<0.0050	DM
Well A-06	RESE-1000255	24-Sep-07	<0.50	<0.0020	0.0015	0.017	<0.0040	<0.50	<0.0010	<0.010	<0.050	<0.020	<0.0020	<0.20	0.0014	0.048	<0.00020	<0.050	<0.050	<0.0020	<0.0010	<0.10	<0.0010	0.17	TA
Well A-06 (duplicate)	RESE-1000256	24-Sep-07	<0.50	<0.0020	0.0016	0.016	<0.0040	<0.50	<0.0010	<0.010	<0.050	<0.020	<0.0020	<0.20	0.0018	0.048	<0.00020	<0.050	<0.050	<0.0020	<0.0010	<0.10	<0.0010	0.16	TA
Well A-06	RESE-1003008	2-Jun-08	<0.20	<0.0030	0.0016	0.016	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	0.0016	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	0.48	TA
Well A-06	RESE-1003016	28-Aug-08	<0.20	<0.0030	0.0023	0.015	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	0.34	TA
Well A-06	RESE-1003030	4-Dec-08	<0.20	<0.0030	0.0021	0.014	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.10	<0.0010	0.39	TA
Well A-06	RESE-1003039	5-Mar-09	<0.20	<0.0030	0.0021	0.014	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	0.0018	<0.020	<0.050	<0.0010	0.034	<0.00020	<0.0010	0.0018	<0.0020	<0.0010	<0.040	<0.0010	0.25	TA
Well A-06	RESE-1003046	4-Jun-09	<0.20	<0.0030	0.0020	0.014	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	<0.0010	<0.020	<0.050	<0.0010	0.026	<0.00020	<0.0010	<0.0010	<0.0020	<0.0010	<0.040	<0.0010	0.16	TA
Well HRES-01	HRES-1d; open borehole test	8-Feb-04	<0.50	<0.050	<0.050	<0.010	<0.0040	<0.50	<0.0050	<0.010	<0.050	<0.020	---	0.20	<0.050	<0.020	<0.00020	<0.050	<0.050	<0.050	<0.0050	---	<0.050	<0.050	DM
Well HRES-01	RESE-1001102	15-Mar-04	<0.020	<0.0050	<0.010	0.0038	<0.0020	<0.040	<0.0020	<0.0060	<0.0060	<0.0030	---	0.083	<0.0050	0.0216	<0.00020	<0.0080	<0.010	<0.010	<0.0050	---	<0.010	0.0138	DM
Well HRES-01	RESE-1001103	18-Mar-04	<0.020	<0.0050	<0.010	0.0037	<0.0020	<0.040	<0.0020	<0.0060	<0.0060	<0.0030	---	0.155	<0.0050	0.0171	<0.00020	<0.0080	<0.010	<0.010	<0.0050	---	<0.010	0.0277	DM
Well HRES-02	HRES-2; open borehole test	18-Feb-04	<0.50	<0.050	<0.050	0.011	<0.0040	<0.50	<0.0050	<0.010	<0.050	<0.020	---	<0.20	<0.050	<0.020	<0.00020	<0.050	<0.050	<0.050	<0.0050	---	<0.050	0.057	DM
Well HRES-02	RESE-1001105	6-Apr-04	<0.020	<0.0030	0.003	0.0114	<0.0020	<0.040	<0.00010	<0.0060	<0.0060	0.0135	---	0.037	0.006	0.02	<0.00020	<0.0080	<0.010	<0.0030	<0.00010	---	<0.0020	0.0316	DM
Well HRES-02	RESE-1001108	8-Apr-04	*0.143*	<0.0030	**0.01**	0.0038	<0.0020	0.043	<0.00010	<0.0060	<0.0060	0.0189	---	0.19	<0.0030	0.0183	<0.00020	<0.0080	<0.010	<0.0030	<0.00010	---	<0.0020	0.0206	DM
Well HRES-02	RESE-1001109	10-Apr-04	*0.062*	<0.0030	0.009	<0.0020	<0.0020	0.043	<0.00010	<0.0060	<0.0060	<0.0030	---	0.021	<0.0030	0.0037	<0.00020	<0.0080	<0.010	<0.0030	<0.00010	---	<0.0020	<0.0050	DM
Well HRES-03	HRES-3AL; open borehole test	25-Feb-04	<0.50	<0.050	<0.050	<0.010	<0.0040	<0.50	<0.0050	<0.010	<0.050	<0.020	---	<0.20	<0.050	0.048	<0.00020	<0.050	<0.050	<0.050	<0.0050	---	<0.050	<0.050	DM
Well HRES-03	RESE-1001111; Test 1	16-Apr-04	0.035	<0.0030	<0.0030	<0.0020	<0.0020	0.061	<0.00010	<0.0060	<0.0060	<0.0030	---	0.263	<0.0030	0.006	<0.00020	0.0258	<0.010	<0.0030	<0.00010	---	<0.0020	0.007	DM

TABLE D-2. SUMMARY OF TRACE CONSTITUENTS FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	TRACE CONSTITUENTS[a] (mg/L)[b]																					ANALYTICAL LABORATORY[c]
			Al	Sb	As	Ba	Be	B	Cd	Cr	Co	Cu	CN	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	S	Tl	Zn	
GROUNDWATER (APACHE LEAP TUFF AQUIFER)- continued																									
Well HRES-04	HRES-4AL; open borehole test	3-Mar-04	<0.50	<0.050	<0.050	<0.010	<0.0040	<0.50	<0.0050	<0.010	<0.050	<0.020	---	<0.20	<0.050	0.024	<0.00020	<0.050	<0.050	<0.050	<0.0050	---	<0.050	<0.050	DM
Well HRES-04	RESE-1001110; Test 1	15-Apr-04	<0.020	<0.0030	<0.0030	0.0105	<0.0020	<0.040	<0.00010	<0.0060	<0.0060	<0.0030	---	0.061	<0.0030	*0.0775*	<0.00020	0.0094	<0.010	<0.0030	<0.00010	---	<0.0020	0.017	DM
Well HRES-04	4531; 30-day pumping test	3-Nov-06	<0.50	<0.002	0.0042	<0.010	<0.0040	<0.50	<0.0050	0.012	<0.050	<0.020	---	<0.20	<0.001	<0.020	<0.00020	---	<0.050	<0.002	<0.0050	---	<0.001	0.057	DM
Well HRES-04	RESE-1001114	18-Jan-08	<0.50	<0.002	0.0025	0.010	<0.0040	---	<0.001	<0.010	---	<0.020	<0.020	<0.20	0.0016	---	<0.00020	<0.050	<0.050	<0.002	<0.001	<0.10	<0.001	0.17	TA
Well HRES-04	RESE-1003021	3-Sep-08	<0.20	<0.0030	0.0035	<0.010	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.020	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	0.0023	<0.0010	<0.040	<0.0010	0.099	TA
Well HRES-04	RESE-1003031	2-Mar-09	<0.20	<0.0030	0.0036	0.0084	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	0.0018	<0.020	<0.050	<0.0010	<0.0050	<0.00020	0.0030	0.0017	<0.0020	<0.0010	<0.040	<0.0010	0.150	TA
Well HRES-04	RESE-1003040	1-Jun-09	<0.20	<0.0030	0.0035	0.0078	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	0.0011	<0.020	<0.050	<0.0010	<0.0050	<0.00020	0.0024	<0.0010	<0.0020	<0.0010	<0.040	<0.0010	0.140	TA
Well HRES-05	HRES-5AL; open borehole test	10-Mar-04	<0.50	<0.050	<0.050	0.019	<0.0040	<0.50	<0.0050	<0.010	<0.050	<0.020	---	<0.20	<0.050	0.028	<0.00020	<0.050	<0.050	<0.050	<0.0050	---	<0.050	<0.050	DM
Well HRES-05	RESE-1001104; Test 1	2-Apr-04	<0.020	<0.0030	<0.0030	0.028	<0.0020	<0.040	<0.00010	<0.0060	<0.0060	<0.0030	---	0.111	<0.0030	0.0339	<0.00020	0.0082	<0.010	<0.0030	<0.00010	---	<0.0020	0.0178	DM
Well HRES-05	RESE-1000264	27-Feb-08	<0.20	<0.0030	0.0023	0.030	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.020	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	0.059	TA
Well HRES-05	RESE-1003001	28-May-08	<0.20	<0.0030	0.0023	0.030	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	0.23	TA
Well HRES-05	RESE-1003012	25-Aug-08	<0.20	<0.0030	0.0086	0.032	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	0.0058	<0.0010	<0.040	<0.0010	0.26	TA
Well HRES-05	RESE-1003025	2-Dec-08	<0.20	<0.0030	0.0024	0.030	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.10	<0.0010	0.26	TA
Well HRES-05	RESE-1003034	3-Mar-09	<0.20	<0.0030	0.0025	0.031	<0.0010	<0.20	<0.0010	<0.0010	0.0021	0.0015	<0.020	<0.050	<0.0010	0.0210	<0.00020	0.0023	0.0023	<0.0020	<0.0010	<0.040	<0.0010	0.22	
Well HRES-05	RESE-1003043	3-Jun-09	<0.20	<0.0030	0.0024	0.031	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	0.0014	<0.020	<0.050	<0.0010	0.0150	<0.00020	0.002	<0.0010	0.002	<0.0010	<0.040	<0.0010	0.22	
Well HRES-06	RESE-1000301	12-Jun-07	<0.50	<0.002	0.0014	0.027	<0.0040	---	<0.001	<0.010	---	<0.020	<0.020	<0.20	0.0011	---	---	<0.050	<0.050	<0.002	<0.001	<0.10	<0.001	0.78	TA
Well HRES-06	RESE-1000265	27-Feb-08	<0.20	<0.0030	0.0015	0.025	<0.0010	---	<0.0010	<0.010	---	0.013	<0.020	*1.1*	0.0031	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	0.96	TA
Well HRES-06 (duplicate)	RESE-1000266	27-Feb-08	<0.20	<0.0030	0.0013	0.026	<0.0010	---	<0.0010	<0.010	---	0.010	<0.020	0.23	0.0024	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	0.85	TA
Well HRES-06	RESE-1003003	28-May-08	<0.20	<0.0030	0.0014	0.026	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	0.76	TA
Well HRES-06	RESE-1003013	25-Aug-08	<0.20	<0.0030	0.0025	0.026	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	0.12	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	0.84	TA
Well HRES-06	RESE-1003026	3-Dec-08	<0.20	<0.0030	0.0014	0.024	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	0.053	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.10	<0.0010	1.9	TA
Well HRES-06 (duplicate)	RESE-1003027	3-Dec-08	<0.20	<0.0030	0.0014	0.025	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	0.051	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.10	<0.0010	1.9	TA
Well HRES-06	RESE-1003035	4-Mar-09	<0.20	<0.0030	0.0016	0.025	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	0.002	<0.020	<0.050	<0.0010	0.025	<0.00020	0.0024	0.002	<0.0020	<0.0010	<0.040	<0.0010	0.87	TA
Well HRES-06 (duplicate)	RESE-1003036	4-Mar-09	<0.20	<0.0030	0.0016	0.026	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	0.0011	<0.020	<0.050	<0.0010	0.024	<0.00020	0.0021	0.0021	<0.0020	<0.0010	<0.040	<0.0010	0.91	TA
Well HRES-06	RESE-1003044	3-Jun-09	<0.20	<0.0030	0.0016	0.026	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	<0.0010	<0.020	<0.050	<0.0010	0.019	<0.00020	0.0020	0.001	<0.0020	<0.0010	<0.040	<0.0010	0.87	TA
Well HRES-06 (duplicate)	RESE-1003045	3-Jun-09	<0.20	<0.0030	0.0015	0.026	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	<0.0010	<0.020	<0.050	<0.0010	0.019	<0.00020	0.002	<0.0010	<0.0020	<0.0010	<0.040	<0.0010	0.84	TA
Well HRES-07	RESE-1000262	26-Feb-08	<0.20	<0.0030	0.0015	0.019	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.020	0.10	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	<0.050	TA
Well HRES-07	RESE-1003009	3-Jun-08	<0.20	<0.0030	0.0012	0.015	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	*0.50*	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	<0.050	TA
Well HRES-07 (duplicate)	RESE-1003010	3-Jun-08	<0.20	<0.0030	0.0012	0.014	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	*0.47*	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	<0.050	TA
Well HRES-07	RESE-1003018	2-Sep-08	<0.20	<0.0030	0.0014	0.012	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.020	0.27	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	<0.050	TA
Well HRES-07	RESE-1003022	1-Dec-08	<0.20	<0.0030	0.0014	0.015	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	*0.52*	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.10	<0.0010	<0.050	TA
Well HRES-07	RESE-1003032	3-Mar-09	<0.20	<0.0030	0.0014	0.015	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	<0.0010	<0.020	*0.36*	<0.0010	*0.089*	<0.00020	0.0016	0.010	<0.0020	<0.0010	<0.040	<0.0010	0.044	TA
Well HRES-07	RESE-1003041	2-Jun-09	<0.20	<0.0030	0.0015	0.015	<0.0010	<0.20	<0.0010	<0.0010	<0.0010	<0.0010	<0.020	0.29	<0.0010	*0.076*	<0.00020	0.0014	0.0032	0.0023	<0.0010	<0.040	<0.0010	0.036	TA
Well MJ-11	RESE-1000257	28-Sep-07	<0.50	<0.002	0.0021	0.016	<0.0040	<0.50	<0.001	<0.010	<0.050	<0.020	<0.020	<0.20	0.0014	<0.020	<0.00020	<0.050	<0.050	<0.002	<0.001	<0.10	<0.001	<0.050	TA
Well MJ-11	RESE-1000261	20-Feb-08	<0.50	<0.002	0.0019	0.014	<0.0040	---	<0.001	<0.010	---	<0.020	<0.020	<0.20	<0.001	---	<0.00020	<0.050	<0.050	<0.002	<0.001	<0.10	<0.001	<0.050	TA
Well MJ-11	RESE-1003007	2-Jun-08	<0.20	<0.0030	0.0022	0.015	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	<0.0020	<0.0010	<0.040	<0.0010	<0.050	TA
Well MJ-11	RESE-1003015	26-Aug-08	<0.20	<0.0030	0.0018	0.015	<0.0010	---	<0.0010	<0.010	---	<0.010	<0.025	<0.050	<0.0010	---	<0.00020	<0.010	<0.010	0.022	<0.0010	<0.040	<0.0010	<0.050	TA

TABLE D-2. SUMMARY OF TRACE CONSTITUENTS FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	TRACE CONSTITUENTS[a] (mg/L)[b]																						ANALYTICAL LABORATORY[c]
			Al	Sb	As	Ba	Be	B	Cd	Cr	Co	Cu	CN	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	S	Tl	Zn	
GROUNDWATER (DEEP GROUNDWATER SYSTEM)																									
DHRES-01	RESE-112808	28-Nov-08	<0.2	<0.0030	0.0056	0.48	<0.0010	---	<0.0010	<0.010	---	0.0081	<0.020	*2.7*	<0.0010	*0.16*	<0.00020	0.032	<0.010	<0.0020	<0.0010	<0.040	<0.0010	<0.050	TA
U.S. EPA National Primary Drinking Water Regulations			---	0.006	0.010	2	0.004	--	0.005	0.1	---	1.3	---	---	0.015	---	0.002	---	---	0.05	---	---	0.002	---	---
U.S. EPA National Secondary Drinking Water Regulations			0.05 to 0.2	---	---	---	---	---	---	---	---	1.0	---	0.3	---	0.050	---	---	---	---	0.1	---	---	5	---
Arizona Numeric Aquifer Water Quality Standards			---	0.006	0.05	2.0	0.004	--	0.005	0.1	---	1.3	0.20	---	0.05	---	0.002	---	0.1	0.05	---	---	0.002	---	---

Values in bold red are out of compliance with applicable primary water quality standards

Values in red italics are out of compliance with applicable secondary water quality standards

[a] Al = Aluminum
Sb = Antimony
As = Arsenic
Ba = Barium
Be = Beryllium
B = Boron
Cd = Cadmium
Cr = Chromium (total)
Co = Cobalt
Cu = Copper
CN = Cyanide (amenable)
Fe = Iron
Pb = Lead
Mn = Manganese
Hg = Mercury
Mo = Molybdenum
Ni = Nickel
Se = Selenium
Ag = Silver
S = Sulfide
Tl = Thallium
Zn = Zinc

[b] mg/L = milligrams per liter

[c] ANALYTICAL LABORATORIES

TA = Test America, Phoenix, AZ

DM = Del Mar Analytical, Phoenix, AZ

--- = not available, not applicable

< = Less than reported detection limit

TABLE D-3. SUMMARY OF RADIOLOGICAL DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	RADIOLOGICAL CONSTITUENTS[a]						
			Gross Alpha (pCi/L)[b]	Gross Beta (pCi/L)	Ra-226 (pCi/L)	Ra-228 (pCi/L)	Ra-226 + Ra-228 (pCi/L)	Total U (pCi/L)	Total U (mg/L)
GROUNDWATER (SHALLOW AQUIFERS)									
Hackberry Windmill Well	RESE-1000263	27-Feb-08	<1.3	2.5 ± 1.4	<0.1	<1.3	<1.4	<0.2	<0.0003
Hackberry Windmill Well	RESE-1003011	3-Jun-08	<1.5	<2.6	0.25 ± 0.15	2.8 ± 0.85	3.05	<0.2	<0.0003
Hackberry Windmill Well	RESE-1003019	2-Sep-08	<1.4	2.9 ± 1.7	<0.23	<1.2	<1.43	<0.2	<0.0003
Hackberry Windmill (duplicate)	RESE-1003020	2-Sep-08	<1.4	<2.7	<0.19	<1.2	<1.39	<0.2	<0.0003
Hackberry Windmill Well	RESE-1003024	2-Dec-08	3.5 ± 1.1	6.0 ± 1.7	<0.15	<1.2	<1.35	<0.2	<0.0003
JI Ranch Corral Well	RESE-1000302	21-Jun-07	<1.0	<2.0	0.6 ± 0.3	<1.0	0.6	<0.2	<0.0003
JI Ranch Corral Well	RESE-1003005	29-May-08	2.6 ± 1.6	<2.7	0.55 ± 0.15	1.1 ± 0.55	1.65	<0.2	<0.0003
JI Ranch Corral Well	RESE-1003014	25-Aug-08	<3.1	<4.0	<0.23	<1.2	<1.43	<0.2	<0.0003
JI Ranch Corral Well	RESE-1003029	3-Dec-08	8.6 ± 3.0	5.1 ± 2.8	<0.18	1.7 ± 0.80	1.7	<0.2	<0.0003
JI Ranch Middle Well	RESE-1003006	30-May-08	<1.5	<2.6	0.29 ± 0.11	<0.85	0.29	<0.2	<0.0003
JI Ranch Middle Well	RESE-1003017	27-Aug-08	<1.6	<2.7	<0.25	<1.2	<1.45	<0.2	<0.0003
JI Ranch Middle Well	RESE-1003028	3-Dec-08	4.6 ± 1.5	3.9 ± 1.7	<0.16	2.0 ± 0.81	2.0	<0.2	<0.0003
GROUNDWATER (APACHE LEAP TUFF AQUIFER)									
JI Ranch House Well	RESE-1000303	21-Jun-07	<1.0	<2.0	<0.2	<1.0	<1.2	<0.2	<0.0003
Well A-06	RESE-1000255	24-Sep-07	1.8 ± 0.5	<2.0	<0.2	<1.0	<1.2	0.7 ± 0.5	0.0004
Well A-06 (duplicate)	RESE-1000256	24-Sep-07	1.3 ± 0.5	<2.0	<0.2	<1.0	<1.2	3.1 ± 0.7	0.0004
Well A-06	RESE-1003008	2-Jun-08	<1.6	<2.7	0.12 ± 0.09	<1.0	0.12	1.0 ± 0.3	0.0003
Well A-06	RESE-1003016	28-Aug-08	<1.5	<2.7	<0.23	<1.0	<1.23	0.9 ± 0.4	<0.0003
Well A-06	RESE-1003030	4-Dec-08	<1.5	<2.6	<0.17	<1.0	<1.17	0.7 ± 0.3	0.0003
Well HRES-04	RESE-1001114	18-Jan-08	2.3 ± 0.7	<2.0	<0.2	<1.0	<1.2	2.8 ± 1.0	0.0022
Well HRES-04	RESE-1003021	3-Sep-08	1.7 ± 1.0	<2.7	<0.2	<1.2	<1.4	2.6 ± 0.6	0.0016

TABLE D-3. SUMMARY OF RADIOLOGICAL DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	RADIOLOGICAL CONSTITUENTS[a]						
			Gross Alpha (pCi/L)[b]	Gross Beta (pCi/L)	Ra-226 (pCi/L)	Ra-228 (pCi/L)	Ra-226 + Ra-228 (pCi/L)	Total U (pCi/L)	Total U (mg/L)
GROUNDWATER (APACHE LEAP TUFF AQUIFER) - continued									
Well HRES-05	RESE-1000264	27-Feb-08	5.5 ± 1.0	<2.5	<0.1	<1.3	<1.4	2.9 ± 0.5	0.0012
Well HRES-05	RESE-1003001	28-May-08	<1.8	<2.7	0.13 ± 0.09	<0.85	0.13	2.6 ± 0.5	0.0010
Well HRES-05	RESE-1003012	25-Aug-08	2.0 ± 1.1	<2.7	<0.22	<1.2	<1.42	2.6 ± 0.6	0.0008
Well HRES-05	RESE-1003025	2-Dec-08	<1.6	<2.6	<0.15	<1.2	<1.35	2.4 ± 0.6	0.0009
Well HRES-06	RESE-1000301	12-Jun-07	<1.0	<2.0	<0.2	<1.0	<1.2	1.1 ± 0.6	0.0004
Well HRES-06	RESE-1000265	27-Feb-08	2.0 ± 0.7	<2.5	<0.1	<1.3	<1.4	0.4 ± 0.2	0.0003
Well HRES-06 (duplicate)	RESE-1000266	27-Feb-08	3.7 ± 0.8	<2.5	<0.1	<1.3	<1.4	0.6 ± 0.2	<0.0003
Well HRES-06	RESE-1003003	28-May-08	<1.5	<2.6	<0.14	2.2 ± 0.60	2.20	0.4 ± 0.2	<0.0003
Well HRES-06	RESE-1003013	25-Aug-08	<1.4	<2.7	<0.23	<1.2	<1.43	0.4 ± 0.2	<0.0003
Well HRES-06	RESE-1003026	3-Dec-08	<1.4	<2.6	<0.15	<1.2	<1.35	<0.2	<0.0003
Well HRES-06 (duplicate)	RESE-1003027	3-Dec-08	1.5 ± 1	<2.6	<0.15	<1.2	<1.35	<0.2	<0.0003
Well HRES-07	RESE-1000262	26-Feb-08	2.7 ± 0.8	3.3 ± 1.5	<0.1	<1.3	<1.4	1.1 ± 0.3	0.0006
Well HRES-07	RESE-1003009	3-Jun-08	1.6 ± 1.1	<2.6	<0.14	1.8 ± 0.58	1.8	1.4 ± 0.4	0.0007
Well HRES-07 (duplicate)	RESE-1003010	3-Jun-08	<1.6	<2.6	0.19 ± 0.10	<0.85	0.19	1.6 ± 0.4	0.0008
Well HRES-07	RESE-1003018	2-Sep-08	<1.4	<2.7	<0.23	<1.2	<1.43	1.2 ± 0.4	0.0006
Well HRES-07	RESE-1003022	1-Dec-08	<1.5	<2.6	<0.16	<1.2	<1.36	1.7 ± 0.4	0.0007
Well MJ-11	RESE-1000257	29-Sep-07	1.3 ± 0.5	<2.0	<0.2	<1.0	<1.2	1.2 ± 0.5	0.0003
Well MJ-11	RESE-1000261	20-Feb-08	2.9 ± 0.8	<2.5	<0.1	<1.3	<1.4	0.6 ± 0.3	0.0003
Well MJ-11	RESE-1003007	2-Jun-08	<1.6	<2.7	0.17 ± 0.12	1.5 ± 0.79	1.67	0.8 ± 0.3	<0.0003
Well MJ-11	RESE-1003015	26-Aug-08	<1.4	<2.7	<0.23	<1.2	<1.43	0.6 ± 0.4	<0.0003
GROUNDWATER (DEEP GROUNDWATER SYSTEM)									
DHRES-01	RESE-112808	28-Nov-08	9.5 ± 2.3	25.0 ± 2.2	2.4 ± 0.31	2.3 ± 0.82	4.7	<0.2	<0.0003

TABLE D-3. SUMMARY OF RADIOLOGICAL DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	RADIOLOGICAL CONSTITUENTS[a]						
			Gross Alpha (pCi/L)[b]	Gross Beta (pCi/L)	Ra-226 (pCi/L)	Ra-228 (pCi/L)	Ra-226 + Ra-228 (pCi/L)	Total U (pCi/L)	Total U (mg/L)
SPRING AND SURFACE WATER SAMPLES (DEVILS CANYON WATERSHED)									
DC6.1E	RESE-1002007	7-Aug-08	<1.6	<2.7	<0.18	<1.2	<1.38	1.1 ± 0.4	0.0005
DC6.14C	RESE-1002013	20-Aug-08	3.9 ± 1.3	<3.2	<0.24	<1.2	<1.44	<0.2	<0.0003
DC 8.1 C	RESE-1002005	6-Aug-08	<1.5	<2.7	<0.20	<1.2	<1.40	1.1 ± 0.4	<0.0003
DC8.2W	RESE-1000260	19-Feb-08	2.9 ± 0.8	<2.5	<0.1	<1.3	<1.31	1.1 ± 0.3	0.0006
DC8.2W	RESE-1003002	27-May-08	<1.6	<2.7	<0.12	1.1 ± 0.56	1.1	1.3 ± 0.4	0.0005
DC8.2W	RESE-1002004	6-Aug-08	<1.4	<2.7	<0.18	1.4 ± 0.79	1.4	0.9 ± 0.4	0.0005
DC8.2W	RESE-1003023	2-Dec-08	<1.5	<2.6	<0.15	<1.2	<1.35	0.7 ± 0.4	0.0004
DC 13.5 C	RESE-1002014	21-Aug-08	5.1 ± 1.3	<3.2	<0.22	<1.2	<1.42	<0.2	<0.0003
DC14.7C	RESE-1002015	27-Aug-08	**20.8** ± 2.7	18.4 ± 2.3	<0.19	<0.12	<0.31	0.4 ± 0.4	<0.0003
DC 15.7 C	RESE-1002003	5-Aug-08	<1.0	<2.6	<0.19	1.4 ± 0.79	1.4	<0.2	<0.0003
H0.1C	RESE-1002011	19-Aug-08	3.4 ± 1.2	<3.2	<0.20	<1.2	<1.22	<0.2	<0.0003
IC1.0C	RESE-1002019	28-Aug-08	**18.2** ± 2.0	23.8 ± 2.3	<0.21	<1.2	<1.41	<0.2	<0.0003
RR1.5C	RESE-1002012	19-Aug-08	1.9 ± 1.0	<3.2	<0.28	<1.2	<1.48	<0.2	<0.0003
SPRING AND SURFACE WATER SAMPLES (QUEEN CREEK WATERSHED)									
Boulder Hole	RESE-1002006	6-Aug-08	<2.5	<3.1	<0.23	<1.2	<1.43	2.4 ± 0.6	0.0017
QC22.6E	RESE-1002017	28-Aug-08	9.1 ± 2.5	<3.4	<0.21	<1.2	<1.41	1.5 ± 0.5	<0.0003
Number Nine	RESE-1002020	28-Aug-08	3.8 ± 1.1	<3.2	<0.22	<1.2	<1.42	<0.2	<0.0003
Oak Flat Tributary	RESE-1002016	27-Aug-08	4 ± 1.1	<3.2	<0.20	<1.2	<1.4	<0.2	<0.0003
Pump Station Spring	RESE-1002001	5-Aug-08	<3.5	<4.1	<0.18	<1.2	<1.38	1.1 ± 0.4	0.0011

TABLE D-3. SUMMARY OF RADIOLOGICAL DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	RADIOLOGICAL CONSTITUENTS[a] Gross Alpha (pCi/L)[b]	Gross Beta (pCi/L)	Ra-226 (pCi/L)	Ra-228 (pCi/L)	Ra-226 + Ra-228 (pCi/L)	Total U (pCi/L)	Total U (mg/L)
SPRING AND SURFACE WATER SAMPLES (QUEEN CREEK WATERSHED) - continued									
QC21.7C	RESE-1002018	28-Aug-08	4.7 ± 1.5	<3.3	<0.20	<1.2	<1.40	0.3 ± 0.3	<0.0003
QC19.7C	RESE-1002021	28-Aug-08	5.9 ± 1.8	4.2 ± 2.0	<0.21	<1.2	<1.41	0.3 ± 0.3	<0.0003
QC 27.3C	RESE-1002002	5-Aug-08	<1.9	2.9 ± 1.7	0.87 ± 0.62	<1.2	0.87	<0.2	0.0003
SPRING AND SURFACE WATER SAMPLES (APACHE LEAP ESCARPMENT)									
Blue Spring	RESE-1002009	19-Aug-08	3.8 ± 1.6	<3.3	<0.19	<1.2	<1.39	0.9 ± 0.4	0.0006
Blue Spring (duplicate)	RESE-1002010	19-Aug-08	5.8 ± 1.8	<3.3	<0.20	<1.2	<1.40	0.5 ± 0.3	0.0006
Hidden Spring	RESE-1002008	19-Aug-08	3.7 ± 2.4	<4.2	<0.19	<1.2	<1.39	0.8 ± 0.4	0.0005
Kane Spring	RESE-1002022	29-Aug-08	8.4 ± 2.7	<3.4	<0.20	<1.2	<1.40	2.4 ± 0.6	0.0004
SPRING AND SURFACE WATER SAMPLES (MINERAL CREEK WATERSHED)									
Ranch Fork Headwater Spring (MC8.4C)	RESE-1002090	14-May-09	<3.6	<3.0	<0.21	1.3 ± 0.79	1.3	3.2 ± 0.5	---
Ranch Fork Headwater Spring (MC8.4C)	RESE-1002093	14-May-09	<3.7	<3.5	<0.20	<1.2	<1.40	3.4 ± 0.6	---
Lyons Fork Headwater Spring (LF0.2C)	RESE-1002093	14-May-09	4.9 ± 1.8	<2.7	<0.20	<1.2	<1.40	3.3 ± 0.5	---
Wet Leg Spring (MC3.4W)	RESE-1002094	14-May-09	<2.5	<2.7	<0.19	<1.1	<1.29	2.6 ± 0.4	---
Mineral Creek (MC 3.3C)	RESE-1002095	14-May-09	<2.4	<2.6	<0.20	<1.2	<1.40	0.3 ± 0.2	---
U.S.EPA National Primary Drinking Water Regulations			15 pCi/L	4 mrem/year[c]	---	---	5 pCi/L	---	0.03 mg/L
Arizona Numeric Aquifer Water Quality Standards			15 pCi/L	Numerical std 4 mrem/yr for man-made beta emitters only	---	---	5 pCi/L	---	0.035 mg/L

Values in bold red are out of compliance with applicable primary water quality standards

[a] Ra-226 = Radium 226
Ra-228 = Radium 228
U = Uranium

< = Less than reported detection limit
--- = Not analyzed, not available

[b] pCi/L = picocuries per liter

[c] mrem/year = milliroentgen equivalent man per year

Total U is calculated as sum of the three U isotopes (Table D-5)

Uncertainty in total U is calculated as the square root of the sum of the squaresof the uncertainties associated with each U isotope analysis (Table D-5)

Analytical data provided by Energy Laboratories, Inc., Casper, WY

TABLE D-4. SUMMARY OF STABLE ISOTOPE DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	ISOTOPES				
			$\delta^{18}O$ (‰)[a]	δD (‰)[b]	$\delta^{13}C$ in DIC (‰)[c]	$\delta^{34}S$ (‰)[d]	$\delta^{18}O$ in SO_4 (‰)[e]
GROUNDWATER (SHALLOW AQUIFERS)							
Hackberry Windmill Well	WM-ALU[f]	17-Jun-86	-8.3	-62	---	---	---
Hackberry Windmill Well	001225	4-Jun-03	-5.6	-43	---	---	---
Hackberry Windmill Well	RESE-1000263	27-Feb-08	-7.6	-52	-10.5	1.7	8.4
Hackberry Windmill Well	RESE-1003011	3-Jun-08	-7.2	-50	-14.7	3.5	12.6
Hackberry Windmill Well	RESE-1003019	2-Sep-08	-7.1	-52	-15.9	0.3	10.8
Hackberry Windmill Well (duplicate)	RESE-1003020	2-Sep-08	-7.2	-52	---	0.4	9.5
Hackberry Windmill Well	RESE-1003024	2-Dec-08	-7.4	-59	-15.3	4.6	8.0
Hackberry Windmill Well	RESE-1003033	3-Mar-09	-7.7	-55	---	2.0	5.6
Hackberry Windmill Well	RESE-1003042	2-Jun-09	-7.3	-54	---	---	---
JI Ranch Corral Well	RESE-1003005	29-May-08	-9.6	-64	---	-5.4	5.6
JI Ranch Corral Well	RESE-1003014	25-Aug-08	-10.4	-72	-19.4	-4.9	-0.7
JI Ranch Corral Well	RESE-1003029	3-Dec-08	-10.5	-73	-20.0	-4.0	0.9
JI Ranch Corral Well	RESE-1003038	4-Mar-09	-10.3	-71	-18.0	-3.4	-0.1
JI Ranch Corral Well	RESE-1003047	5-Jun-09	-10.2	-71	---	---	---
JI Ranch Middle Well	RESE-1003006	30-May-08	-9.5	-63	---	-2.1	28.8
JI Ranch Middle Well	RESE-1003017	27-Aug-08	-9.9	-67	-18.9	-2.7	32.3
JI Ranch Middle Well	RESE-1003028	3-Dec-08	-10.0	-69	-18.8	-2.4	4.3
JI Ranch Middle Well	RESE-1003037	4-Mar-09	-9.8	-65	-18.9	-2.0	3.9
JI Ranch Middle Well	RESE-1003048	5-Jun-09	-10.0	-68	---	---	---
GROUNDWATER (APACHE LEAP TUFF AQUIFER)							
JI Ranch House Well	RESE-1000303	21-Jun-07	-10.3	-72	-16.2	5.1	---
Well A-06	RESE-1000255	24-Sep-07	-10.4	-70	-16.4	10.0	13.5
Well A-06 (duplicate)	RESE-1000256	24-Sep-07	-10.4	-71	NA	9.2	insufficient sample
Well A-06	RESE-1003008	02-Jun-08	-10.4	-70	-15.8	6.6	8.3
Well A-06	RESE-1003016	28-Aug-08	-10.5	-71	-16.3	6.2	12.5
Well A-06	RESE-1003030	04-Dec-08	-10.4	-71	-16.0	7.1	insufficient sample
Well A-06	RESE-1003039	05-Mar-09	-10.5	-70	-15.9	6.8	6.3
Well A-06	RESE-1003046	04-Jun-09	-10.4	-70	---	---	---
Well HRES-01	RESE-1001103	18-Mar-04	-9.5	-66	---	---	---

TABLE D-4. SUMMARY OF STABLE ISOTOPE DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	ISOTOPES				
			$\delta^{18}O$ (‰)[a]	δD (‰)[b]	$\delta^{13}C$ in DIC (‰)[c]	$\delta^{34}S$ (‰)[d]	$\delta^{18}O$ in SO_4 (‰)[e]
GROUNDWATER (APACHE LEAP TUFF AQUIFER) - continued							
Well HRES-02	RESE-1001105	6-Apr-04	-9.1	-64	---	---	---
Well HRES-02	RESE-1001108	8-Apr-04	-9.9	-68	---	---	---
Well HRES-02	RESE-1001109	10-Apr-04	-9.9	-68	---	---	---
Well HRES-03	RESE-1001111	16-Apr-04	-11.4	-79	---	---	---
Well HRES-04	RESE-1001110	15-Apr-04	-9.6	-65	-15.6	5.0	8.2
Well HRES-04	RESE-1001114	18-Jan-08	-9.7	-66	-15.1	6.3	12.0
Well HRES-04	RESE-1003021	3-Sep-08	-9.6	-67	-14.5	4.9	16.7
Well HRES-04	RESE-1003031	2-Mar-09	-9.6	-65	-14.0	3.6	5.3
Well HRES-04	RESE-1003040	1-Jun-09	-9.6	-65	---	---	---
Well HRES-05	RESE-1001104	2-Apr-04	-9.5	-65	---	---	---
Well HRES-05	RESE-1000264	27-Feb-08	-9.7	-66	-13.3	8.5	13.5
Well HRES-05	RESE-1003001	28-May-08	-9.5	-65	-14.0	5.3	13.1
Well HRES-05	RESE-1003012	25-Aug-08	-9.1	-72	-14.2	7.8	7.8
Well HRES-05	RESE-1003025	2-Dec-08	-9.5	-67	-14.7	6.6	insufficient sample
Well HRES-05	RESE-1003034	3-Mar-09	-9.6	-65	-14.2	8.6	3.3
Well HRES-05	RESE-1003043	3-Jun-09	-9.7	-65	---	---	---
Well HRES-06	RESE-1000301	12-Jun-07	-10.3	-70	-15.6	4.5	9.9
Well HRES-06	RESE-1000265	27-Feb-08	-10.3	-71	-7.7	4.9	9.2
Well HRES-06 (duplicate)	RESE-1000266	27-Feb-08	-10.3	-71	-15	4.8	9.3
Well HRES-06	RESE-1003003	28-May-08	-10.1	-71	-16.5	8.5	18.7
Well HRES-06	RESE-1003013	25-Aug-08	-10.2	-72	-15.6	5	11.6
Well HRES-06	RESE-1003026	3-Dec-08	-10.2	-72	-16.1	5.2	9.6
Well HRES-06 (duplicate)	RESE-1003027	3-Dec-08	-10.3	-71	-15.8	4.9	8.0
Well HRES-06	RESE-1003035	4-Mar-09	-10.4	-70	-15.4	4.5	8.7
Well HRES-06 (duplicate)	RESE-1003036	4-Mar-09	-10.4	-70	-15.3	5	5.6
Well HRES-06	RESE-1003044	3-Jun-09	-10.3	-71	---	---	---
Well HRES-06 (duplicate)	RESE-1003045	3-Jun-09	-10.3	-70	---	---	---

TABLE D-4. SUMMARY OF STABLE ISOTOPE DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	ISOTOPES $\delta^{18}O$ (‰)[a]	δD (‰)[b]	$\delta^{13}C$ in DIC (‰)[c]	$\delta^{34}S$ (‰)[d]	$\delta^{18}O$ in SO_4 (‰)[e]
GROUNDWATER (APACHE LEAP TUFF AQUIFER) - continued							
Well HRES-07	RESE-1000262	26-Feb-08	-9.8	-67	-14.2	4.5	17.6
Well HRES-07	RESE-1003009	3-Jun-08	-9.8	-70	-13.5	4.6	9.0
Well HRES-07 (duplicate)	RESE-1003010	3-Jun-08	-9.8	-67	-13.9	4.8	6.5
Well HRES-07	RESE-1003018	2-Sep-08	-9.7	-68	-14.3	4.3	9.0
Wel HRES-07	RESE-1003022	1-Dec-08	-9.8	-68	-15.1	4.3	5.2
Well HRES-07	RESE-1003032	3-Mar-09	-10.0	-67	---	4.3	5.8
Wel HRES-07	RESE-1003041	2-Jun-09	-9.8	-69	---	---	---
Well HRES-07	RESE-1000290	6-Dec-09	---	---	-15.1	---	---
Well MJ-11	RESE-1000257	29-Sep-07	-10.4	-71	-16.7	8.1	9.8
Well MJ-11	RESE-1000261	20-Feb-08	-10.4	-67	-15.6	6.6	insufficient sample
Well MJ-11	RESE-1003007	02-Jun-08	-10.4	-70	-15.6	6.4	10.6
Well MJ-11	RESE-1003015	26-Aug-08	-10.4	-71	-15.9	5.5	8.3
GROUNDWATER (DEEP GROUNDWATER SYSTEM)							
DHRES-01	RESE-112808	28-Nov-08	-11.8	-83	-7.3	7.7	2.0
SPRING AND SURFACE WATER SAMPLES (DEVILS CANYON WATERSHED)							
DC6.1E	001226	5-Jun-03	-10.0	-69	---	---	---
DC6.1E	RESE-1002007	7-Aug-08	-10.3	-70	---	1.5	6.8
DC6.1E	RESE-1002064	25-Feb-09	-10.3	-70	---	1.5	4.2
DC6.1E	RESE-1002099	20-May-09	-10.5	-70	---	---	---
DC6.14C	RESE-1002013	20-Aug-08	-10.5	-82	---	6.7	13.4
DC6.14C	RESE-1002037	12-Nov-08	-8.4	-68	---	---	---
DC6.14C	RESE-1002056	18-Feb-09	-8.0	-50	---	0.6	7.3
DC6.14C	RESE-1002078	6-May-09	-7.8	-55	---	---	---
DC6.6W	001227	5-Jun-03	-9.9	-68	---	---	---
DC8.1C	RESE-1002005	6-Aug-08	-9.9	-71	---	5.3	16.0
DC8.1C	RESE-1002062	24-Feb-09	-8.2	-51	---	0.6	8.5
DC8.1C	RESE-1002098	19-May-09	-9.7	-66	---	---	---
DC8.2W	RESE-1000260	19-Feb-08	-10.0	-68	-15	4.5	9.8
DC8.2W	RESE-1003002	27-May-08	-9.8	-68	---	4.8	8.7
DC8.2W	RESE-1002004	6-Aug-08	-10.0	-68	---	5.2	14.1
DC8.2W	RESE-1003023	2-Dec-08	-10.1	-68	---	4.5	1.8
DC8.2W	RESE-1002063	24-Feb-09	-9.8	-66	---	3.7	7.1

TABLE D-4. SUMMARY OF STABLE ISOTOPE DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	ISOTOPES				
			$\delta^{18}O$ (‰)[a]	δD (‰)[b]	$\delta^{13}C$ in DIC (‰)[c]	$\delta^{34}S$ (‰)[d]	$\delta^{18}O$ in SO_4 (‰)[e]
DC8.2W	RESE-1002097	19-May-09	-10.3	-69	---	---	---

TABLE D-4. SUMMARY OF STABLE ISOTOPE DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	ISOTOPES $\delta^{18}O$ (‰)[a]	δD (‰)[b]	$\delta^{13}C$ in DIC (‰)[c]	$\delta^{34}S$ (‰)[d]	$\delta^{18}O$ in SO_4 (‰)[e]
SPRING AND SURFACE WATER SAMPLES (DEVILS CANYON WATERSHED) - continued							
DC13.5C	RESE-1002014	21-Aug-08	-8.7	-73	---	1.6	insufficient sample
DC13.5C	RESE-1002057	19-Feb-09	-8.2	-52	---	0.8	7.4
DC13.5C	RESE-1002103	21-May-09	-5.9	-46	---	---	---
DC14.7C	RESE-1002015	27-Aug-08	-13.5	-99	---	-1.8	10.3
DC15.5C	RESE-1002003	5-Aug-08	-12.1	-97	---	insufficient sample	insufficient sample
DC15.5C	RESE-1002069	26-Feb-09	-8.0	-51	---	1.3	5.1
DC15.5C	RESE-1002075	5-May-09	-11.6	-82	---	4.8	1.1
H0.1C	RESE-1002011	19-Aug-08	-3.5	-46	---	8.7	13.1
H0.1C	RESE-1002061	24-Feb-09	-7.4	-49	---	0.3	4.7
H0.1C	RESE-1002096	19-May-09	-3.6	-43	---	---	---
IC1.0C	RESE-1002019	28-Aug-08	-12.6	-93	---	-7.7	6.8
IC1.0C	RESE-1002055	17-Feb-09	-8.3	-52	---	0.4	7.4
IC1.0C	RESE-1002085	12-May-09	-7.6	-55	---	---	---
RR1.5C	RESE-1002012	19-Aug-08	-9.6	-66	---	1.0	8.4
RR1.5C	RESE-1002065	26-Feb-09	-7.7	-51	---	1.1	6.5
RR1.5C (duplicate)	RESE-1002066	26-Feb-09	-7.7	-50	---	1.1	5.3
RR1.5C	RESE-1002100	21-May-09	-8.4	-58	---	---	---
RR1.5C (duplicate)	RESE-1002101	21-May-09	-8.3	-58	---	---	---
SPRING AND SURFACE WATER SAMPLES (QUEEN CREEK WATERSHED)							
Boulder Hole	RESE-1002006	6-Aug-08	-11.0	-81	---	15.9	14.8
Boulder Hole	RESE-1002060	19-Feb-09	-7.8	-50	---	0.2	3.3
Boulder Hole	RESE-1002082	7-May-09	-7.4	-53	---	---	---
QC22.6E	RESE-1002017	28-Aug-08	-11.1	-80	---	1.7	6.0
QC22.6E	RESE-1002049	11-Feb-09	-8.4	-57	---	0.7	5.3
QC22.6E (duplicate)	RESE-1002050	11-Feb-09	-8.5	-56	---	0.5	4.5
Number Nine	RESE-1002020	28-Aug-08	-12.8	-98	---	-0.5	6.7
Number Nine	RESE-1002058	19-Feb-09	-7.5	-47	---	0.9	6.2
Number Nine duplicate	RESE-1002059	19-Feb-09	-7.6	-47	---	0.5	6.3
Number Nine	RESE-1002077	5-May-09	-3.5	-36	---	---	---

TABLE D-4. SUMMARY OF STABLE ISOTOPE DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	ISOTOPES $\delta^{18}O$ (‰)[a]	δD (‰)[b]	$\delta^{13}C$ in DIC (‰)[c]	$\delta^{34}S$ (‰)[d]	$\delta^{18}O$ in SO_4 (‰)[e]
SPRING AND SURFACE WATER SAMPLES (QUEEN CREEK WATERSHED)							
Oak Flat Tributary	RESE-1002016	27-Aug-08	-14.1	-105	---	-0.4	6.0
Oak Flat Tributary	RESE-1002068	26-Feb-09	-7.0	-45	---	2.4	5.4
Oak Flat Tributary	RESE-1002076	5-May-09	-2.2	-30	---	---	---
Pump Station Spring	RESE-1002001	5-Aug-08	-9.9	-67	---	-1.1	14.6
Pump Station Spring	RESE-1002053	17-Feb-09	-7.7	-47	---	1.2	7.0
Pump Station Spring	RESE-1002080	12-May-09	-9.5	-63	---	---	---
Pump Station Spring (duplicate)	RESE-1002084	12-May-09	-9.7	-64	---	---	---
QC21.7C	RESE-1002018	28-Aug-08	-11.9	-89	---	-1.1	4.9
QC21.7C	RESE-1002047	11-Feb-09	-8.4	-55	---	0.8	6.5
QC21.7C	RESE-1002083	7-May-09	7.5	4	---	---	---
QC19.7C	RESE-1002021	28-Aug-08	-12.0	-91	---	0.1	4.4
QC19.7C	RESE-1002048	11-Feb-09	-8.3	-54	---	0.9	7.2
SPRING AND SURFACE WATER SAMPLES (APACHE LEAP ESCARPMENT)							
QC27.3C	RESE-1002002	5-Aug-08	-2.2	-48	---	12.2	11.3
QC27.3C	RESE-1002054	17-Feb-09	-7.8	-47	---	0.8	5.3
QC27.3C	RESE-1002079	7-May-09	-0.5	-24	---	---	---
Blue Spring	RESE-1002009	19-Aug-08	-9.7	-67	---	4.5	17.7
Blue Spring (duplicate)	RESE-1002010	19-Aug-08	-9.7	-67	---	4.7	17.8
Blue Spring	RESE-1002052	12-Feb-09	-7.9	-54	---	3.7	4.9
Blue Spring	RESE-1002088	13-May-29	-9.8	-67	---	---	---
Bored Spring	RESE-1002051	12-Feb-09	-6.8	-56	---	7.7	6.4
Bored Spring	RESE-1002089	13-May-09	-4.7	-49	---	---	---
Hidden Spring	RESE-1002008	19-Aug-08	-9.4	-68	---	0.2	5.9
Hidden Spring	RESE-1002045	10-Feb-09	-9.5	-68	---	-0.3	4.6
Hidden Spring	RESE-1002086	12-May-09	-9.7	-68	---	---	---
Kane Spring	RESE-1002022	29-Aug-08	-10.2	-73	---	3.9	9.9
Kane Spring	RESE-1002046	10-Feb-09	-9.9	-69	---	4.2	5.3
Kane Spring	RESE-1002087	13-May-09	-10.3	-71	---	---	---

TABLE D-4. SUMMARY OF STABLE ISOTOPE DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	ISOTOPES				
			$\delta^{18}O$ (‰)[a]	δD (‰)[b]	$\delta^{13}C$ in DIC (‰)[c]	$\delta^{34}S$ (‰)[d]	$\delta^{18}O$ in SO_4 (‰)[e]
SURFACE WATER SAMPLES (MINERAL CREEK WATERSHED)							
LC0.2C	RESE-1002039	13-Nov-08	-9.5	-68	---	---	---
LC0.2C	RESE-1002072	5-Mar-09	-9.1	-61	---	-2.5	5.2
LC0.2C	RESE-1002093	14-May-09	-9.1	-62	---	---	---
MC 3.3C	RESE-1002040	13-Nov-08	-9.6	-69	---	---	---
MC 3.3C	RESE-1002074	5-Mar-09	-9.1	-64	---	-0.7	3.9
MC 3.3C	RESE-1002095	14-May-09	-9.3	-65	---	---	---
MC8.4C	RESE-1002038	13-Nov-08	-9.6	-69	---	---	---
MC8.4C	RESE-1002071	5-Mar-09	-9.5	-66	---	0.1	4.9
MC8.4C	RESE-1002090	14-May-09	-9.4	-67	---	---	---
MC8.4C	RESE-1002091	14-May-09	-9.6	-67	---	---	---
MC3.4W	RESE-1002041	13-Nov-08	-10.2	-71	---	---	---
MC3.4W	RESE-1002073	5-Mar-09	-10.2	-71	---	3.3	3.6
MC3.4W	RESE-1002094	14-May-09	-10.2	-70	---	---	---

TABLE D-4. SUMMARY OF STABLE ISOTOPE DATA FOR WATER SAMPLES OBTAINED IN DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	ISOTOPES				
			$\delta^{18}O$ (‰)[a]	δD (‰)[b]	$\delta^{13}C$ in DIC (‰)[c]	$\delta^{34}S$ (‰)[d]	$\delta^{18}O$ in SO_4 (‰)[e]
PRECIPITATION SAMPLES							
Apache Leap Study Area[g]	Rain sample	1989-1992	-5.7	-20	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-5.1	-20	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-3.3	-20	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-5.0	-26	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-5.6	-27	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-1.1	-29	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-5.8	-37	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-7.4	-44	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-5.4	-46	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-9.5	-50	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-9.7	-52	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-11.0	-70	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-13.8	-72	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-12.5	-73	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-12.2	-75	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-13.7	-94	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-14.9	-101	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-14.7	-110	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-15.5	-112	---	---	---
Apache Leap Study Area[g]	Rain sample	1989-1992	-10.0	-55	---	---	---

[a] $\delta^{18}O$ (‰) = delta oxygen-18 (per mil)
[b] δD (‰) = delta deuterium (per mil)
[c] $\delta^{13}C$ in DIC (‰) = delta carbon-13 in dissolved inorganic carbon (per mil)
[d] $\delta^{34}S$ (‰) = delta sulfur-34 (per mil)
[e] $\delta^{18}O$ in SO_4 (‰) = delta oxygen-18 in sulfate (per mil)
[f] Weber and Evans, 1988
[g] Bassett and others, 1994

--- = Not available, not applicable

Analytical data for the current report provided by University of Arizona Isotope Geochemistry Laboratory.

TABLE D-5. SUMMARY OF RADIOISOTOPE DATA FOR WATER SAMPLES OBTAINED IN APACHE DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	RADIOISOTOPE DATA							
			^{3}H (TU)[a]	^{14}C (pmC)[b]	Sr (ppm)[c]	$^{87}Sr/^{86}Sr$[d]	^{234}U (pCi/L)[e]	^{235}U (pCi/L)[f]	^{238}U (pCi/L)[g]	$^{234}U/^{238}U$[h]
GROUNDWATER (SHALLOW AQUIFERS)										
Hackberry Windmill	RESE-1000263	27-Feb-08	2.7 ± 0.26	106.1 ± 2.6	0.2868	0.709723 ± 0.000007	<0.2	<0.2	<0.2	---
Hackberry Windmill	RESE-1003011	3-Jun-08	3.9 ± 0.28	108.5 ± 1.2	0.2395	0.709750 ± 0.000009	<0.2	<0.2	<0.2	---
Hackberry Windmill	RESE-1003019	2-Sep-08	5.8 ± 0.42	106.9 ± 1.3	0.2481	0.709744 ± 0.000014	<0.2	<0.2	<0.2	---
Hackberry Windmill (duplicate)i	RESE-1003020	2-Sep-08	5.1 ± 0.41	--	0.2477	0.709722 ± 0.000011	<0.2	<0.2	<0.2	---
Hackberry Windmill	RESE-1003024	2-Dec-08	3.8 ± 0.35	107.4 ± 1.5	0.2442	0.709737 ± 0.000009	<0.2	<0.2	<0.2	---
Hackberry Windmill	RESE-1003033	3-Mar-09	3.0 ± 0.34	---	---	---	---	---	---	---
Hackberry Windmill	RESE-1003042	2-Jun-09	6.2 ± 0.30	---	---	---	---	---	---	---
JI Ranch Corral Well	RESE-1000302	21-Jun-07	---	---	---	---	<0.2	<0.2	<0.2	---
JI Ranch Corral Well	RESE-1003005	29-May-08	3.2 ± 0.29	---	0.6607	0.710617 ± 0.000007	<0.2	<0.2	<0.2	---
JI Ranch Corral Well	RESE-1003014	25-Aug-08	2.5 ± 0.34	91.1 ± 1.1	1.0042	0.710626 ± 0.000007	<0.2	<0.2	<0.2	---
JI Ranch Corral Well	RESE-1003029	3-Dec-08	2.3 ± 0.34	94.1 ± 0.7	0.6636	0.710609 ± 0.000009	<0.2	<0.2	<0.2	---
JI Ranch Corral Well (Geochron duplicate)[j]	RESE-1003029	3-Dec-08	---	---	0.6642	0.710611 ± 0.000010	---	---	---	---
JI Ranch Corral Well	RESE-1003038	4-Mar-09	3.0 ± 0.30	91.3 ± 0.8	---	---	---	---	---	---
JI Ranch Corral Well	RESE-1003047	5-Jun-09	4.8 ± 0.28	---	---	---	---	---	---	---
JI Ranch Middle Well	RESE-1003006	30-May-08	3.3 ± 0.24	---	0.2667	0.710693 ± 0.000007	<0.2	<0.2	<0.2	---
JI Ranch Middle Well	RESE-1003017	27-Aug-08	2.5 ± 0.46	96.8 ± 0.9	0.3694	0.710692 ± 0.000009	<0.2	<0.2	<0.2	---
JI Ranch Middle Well	RESE-1003028	3-Dec-08	3.8 ± 0.32	105.6 ± 1.6	0.4056	0.710638 ± 0.000009	<0.2	<0.2	<0.2	---
JI Ranch Middle Well	RESE-1003037	4-Mar-09	4.2 ± 0.36	97.0 ± 1.3	---	---	---	---	---	---
JI Ranch Middle Well	RESE-1003048	5-Jun-09	3.8 ± 0.39	---	---	---	---	---	---	---
GROUNDWATER (APACHE LEAP TUFF AQUIFER)										
JI Ranch House Well	RESE-1000303	21-Jun-07	<1.0	81.1 ± 1.6	0.1299	0.710837 ± 0.000011	<0.2	<0.2	<0.2	---
Well A-06	RESE-1000255	24-Sep-07	<0.7	63.6 ± 0.9	0.1271	0.710390 ± 0.000007	0.7 ± 0.5	<0.2	<0.2	---
Well A-06 (duplicate)	RESE-1000256	24-Sep-07	<0.6 (apparent 0.3)	--	0.1281	0.710386 ± 0.000009	1.9 ± 0.6	<0.2	1.2 ± 0.4	1.58
Well A-06	RESE-1003008	2-Jun-08	1.6 ± 0.23	62.7 ± 0.6	0.1279	0.710372 ± 0.000009	1.0 ± 0.3	<0.2	<0.2	---
Well A-06	RESE-1003016	28-Aug-08	<0.7	63.3 ± 1.1	0.1281	0.710385 ± 0.000010	0.6 ± 0.3	<0.2	0.3 ± 0.2	2.00
Well A-06	RESE-1003030	4-Dec-08	3.3 ± 0.33	64.6 ± 1.0	0.1270	0.710360 ± 0.000007	0.6 ± 0.3	<0.2	<0.2	---
Well A-06	RESE-1003039	5-Mar-09	0.7 ± 0.28	64.3 ± 0.8	---	---	---	---	---	---
Well A-06	RESE-1003046	4-Jun-09	0.6 ± 0.29	---	---	---	---	---	---	---
Well HRES-04	RESE-1001110	15-Apr-04	<1.1	55.3 ± 1	---	---	---	---	---	---
Well HRES-04	RESE-1001114	18-Jan-08	2.5 ± 0.29	58.4 ± 0.4	0.1923	0.710492 ± 0.000007	2.0 ± 0.6	<0.2	0.8 ± 0.4	2.50
Well HRES-04	RESE-1003021	3-Sep-08	<0.6	58.8 ± 0.8	0.1867	0.710550 ± 0.000011	2.0 ± 0.5	<0.2	0.6 ± 0.3	3.33
Well HRES-04	RESE-1003031	2-Mar-09	<0.5	57.8 ± 0.3	---	---	---	---	---	---
Well HRES-04	RESE-1003040	1-Jun-09	<1.2	---	---	---	---	---	---	---

TABLE D-5. SUMMARY OF RADIOISOTOPE DATA FOR WATER SAMPLES OBTAINED IN APACHE DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	RADIOISOTOPE DATA							
			^{3}H (TU)[a]	^{14}C (pmC)[b]	Sr (ppm)[c]	$^{87}Sr/^{86}Sr$[d]	^{234}U (pCi/L)[e]	^{235}U (pCi/L)[f]	^{238}U (pCi/L)[g]	$^{234}U/^{238}U$[h]
GROUNDWATER (APACHE LEAP TUFF AQUIFER)- continued										
Well HRES-05	RESE-1000264	27-Feb-08	<0.8 (apparent 0.3)	59.6 ± 1.5	0.1979	0.709890 ± 0.000009	2.6 ± 0.5	<0.2	0.3 ± 0.2	8.67
Well HRES-05	RESE-1003001	28-May-08	0.6 ± 0.23	58.5 ± 0.7	0.2042	0.709882 ± 0.000010	2.3 ± 0.5	<0.2	0.3 ± 0.2	7.67
Well HRES-05	RESE-1003012	25-Aug-08	<0.6	59.6 ± 1	0.2003	0.709908 ± 0.000009	2.0 ± 0.5	<0.2	0.6 ± 0.3	3.33
Well HRES-05	RESE-1003025	2-Dec-08	<0.9	59.4 ± 0.3	0.2006	0.709914 ± 0.000010	2.3 ± 0.6	<0.2	<0.2	---
Well HRES-05	RESE-1003034	3-Mar-09	<0.6	60.8 ± 0.3	---	---	---	---	---	---
Well HRES-05	RESE-1003043	3-Jun-09	<0.9	---	---	---	---	---	---	---
Well HRES-06	RESE-1000301	12-Jun-07	<0.4	81.6 ± 1.4	0.1757	0.710635 ± 0.000009	1.1 ± 0.6	<0.2	<0.2	---
Well HRES-06	RESE-1000265	27-Feb-08	<0.4	81.3 ± 1.2	0.1645	0.710579 ± 0.000009	0.3 ± 0.2	<0.2	<0.2	---
Well HRES-06 (duplicate)	RESE-1000266	27-Feb-08	<0.8 (apparent 0.3)	82.6 ± 1.6	0.1639	0.710558 ± 0.000009	0.5 ± 0.2	<0.2	<0.2	---
Well HRES-06	RESE-1003003	28-May-08	0.9 ± 0.26	81.1 ± 0.9	0.1601	0.710525 ± 0.000013	0.4 ± 0.2	<0.2	<0.2	---
Well HRES-06	RESE-1003013	25-Aug-08	<0.6	84.0 ± 1.1	0.1586	0.710587 ± 0.000010	0.4 ± 0.2	<0.2	<0.2	---
Well HRES-06	RESE-1003026	3-Dec-08	<1.0 (apparent 0.4)	83.0 ± 1.2	0.1581	0.710571 ± 0.000011	<0.2	<0.2	<0.2	---
Well HRES-06 (duplicate)	RESE-1003027	3-Dec-08	<0.6	82.6 ± 1.7	0.1581	0.710574 ± 0.000010	<0.2	<0.2	<0.2	---
Well HRES-06	RESE-1003035	4-Mar-09	1.8 ± 0.28	84.3 ± 1.3	---	---	---	---	---	---
Well HRES-06 (C-14 split)	RESE-1003035	4-Mar-09	---	79.79 ± 0.40	---	---	---	---	---	---
Well HRES-06 (duplicate)	RESE-1003036	4-Mar-09	<0.9	85.7 ± 1.2	---	---	---	---	---	---
Well HRES-06 (duplicate; C-14 split)	RESE-1003036	4-Mar-09	---	81.50 ± 0.41	---	---	---	---	---	---
Well HRES-06	RESE-1003044	3-Jun-09	1.2 ± 0.31	---	---	---	---	---	---	---
Well HRES-06 (duplicate)	RESE-1003045	3-Jun-09	0.6 ± 0.28	---	---	---	---	---	---	---
Well HRES-07	RESE-1000262	26-Feb-08	1.0 ± 0.27	68.5 ± 0.7	0.1492	0.710245 ± 0.000009	0.8 ± 0.3	<0.2	0.2 ± 0.1	4.00
Well HRES-07	RESE-1003009	3-Jun-08	2.2 ± 0.27	67.8 ± 0.6	0.1458	0.710247 ± 0.000011	1 ± 0.3	<0.2	0.4 ± 0.2	2.50
Well HRES-07 (duplicate)	RESE-1003010	3-Jun-08	1.4 ± 0.29	66.3 ± 0.7	0.1462	0.710271 ± 0.000009	1.3 ± 0.4	<0.2	0.3 ± 0.2	4.33
Well HRES-07	RESE-1003018	2-Sep-08	<0.9	67.1 ± 0.6	0.1389	0.710209 ± 0.000011	1 ± 0.4	<0.2	0.2 ± 0.2	5.00
Well HRES-07 (Geochron duplicate)	RESE-1003018	2-Sep-08	---	---	0.1396	0.710229 ± 0.000009	---	---	---	---
Well HRES-07	RESE-1003022	1-Dec-08	<0.7	67.7 ± 1.1	0.1383	0.710237 ± 0.000009	1.3 ± 0.4	<0.2	0.3 ± 0.2	4.33
Well HRES-07	RESE-1003032	3-Mar-09	<0.6	---	---	---	---	---	---	---
Well HRES-07	RESE-1003041	2-Jun-09	<0.9	---	---	---	---	---	---	---
Well MJ-11	RESE-1000257	29-Sep-07	< 0.3	67.1 ± 1.2	0.1222	0.710397 ± 0.000009	1.2 ± 0.5	<0.2	<0.2	---
Well MJ-11	RESE-1000261	20-Feb-08	0.6 ± 0.23	65.9 ± 1.1	0.1218	0.710404 ± 0.000009	0.6 ± 0.3	<0.2	<0.2	---
Well MJ-11	RESE-1003007	2-Jun-08	0.8 ± 0.24	66.7 ± 0.8	0.1212	0.710392 ± 0.000010	0.6 ± 0.3	<0.2	0.2 ± 0.1	3.00
Well MJ-11 (Geochron duplicate)	RESE-1003007	2-Jun-08	---	---	0.1201	0.710403 ± 0.000009	---	---	---	---
Well MJ-11	RESE-1003015	26-Aug-08	<0.6	66.4 ± 1.4	0.1208	0.710415 ± 0.000011	0.6 ± 0.4	<0.2	<0.2	---

TABLE D-5. SUMMARY OF RADIOISOTOPE DATA FOR WATER SAMPLES OBTAINED IN APACHE DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	RADIOISOTOPE DATA ^{3}H (TU)[a]	^{14}C (pmC)[b]	Sr (ppm)[c]	$^{87}Sr/^{86}Sr$[d]	^{234}U (pCi/L)[e]	^{235}U (pCi/L)[f]	^{238}U (pCi/L)[g]	$^{234}U/^{238}U$[h]
GROUNDWATER (DEEP GROUNDWATER SYSTEM)										
DHRES-01	RESE-112808	28-Nov-08	<0.5	4.9 ± 0.2	0.6118	0.716824 ± 0.000009	<0.2	<0.2	<0.2	---
SPRING AND SURFACE WATER SAMPLES (DEVILS CANYON WATERSHED)										
DC6.1E	RESE-1002007	7-Aug-08	<0.9	---	0.1573	0.710261 ± 0.000010	1.1 ± 0.4	<0.2	<0.2	---
DC6.1E (Geochron duplicate)	RESE-1002007	7-Aug-08	---	---	0.1574	0.710281 ± 0.000011	---	---	---	---
DC6.1E	RESE-1002099	20-May-09	<1.0	---	---	---	---	---	---	---
DC8.2W	RESE-1000260	19-Feb-08	0.6 ± 0.24	72.8 ± 1.7	0.1553	0.709962 ± 0.000014	0.9 ± 0.3	<0.2	0.2 ± 0.1	4.50
DC8.2W	RESE-1003002	27-May-08	0.9 ± 0.21	---	0.1542	0.709959 ± 0.000009	1.1 ± 0.3	<0.2	0.2 ± 0.2	5.50
DC8.2W	RESE-1002004	6-Aug-08	<0.7	---	0.1540	0.709962 ± 0.000010	0.7 ± 0.3	<0.2	0.2 ± 0.2	3.50
DC8.2W	RESE-1003023	2-Dec-08	<0.5	---	0.1550	0.709973 ± 0.000007	0.6 ± 0.3	<0.2	<0.2	---
DC 8.2 W	RESE-1002097	19-May-09	0.7 ± 0.28	---	---	---	---	---	---	---
DC6.14C	RESE-1002013	20-Aug-08	3.8 ± 0.36	---	0.1557	0.71004 ± 0.000010	<0.2	<0.2	<0.2	---
DC6.14C	RESE-1002078	6-May-09	2.8 ± 0.35	---	---	---	---	---	---	---
DC8.1C	RESE-1002005	6-Aug-08	1.7 ± 0.33	---	0.1613	0.710015 ± 0.000014	0.7 ± 0.3	<0.2	0.4 ± 0.3	---
DC 8.1 C	RESE-1002098	19-May-09	1.2 ± 0.27	---	---	---	---	---	---	---
DC13.5C	RESE-1002014	21-Aug-08	3.9 ± 0.40	---	0.0998	0.710162 ± 0.000014	<0.2	<0.2	<0.2	---
DC 13.5 C	RESE-1002103	21-May-09	4.0 ± 0.31	---	---	---	---	---	---	---
DC14.7C	RESE-1002015	27-Aug-08	3.9 ± 0.41	---	0.0482	0.710313 ± 0.000010	0.4 ± 0.4	<0.2	<0.2	---
DC15.7C	RESE-1002003	5-Aug-08	4.8 ± 0.40	---	0.0257	0.710171 ± 0.000010	<0.2	<0.2	<0.2	---
DC 15.7 C	RESE-1002075	5-May-09	5.1 ± 0.38	---	---	---	---	---	---	---
H0.1C	RESE-1002011	19-Aug-08	6.6 ± 0.38	---	0.1256	0.709784 ± 0.000020	<0.2	<0.2	<0.2	---
H0.1C	RESE-1002096	19-May-09	2.1 ± 0.26	---	---	---	---	---	---	---
IC1.0C	RESE-1002019	28-Aug-08	4.5 ± 0.35	---	0.2035	0.710503 ± 0.000009	<0.2	<0.2	<0.2	---
IC1.0C	RESE-1002085	12-May-09	4.6 0.42	---	---	---	---	---	---	---
RR1.5C	RESE-1002012	19-Aug-08	3.7 ± 0.37	---	0.1530	0.709789 ± 0.000011	<0.2	<0.2	<0.2	---
RR1.5C	RESE-1002100	21-May-09	4.0 ± 0.34	---	---	---	---	---	---	---
RR1.5C (duplicate)	RESE-1002101	21-May-09	4.1 ± 0.33	---	---	---	---	---	---	---

TABLE D-5. SUMMARY OF RADIOISOTOPE DATA FOR WATER SAMPLES OBTAINED IN APACHE DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	RADIOISOTOPE DATA							
			^{3}H (TU)[a]	^{14}C (pmC)[b]	Sr (ppm)[c]	^{87}Sr/^{86}Sr[d]	^{234}U (pCi/L)[e]	^{235}U (pCi/L)[f]	^{238}U (pCi/L)[g]	^{234}U/^{238}U[h]
SPRING AND SURFACE WATER SAMPLES (QUEEN CREEK WATERSHED)										
Boulder Hole	RESE-1002006	6-Aug-08	2.7 ± 0.31	---	0.3099	0.709883 ± 0.000009	1.8 ± 0.5	<0.2	0.6 ± 0.3	3.00
Boulder Hole	RESE-1002082	7-May-09	2.2 ± 0.27	---	---	---	---	---	---	---
Number Nine	RESE-1002020	28-Aug-08	4.6 0.35	---	0.0484	0.710144 ± 0.000007	<0.2	<0.2	<0.2	---
Number Nine	RESE-1002077	5-May-09	6 ± 0.32	---	---	---	---	---	---	---
Oak Flat Tributary	RESE-1002016	27-Aug-08	4.5 ± 0.40	---	0.0479	0.71001 ± 0.000014	<0.2	<0.2	<0.2	---
Oak Flat Tributary	RESE-1002076	5-May-09	5 ± 0.34	---	---	---	---	---	---	---
Pump Station Spring	RESE-1002001	5-Aug-08	3.4 ± 0.33	---	0.2190	0.710048 ± 0.000011	0.7 ± 0.3	<0.2	0.4 ± 0.2	1.75
Pump Station Spring	RESE-1002080	12-May-09	3.1 ± 0.29	---	---	---	---	---	---	---
Pump Station Spring (duplicate)	RESE-1002084	12-May-09	4.8 ± 0.37	---	---	---	---	---	---	---
QC19.7C	RESE-1002021	28-Aug-08	4.2 ± 0.40	---	0.2038	0.710345 ± 0.000007	0.3 ± 0.3	<0.2	<0.2	---
QC21.7C	RESE-1002018	28-Aug-08	4.6 ± 0.39	---	0.1602	0.710004 ± 0.000010	0.3 ± 0.3	<0.2	<0.2	---
QC21.7C (Geochron duplicate)	RESE-1002018	28-Aug-08	---	---	0.1599	0.710004 ± 0.000009	---	---	---	---
QC 21.7C (Magma Avenue)	RESE-1002083	7-May-09	6.7 ± 0.36	---	---	---	---	---	---	---
QC22.6E	RESE-1002017	28-Aug-08	3.2 ± 0.36	---	0.2477	0.709858 ± 0.000700	0.9 ± 0.4	<0.2	0.6 ± 0.3	1.50
QC27.3C	RESE-1002002	5-Aug-08	6.7 ± 0.39	---	0.2046	0.710052 ± 0.000009	<0.2	<0.2	<0.2	---
QC 27.3C	RESE-1002079	7-May-09	5.8 ± 0.31	---	---	---	---	---	---	---
SPRING SAMPLES (APACHE LEAP ESCARPMENT)										
Blue Spring	RESE-1002009	19-Aug-08	<0.8	---	0.1636	0.711123 ± 0.000010	0.9 ± 0.4	<0.2	<0.2	---
Blue Spring (duplicate)	RESE-1002010	19-Aug-08	<0.8	---	0.1642	0.711117 ± 0.000009	0.5 ± 0.3	<0.2	<0.2	---
Blue Spring	RESE-1002088	13-May-09	0.8 ± 0.31	---	---	---	---	---	---	---
Hidden Spring	RESE-1002008	19-Aug-08	2.1 ± 0.39	---	0.1907	0.709949 ± 0.000010	0.5 ± 0.3	<0.2	0.3 ± 0.2	1.67
Hidden Spring	RESE-1002086	12-May-09	2.8 ± 0.33	---	---	---	---	---	---	---
Kane Spring	RESE-1002022	29-Aug-08	0.9 ± 0.38	---	0.1966	0.710588 ± 0.000014	1.9 ± 0.5	<0.2	0.5 ± 0.3	3.80
Kane Spring	RESE-1002087	13-May-09	1.1 ± 0.31	---	---	---	---	---	---	---

TABLE D-5. SUMMARY OF RADIOISOTOPE DATA FOR WATER SAMPLES OBTAINED IN APACHE DEVILS CANYON/UPPER QUEEN CREEK STUDY AREA

SAMPLE LOCATION	SAMPLE IDENTIFIER and/or DESCRIPTION	SAMPLE DATE	RADIOISOTOPE DATA							
			^{3}H (TU)[a]	^{14}C (pmC)[b]	Sr (ppm)[c]	$^{87}Sr/^{86}Sr$[d]	^{234}U (pCi/L)[e]	^{235}U (pCi/L)[f]	^{238}U (pCi/L)[g]	$^{234}U/^{238}U$[h]
SPRING AND SURFACE WATER SAMPLES (MINERAL CREEK WATERSHED)										
LF0.2C	RESE-1002093	14-May-09	3.3 ± 0.35		0.3723	0.722708 ± 0.000007	1.9 ± 0.4	<0.1	1.4 ± 0.3	1.36
Mineral Creek (MC 3.3C)	RESE-1002095	14-May-09	2.6 ± 0.29		0.2660	0.716595 ± 0.000010	0.3 ± 0.2	<0.2	<0.2	---
Wet Leg Spring (MC3.4W)	RESE-1002094	14-May-09	1.8 ± 0.33		0.1361	0.710308 ± 0.000009	1.6 ± 0.3	<0.2	1.0 ± 0.3	1.60
MC8.4C	RESE-1002090	14-May-09	1.7 ± 0.32		0.3690	0.716685 ± 0.000013	2.2 ± 0.4	<0.2	1.0 ± 0.3	2.20
MC8.4C (duplicate)	RESE-1002091	14-May-09	1.6 ± 0.27		0.3689	0.716685 ± 0.000009	2.3 ± 0.5	<0.3	1.1 ± 0.4	2.09

--- = not available or not applicable

[a] ^{3}H = Tritium; TU = tritium unit (1 TU = 1 tritium atom per 10^{18} atoms of hydrogen)
[b] ^{14}C = carbon-14; pmC = percent modern carbon
[c] Sr = strontium; ppm = parts per million
[d] Mass of strontium-87 isotope divided by mass of strontium-86 isotope
[e] Uranium-234 isotope; pCi/L = activity in picoCuries per liter
[f] Uranium-235 isotope; pCi/L = activity in picoCuries per liter
[g] Uranium-238 isotope; pCi/L = activity in picoCuries per liter
[h] Activity of uranium-234 isotope divided by activity of uranium-238 isotope
[i] Duplicate = duplicate sample collected in the field and submitted to analytical laboratories as quality control check
[j] Geochron duplicate = sample analyzed twice as internal analytical quality control check by Geochron Laboratories

ANALYTICAL LABORATORIES

^{3}H, ^{14}C:	University of Arizona, Tucson, AZ
Sr, $^{87}Sr/^{86}Sr$	Geochron Laboratories, Billerica, MA
U, ^{234}U, ^{235}U, ^{238}U	Energy Laboratories, Casper, WY

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APPENDIX E

RADIOCARBON METHODOLOGIES FOR ESTIMATION OF GROUNDWATER RESIDENCE TIMES

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APPENDIX E

RADIOCARBON METHODOLOGIES FOR ESTIMATION OF GROUNDWATER RESIDENCE TIMES

CARBON-14 BACKGROUND

The radioactive isotope of carbon, ^{14}C, is formed in the atmosphere through interactions of cosmic rays with stable isotopes of nitrogen, oxygen, and carbon. The ^{14}C atoms are then incorporated into CO_2 and mixed rapidly throughout the atmosphere and hydrosphere. This mixing, together with the continued production and radioactive decay of ^{14}C, results in an equilibrium ^{14}C concentration that is imparted to precipitation. When water is recharged to an aquifer it is effectively isolated from communication with the atmosphere and the ^{14}C in the groundwater continues to decay but is not replaced. Thus if the ^{14}C concentration at the time of recharge is known (or assumed) and the ^{14}C of a sample is measured, the time since recharge can be calculated. Radiocarbon ages are calculated assuming first-order radioactive decay from a source with some known or assumed initial specific activity:

$$t = \frac{\tau}{\ln 2} \ln \frac{A_0}{A_t}$$

t = radiometric age of dissolved carbon in sample
τ = 5730 +/- 30 years (half-life of ^{14}C)
A_t = specific activity (disintegrations per minute per gram of carbon (dpm/g)) at time sample is obtained
A_0 = specific activity (dpm/g) at t = 0 (i.e. at time of recharge to aquifer)

The radiometric age of groundwater is that of the total dissolved inorganic carbon (TDIC) with an initial specific activity generally far from 100 percent modern carbon (pmC). Two main components are assumed to contribute to the initial ^{14}C activity of groundwater when it is recharged (i.e. enters the aquifer from the unsaturated zone). These two components are:

1. CO_2 of soil gases (active; controlled largely by respiration within the root zone)

2. Solid carbonate from soil and aquifer matrix (often dead (i.e. ^{14}C activity equal to zero) except for Holocene carbonate aquifers or soils containing recent carbonate particles).

METHODS TO DETERMINE THE INITIAL ACTIVITY OF DISSOLVED CARBON

Many approaches exist to account for the relative contributions of soil gas and carbonate along with isotopic exchange between phases. Common approaches are outlined below and the resulting age (aquifer residence time) estimates are shown in **Table E-1**:

Vogel (1967, 1970)
Vogel collected and averaged 100 groundwater samples from NW Europe to get A_0 = 85 +/- 5 pmC. This value may be representative of shallow groundwater in temperate climates is but not based on any theoretical treatment.

Tamers (1967, 1975); Tamers and Scharpenseel (1970)
The Tamers approach is a stoichiometric approach assuming ^{14}C activity of soil CO_2 = 100 pmC and the activity of dissolving carbonate is zero. It is based on stoichiometry of carbonate equilibrium in soil gas and solid carbonate phases and does not consider isotopic exchange.

$$A_0 = \frac{\left(2 \times 10^{-pH}\right) + 10^{-6.3}}{2 \times (10^{-pH} + 10^{-6.3} + 10^{(-16.6+pH)}} \times A_g$$

where A_g is 100 pmC. For soil pH values around neutral this approach generally gives A_0 values approximately equal to 55 pmC.

Ingerson and Pearson (1964); Pearson and Hanshaw (1970); Pearson et al. (1972); Pearson and Swarzenki (1974)

In the Pearson approach, dilution of active carbon is calculated using an isotope mixing model based on the ratio of ^{13}C content (expressed as $\delta^{13}C$) of the sample to that of the soil gas carbon. The ^{13}C content of the soil gas contributing to the dissolved carbon concentration is assumed to be controlled by the type of vegetation that dominates the recharge area. Calculation of initial activity is calculated using the equation:

$$A_0 = \left[\left(A_g - 0.2\varepsilon_2\right) - \left(A_M + 0.2\varepsilon_9\right)\right] \times \left[\frac{\delta_T - \left(\delta_M - \varepsilon_9\right)}{\left(\delta_g - \varepsilon_2\right) - \left(\delta_M + \varepsilon_9\right)}\right] + A_M + 0.2\varepsilon_9$$

where:

A_g = ^{14}C activity of soil gas CO_2
A_M = ^{14}C activity of mineral carbonate (solid)
δ_g = $\delta^{13}C$ of soil gas CO_2
δ_M = $\delta^{13}C$ of mineral carbonate (solid)

$\delta_T = \delta^{13}C$ of total dissolved inorganic carbon
ε_2 = isotopic enrichment factor (‰) at equilibrium between gaseous CO_2 and dissolved inorganic carbon (HCO_3^-) = -8‰
ε_9 = isotopic enrichment factor (‰) at equilibrium between dissolved inorganic carbon (HCO_3^-) and mineral carbonate = -2‰

Fontes and Garnier (1979)

This approach accounts for isotopic exchange between the dissolved carbon, the soil gas CO_2 and a solid carbonate phase in addition to mixing of dissolved carbon derived from soil CO_2 with dissolved carbon derived from solid carbonate.

Initial ^{14}C activity (A_0) is calculated using the following equation:

$$A_0 = \left(1 - \frac{C_M}{C_T}\right)A_g + \frac{C_M}{C_T}A_M + \left(A_g - 0.2\varepsilon - A_M\right)\frac{\delta_T - \frac{C_M}{C_T}\delta_M - (1 - \frac{C_M}{C_T})\delta_g}{\delta_g - \varepsilon - \delta_M}$$

Where:

C_M = dissolved carbon derived from solid carbonate
C_T = total dissolved carbon
A_g = ^{14}C activity of soil gas CO_2
A_M = ^{14}C activity of mineral carbonate (solid)
$\delta_g = \delta^{13}C$ of soil gas CO_2
$\delta_M = \delta^{13}C$ of mineral carbonate (solid)
$\delta_T = \delta^{13}C$ of total dissolved carbon
ε = isotopic enrichment factor (‰) at equilibrium between gaseous CO_2 and solid carbonate = -10‰

$$\frac{C_M}{C_T} = \frac{\left[CO_3^{2-}\right] + 0.5\left[HCO_3^-\right]}{\left[CO_3^{2-}\right] + \left[HCO_3^-\right] + \left[H_2CO_3^*\right]} = 1 - \frac{\left(2 \times 10^{-pH}\right) + 10^{-6.3}}{2 \times (10^{-pH} + 10^{-6.3} + 10^{(-16.6+pH)})}$$

$H_2CO_3^* = H_2CO_3 + CO_2\ (aq)$

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FLOW AND TRANSPORT MODELING COUPLED WITH GEOCHEMICAL MODELING

All the correction approaches discussed here account simply for radioactive decay of ^{14}C, mixing between sources of carbon, and isotopic exchange between sources of carbon. These approaches do not account for:

1. Reactions (dissolution, precipitation, ion exchange) along the flow pathway
2. Hydrodynamic dispersion
3. Matrix diffusion
4. Mixing between discrete bodies of water with different recharge histories

In order to account for these processes it is necessary to model the entire aquifer or basin using a flow and transport model coupled with a geochemical model (e.g. the approach utilized by Zhu (2000)).

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TABLE E-1. RADIOCARBON DATES CALCULATED WITH UNCORRECTED INITIAL C-14 CONCENTRATION AND WITH INITIAL C-14 CONCENTRATIONS CORRECTED USING FOUR ALTERNATIVE MODELS

					Radiometric carbon ages using various approaches to correct the initial ^{14}C activity (A_0)										
SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	C-14 (pmC)	C-14 uncertainty	Radiocarbon Age (yrs B.P.)	Uncertainty (+/- yrs)	Age Vogel	Age Tamers	Age Pearson (C_3)	Age Pearson (CAM)	Age Pearson (Bassett)	Fontes & Garnier Age (C_3)	Fontes & Garnier Age (C_4)	Fontes & Garnier Age (CAM)	Fontes & Garnier Age (Bassett)
GROUNDWATER (SHALLOW AQUIFERS)															
Hackberry Windmill	RESE-1000263	27-Feb-08	106.1	2.6	-545.8	205.1	-1,833	-3549	-6,121	1252	-1953	-13720	4,456	-6,059	-9,358
Hackberry Windmill	RESE-1003011	3-Jun-08	108.5	1.2	-730.7	91.9	-2,018	-3604	-2,965	4396	1194	-7331	10,586	155	-3,087
Hackberry Windmill	RESE-1003019	2-Sep-08	106.9	1.3	-607.9	101.2	-1,895	-4089	-2,092	5267	2066	-5496	12,367	1,954	-1,277
Hackberry Windmill	RESE-1003024	2-Dec-08	107.4	1.5	-646.5	116.3	-1,934	-3324	-2,497	4862	1662	-6787	11,123	695	-2,546
JI Ranch Corral Well	RESE-1003014	25-Aug-08	91.1	1.1	714.3	100.4	-573	-38	1,095	8448	5249	-3428	14,480	4,053	812
JI Ranch Corral Well	RESE-1003029	3-Dec-08	94.1	0.7	446.4	61.7	-841	-71	1,108	8461	5263	-3428	14,479	4,052	811
JI Ranch Middle Well	RESE-1003017	27-Aug-08	96.8	0.9	212.6	77.2	-1,075	-1984	351	7705	4506	-3142	14,715	4,304	1,074
JI Ranch Middle Well	RESE-1003028	3-Dec-08	46.1	0.7	6345.3	126.5	5,058	3374	6,434	13789	10589	3431	21,265	10,862	7,637
JI Ranch House Well	RESE-1000303	21-Jun-07	81.1	1.6	1675.5	164.7	388	-2220	369	7727	4526	-2663	15,180	4,774	1,547
GROUNDWATER (APACHE LEAP TUFF AQUIFER)															
Well HRES-4	RESE-1001110	15-Apr-04	55.3	1.0	4841.0	150.9	3,554	1177	3,176	10535	7334	-186	17,675	7,263	4,032
Well HRES-4	RESE-1001114	18-Jan-08	58.4	0.4	4,390.1	56.8	3,103	-1100	2,413	9773	6572	71	17,888	7,490	4,269
Well HRES-4	RESE-1003021	3-Sep-08	58.8	0.8	4,333.7	113.2	3,046	-599	1,967	9329	6127	-844	16,996	6,590	3,365
Well HRES-5	RESE-1000264	27-Feb-08	59.6	1.5	4,222.0	210.7	2,935	-977	1,017	8381	5178	-1969	15,885	5,475	2,246
Well HRES-5	RESE-1003001	26-May-08	58.5	0.7	4,376.0	99.5	3,089	-643	1,670	9033	5831	-1225	16,621	6,214	2,987
Well HRES-5	RESE-1003012	25-Aug-08	59.6	1.0	4,222.0	139.9	2,935	-837	1,654	9016	5814	-1159	16,683	6,277	3,051
Well HRES-5	RESE-1003025	2-Dec-08	59.4	0.3	4,249.8	41.9	2,962	-1,088	2,015	9376	6175	-500	17,326	6,925	3,702
Well HRES-6	RESE-1000301	12-Jun-07	81.6	1.4	1,624.7	143.1	337	-2,039	-41	7318	4118	-3402	14,459	4,047	816
Well HRES-6	RESE-1000266	27-Feb-08	82.6	1.2	1,524.0	121.0	237	-3,393	-516	6844	3643	-3209	14,624	4,221	997
Well HRES-6	RESE-1003003	28-May-08	81.1	0.9	1,675.5	92.3	388	-1,328	542	7900	4700	-3035	14,834	4,419	1,187
Well HRES-6	RESE-1003013	25-Aug-08	84.0	1.1	1,385.1	109.0	98	-4,026	-280	7079	3878	-2564	15,248	4,852	1,632
Well HRES-6	RESE-1003026	3-Dec-08	83.0	1.2	1,484.1	120.4	197	-1,519	119	7477	4276	-3587	14,289	3,872	638
Well HRES-7	RESE-1000262	26-Feb-08	68.5	0.7	3,071.4	84.9	1,784	-2,138	503	7865	4663	-2213	15,624	5,219	1,994
Well HRES-7	RESE-1003009	3-Jun-08	67.8	0.6	3,156.3	73.5	1,869	-1,834	97	7460	4258	-2971	14,886	4,475	1,245
Well HRES-7	RESE-1003018	2-Sep-08	67.1	0.6	3,242.1	74.3	1,955	-1,491	742	8103	4902	-2258	15,592	5,183	1,955
Well HRES-7	RESE-1003022	1-Dec-08	67.7	1.1	3,168.5	135.4	1,881	-1,808	1,192	8552	5351	-1441	16,389	5,987	2,763
GROUNDWATER (DEEP AQUIFER)															
DHRES-01	RESE-112808	28-Nov-08	4.9	0.7	24,876.4	1,274.4	23,588	20,072	15,356	22,753	19,539	5348	23,863	13,242	9,869
SPRING WATER (DEVILS CANYON DRAINAGE)															
Spring DC 8.2W	RESE-1000260	19-Feb-08	72.8	1.7	2,568.1	195.3	1,281	-1328	528	7888	4687	-2852	15,013	4,600	1,369

APPENDIX F

QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES FOR LABORATORY CHEMICAL ANALYSES OF WATER SAMPLES

APPENDIX F

QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES FOR LABORATORY CHEMICAL ANALYSES OF WATER SAMPLES

Laboratory chemical results for groundwater and surface water samples obtained in the project area during the reporting period were evaluated in accordance with Montgomery & Associates quality assurance/quality control (QA/QC) procedures.

During the reporting period, groundwater samples were obtained from monitor wells completed within the shallow and ALT aquifers and the deep groundwater system and were submitted for chemical laboratory analysis. Samples were collected for common and trace constituents, routine parameters, radiological parameters, stable isotopes, and radioactive/radiogenic isotopes. In addition, spring and surface water samples for isotopic analysis were collected in collaboration with Golder Associates (Golder). Analysis, QA/QC, and reporting of routine, trace, and radiological data associated with spring and surface water samples are provided in Golder (2009a and 2009b).

Analysis of common constituents and trace metals was conducted by Test America Laboratories (TestAmerica) in Phoenix, Arizona. Select anions were analyzed by SVL Analytical, Inc. (SVL) in Kellogg, Idaho. Standard radiological analyses were conducted by Energy Laboratories, Inc. in Casper, Wyoming. Analysis of stable isotopes and radioactive isotopes was conducted by the University of Arizona in Tucson, Arizona and BETA Analytic, Inc. in Miami, Florida. Strontium isotopes were analyzed by Geochron Laboratories (Geochron) in Billerica, Massachusetts.

The Montgomery & Associates QA/QC procedures consist of three principal parts: verification of sampling procedures; verification of chain-of-custody documentation; and verification of laboratory chemical results.

Chain-of-custody documentation is verified for each sample. Confirmation of sample identification is achieved by cross-referencing field notes and sample traffic reports with letters of transmittal and analysis request schedules. The dates of sampling and of delivery of the samples to the laboratory are compared, and sample documentation and laboratory reports are inspected. Laboratory documentation is checked to confirm that samples were received in good condition.

Verification of laboratory chemical results consists of several phases. Laboratory reports are compared with original analysis request schedules to confirm that the correct analyses were conducted for each sample. Laboratory analyses of samples are reviewed for adherence to holding times, detection limits, and analytical methods if specified. The laboratory reports are reviewed for the presence of all data for sample results and laboratory quality control procedures, including chromatograms and data summary sheets, when applicable. These items are reviewed for pertinent dates to insure proper assignment of results to the samples. Results are then evaluated with respect to previous data available for each sampling location to determine integrity of the results. The relative percent difference (RPD) is calculated for results of laboratory analyses of duplicates to assess reproducibility of sampling procedures and chemical analyses.

In the event of an error or deficiency in laboratory chemical analyses or laboratory reports, the laboratory is notified and proper corrective action is taken. When errors, such as incorrect calculations or typographical mistakes, are detected in the laboratory results, the laboratory makes appropriate corrections and re-issues the analytical report. If results are considered incorrect, re-analysis or re-sampling may be required.

Laboratory chemical results for groundwater and surface water obtained during the reporting period are summarized in **Appendix C**; **Tables C-1 through C-5;** results of routine analyses of spring and surface water samples are reported by Golder (2009). Overall, results of data verification for water samples obtained by Montgomery & Associates during the reporting period indicate that sampling procedures, sample chain-of-custody, laboratory methods, and representativeness of the results meet Montgomery & Associates QA/QC criteria.

COMPARISON OF DUPLICATE SAMPLES

2007 through 2008

During the period 2007 through 2008, field duplicate samples were obtained from wells HRES-06, HRES-07, A-06, and Hackberry Windmill Well. Additionally, a surface water duplicate was obtained from Blue Spring. Field duplicate samples for common constituents, trace metals, radiologicals, stable isotopes, and radioactive/radiogenic isotopes were obtained at a frequency of about 10 percent. Results of analyses of laboratory duplicates were provided for about 8 percent of isotopic strontium (Sr) samples.

For the samples and their field duplicates, the RPD was calculated for each constituent to assess reproducibility of sampling procedures and chemical analyses. An RPD of zero percent indicates that the results are the same for each duplicate. A higher RPD indicates a larger difference between results. An RPD of 200 percent indicates that one of the duplicate pair had a detection of a given constituent while the other did not. This large RPD may be misleading; if the detection occurred near the reporting limit a much smaller RPD could be indicated. For most analyses, an RPD of less than 20 percent is acceptable.

For the sample and field duplicate obtained from Well A-06 on September 24, 2007, all RPDs for common constituents and trace compounds were less than 10 percent with the exception of an RPD of 25 percent for dissolved lead (Pb). For the radiological constituents, radioactive/ radiogenic isotope, and stable isotope analyses, there was a much greater incidence of high RPDs. These included RPDs for gross alpha of 32; uranium-234 (^{234}U) of 92; total U in picocuries per liter (pCi/L) of 126; and ^{238}U of 200 percent. With the exception of ^{234}U and total U (pCi/L), all of these constituents were detected at concentrations near the reporting limit.

For the sample and field duplicate obtained from Well HRES-06 on February 27, 2008, all RPDs for common constituents and trace compounds were less than 10 percent with the exception of an RPD of 131 percent for dissolved iron (Fe) and 25 percent for Pb. As evident in historical Fe data for the project area, there appears to be non-trending variability over time. The solubility and activity of Fe is sensitive to different pH/Eh conditions. Although the field pH of duplicate samples is assumed to be the same, pH changes over time and may be significantly different by the time a sample is analyzed. This tendency of pH to drift is not standard and could be responsible for different analytical results between duplicates. Both the matrix spike/matrix spike duplicate (MS/MSD) and laboratory control sample/laboratory control sample duplicate (LCS/LCSD) for this analytical batch display acceptable RPDs. Acceptable RPDs for the majority of analytes suggest that proper sampling procedures were followed as well. The variability of analytical results for trace metals seems to be almost exclusively limited to Fe. For the radiological constituents, radioactive/radiogenic isotope, and stable isotope analyses, there was a much greater incidence of high RPDs. These included RPDs for total U (pCi/L) of 40; ^{234}U of 50; gross alpha of 60; carbon 13 in total dissolved inorganic carbon (^{13}C of TDIC) of 64; and total U in milligrams per liter (mg/L) of 200 percent. With the exception of ^{13}C of TDIC, all of these constituents were detected at concentrations near the reporting limit. Results of ^{13}C of TDIC analysis were reported as -7.7 and -15. Previous and subsequent samples at the site indicate that the value of -7.7 is an outlier. Additionally, a second set of duplicates obtained from Well HRES-06 in December 2008 show very good agreement with an RPD of 1.9.

For the sample and field duplicate obtained from Well HRES-07 on June 3, 2008, all RPDs for common constituents and trace compounds were less than 10 percent. For the radiological constituents, radioactive/radiogenic isotope, and stable isotope analyses, there was a much greater incidence of high RPDs. These included RPDs for ^{234}U of 26; ^{238}U of 29; oxygen 18 in sulfate (^{18}O in SO_4) of 32; tritium (^{3}H) of 44; and RPDs of 200 percent for gross alpha, radium-226 (Ra-226), and radium-228 (Ra-228). With the exception of ^{18}O in SO_4, all of these constituents were detected at concentrations near the reporting limit.

For the sample and field duplicate obtained from Hackberry Windmill Well September 2, 2008, all RPDs for common constituents and trace compounds were less than 10 percent. For the radiological constituents, radioactive/radiogenic isotope, and stable isotope analyses, all RPDs were less than 20 percent with the exception of gross beta that had an RPD of 200 percent. The detection of gross beta was near the reporting limit.

For the sample and field duplicate obtained from Well HRES-06 on December 3, 2008, all RPDs for common constituents and trace compounds were less than 10 percent with the exception of an RPD of 20 percent for total dissolve solids (TDS). For the radiological constituents, radioactive/radiogenic isotope, and stable isotope analyses, all RPDs were less than 20 percent with the exception of gross alpha that had an RPD of 200. For gross alpha an RPD of 200 reflects detection in one of the pair only. The detection of gross alpha was near the reporting limit.

A sample and field duplicate were obtained from Blue Spring on August 19, 2008, and submitted for analysis of radiological constituents, radioactive/radiogenic isotopes, and stable isotopes. All RPDs were less than 5 percent with the exception of gross alpha that had an RPD of 42 and ^{234}U that had an RPD of 57 percent.

Geochron conducted and reported analytical results of laboratory duplicates for Sr analyses. These included samples from five sampling sites. For samples collected from Well

HRES-07, Corral Well, Well MJ-11, DC6.1E, and QC21.7C, laboratory RPDs for Sr analysis were all less than 1 percent.

In summary, the RPDs for common constituents and trace compounds were very good. The incidence of RPDs exceeding 20 percent was negligible. Because analysis of the duplicates showed good agreement, there is no indication of systematic variability in either chemical analysis or sampling procedure.

Reviewing the RPDs for analysis of radiological constituents, radioactive/radiogenic isotopes, and stable isotopes, there appears to be a great degree of variability between duplicates. In most of these cases, the detections are very near the reporting limits and represent very small concentrations. This suggests better agreement between duplicates than consideration of the RPDs alone would indicate. The few remaining analytical discrepancies do not indicate systemic variability in either chemical analysis or sampling procedure. Laboratory duplicates conducted by Geochron indicated excellent reproducibility for analysis of Sr.

2009

During 2009, field duplicate samples were obtained from wells HRES-04, HRES-05, HRES-06, HRES-07, A-06, JI Ranch Corral Well, JI Ranch Middle Well, and Hackberry Windmill Well. Additionally, surface water duplicates were obtained from Pump Station Spring, Rancho Rio Creek (RR 1.5C), Number Nine, Karst Spring (QC 22.6E), and Ranch Fork Headwater Spring (MC 8.4C). Field duplicate samples for common constituents and trace metals were obtained at a frequency of about 6.5 percent. Additionally, field duplicate/split samples for analysis of select anions were obtained at a frequency of over 50 percent. Results of analyses of laboratory duplicates were provided for about 16.5 percent of standard radiologicals and 10 percent of stable isotopes. Field duplicate samples for radioactive/radiogenic isotopes were obtained at a frequency of 10 to 20 percent, depending on the isotope. Results of analyses of laboratory duplicates were provided for about 10 percent of isotopic strontium (Sr) samples.

For the sample and field duplicate obtained from Well HRES-06 on March 4, 2009, all RPDs for common constituents and trace compounds were less than 15 percent with the exception of an RPD of 58 for dissolved copper (Cu). Both detections of Cu were very near the reporting limit and neither value is inconsistent with historical data. For the radioactive/ radiogenic isotopes and stable isotope analyses, all RPDs were less 10 percent with the exception of an RPD of 43 for oxygen 18 in sulfate (^{18}O in SO4) and an RPD of 200 for ^{3}H. The RPD of 200 for ^{3}H means that ^{3}H was detected in one sample but not in the duplicate sample. When analytical precision is considered, the samples show reasonable agreement. Standard radiological analyses were not conducted on this sample set.

For the sample and field duplicate obtained from Pump Station Spring on May 12, 2009, samples were analyzed for ^{3}H. The RPD for this analysis was 43 percent. While this appears to indicate poor agreement between the analyses, the laboratory considers these to be in reasonable agreement when analytical precision is factored in.

For the sample and field duplicate obtained from MC 8.4C on May 14, 2009, samples were analyzed for standard radiologicals, radioactive/radiogenic isotopes, and stable isotopes. All RPDs for these analyses were less than 7 percent with the exception of an RPD of 200 for radium 228 (Ra-228). Ra-228 was detected at the reporting limit in the sample and below the reporting limit in the duplicate; actual difference between the results may be much smaller than indicated by the RPD.

For the sample and field duplicate obtained from Well HRES-06 on June 3, 2009, all RPDs for common constituents and trace compounds were less than 20 percent with the exception of an RPD of 200 for dissolved nickel (Ni). Ni was detected at the reporting limit in the sample and below the reporting limit in the duplicate; actual difference between the results may be much smaller than indicated by the RPD. For the radioactive/radiogenic isotope and stable isotope analyses, all RPDs were less than 2 percent with the exception of an RPD of 67 for tritium (^{3}H). Results were 1.2 +/- 0.31 and 0.6 +/- 0.28 for the sample and duplicate respectively. Although the RPD of the raw data indicates a large difference, when analytical precision is factored in, the RPD could be as low as 1 percent. Standard radiological analyses were not conducted on this sample set.

COMPARISON OF SVL AND TESTAMERICA DUPLICATES

In March and again in June 2009, a series of duplicate samples was collected from 8 wells and submitted to both TestAmerica and SVL for analysis of select anions. Wells included were HRES-04; HRES-05; HRES-06; HRES-07; A-06; JI Ranch Corral Well; JI Ranch Middle Well; and Hackberry Windmill Well. Anions included were chloride (Cl); sulfate (SO_4); fluoride (F); and bromide (Br). These duplicates essentially served as split samples and will be referred to as such. The RPDs of reported anion results for each set of duplicates was calculated. Historical results used for comparison of current data are predominantly from TestAmerica.

March 2009

- For the sample and split sample obtained from Well HRES-04 on March 2, 2009, all RPDs were less than 10 percent with the exception of F with an RPD of 92. The F result from TestAmerica is higher than historical data while the result from SVL is lower than historical data.

- For the sample and split sample obtained from Well HRES-05 on March 3, 2009, all RPDs were less than 4 percent with the exception of F with an RPD of 99. The F result from TestAmerica is higher than historical data while the result from SVL is lower than historical data.

- For the sample and split sample obtained from Well HRES-07 on March 3, 2009, all RPDs were less than 6 percent with the exception of F with an RPD of 82. Prior and subsequent F data from HRES-07 show variability with no apparent seasonal fluctuations; it is difficult to determine which of these F results is the more consistent with the other F data for HRES-07.

- For the sample and split sample obtained from Hackberry Windmill Well on March 3, 2009, all RPDs were less than 5 percent.

- For the sample and split sample obtained from Well HRES-06 on March 4, 2009, all RPDs were less than 6 percent with the exception of F with an RPD of 123. The F result from TestAmerica is higher than historical data while the result from SVL is consistent with historical data.

- In addition to the original sample obtained from HRES-06 on March 4 and its SVL split sample, a second set of samples were obtained at the same time and sent to both laboritories. All RPDs were less than 5 percent with the exception of F with an RPD of 121. Again, the F result from TestAmerica is higher than historical data while the result from SVL is consistent with historical data.

- For the sample and field duplicate obtained from JI Ranch Corral Well on March 4, 2009, all RPDs were less than 15 percent.

- For the sample and field duplicate obtained from JI Ranch Middle Well on March 4, 2009, all RPDs were less than 11 percent.

- For the sample and field duplicate obtained from A-06 on March 5, 2009, all RPDs were less than 4 percent with the exception of F with an RPD of 101. The F result from TestAmerica is higher than historical data while the result from SVL is lower. The SVL reporting limit is lower than that of TestAmerica so it is likely that the lower concentration reported by SVL is more consistent with historical data for this well.

June 2009

- For the sample and split sample obtained from Well HRES-04 on June 1, 2009, all RPDs were less than 4 percent with the exception of F with an RPD of 73. The F result from TestAmerica is consistent with historical data while the result from SVL is lower than historical data.

- For the sample and split sample obtained from Well HRES-07 on June 2, 2009, all RPDs were less than 5 percent with the exception of F with an RPD of 90. Prior and subsequent F data from HRES-07 show variability with no apparent seasonal fluctuations; it is difficult to determine which of these F results is the more consistent with the other F data for HRES-07.

- For the sample and split sample obtained from Hackberry Windmill Well on June 2, 2009, all RPDs were less than 7 percent.

- For the sample and split sample obtained from Well HRES-05 on June 3, 2009, all RPDs were less than 8 percent with the exception of F with an RPD of 199. The F result from TestAmerica is higher than historical data while the result from SVL is lower than historical data.

- For the sample and split sample obtained from Well HRES-06 on June 3, 2009, all RPDs were less than 5 percent with the exception of F with an RPD of 122. The F result from TestAmerica is higher than historical data while the result from SVL is consistent with historical data.

- In addition to the original sample obtained from HRES-06 on June 3 and its SVL split sample a second set of samples were obtained at the same time and sent to both laboratories. All RPDs were less than 5 percent with the exception of F with an RPD of

125. Again, the F result from TestAmerica is higher than historical data while the result from SVL is consistent with historical data.

- For the sample and split sample obtained from A-06 on June 4, 2009, all RPDs were less than 5 percent with the exception of F with an RPD of 108. The F result from TestAmerica is higher than historical data while the result from SVL is lower. The SVL reporting limit is lower than that of TestAmerica so it is likely that the lower concentration reported by SVL is more consistent with historical data for this well.

- For the sample and split sample obtained from JI Ranch Corral Well on June 5, 2009, all RPDs were less than 8 percent.

- For the sample and field duplicate obtained from JI Ranch Middle Well on June 5, 2009, all RPDs were less than 15 percent with the exception of SO_4 with an RPD of 33. The SO_4 result from TestAmerica is higher than historical data while the result from SVL is consistent with historical data. Because SO_4 results have been fairly consistent in this well and there has been good agreement between SO_4 results from TestAmerica and SVL in these sampling events, it is likely that the 170 mg/L of SO_4 reported by TestAmerica is an outlier and does not significantly impact the validity of the data set.

In summary, with the exception of F, the RPDs for all common constituents and trace compounds in samples, field duplicates, and split samples were very good. The incidence of RPDs exceeding 20 percent was negligible. Because analysis of the duplicates and splits showed good agreement, there is no indication of systemic variability in either chemical analysis or sampling procedure for the overwhelming majority of compounds.

Inconsistency of F results between TestAmerica and SVL led to much discussion with the two laboratories. Both laboratories re-ran samples and confirmed their previous results.

TestAmerica's results were usually about five times larger than SVL's; their reporting limit was also four times larger than that of SVL's.

This conundrum may be explained in part by the way F analysis is conducted using ion chromatography. When a water sample is loaded into the instrument it goes into a pressurized column containing resinous packing material. Major anions and cations are absorbed on this material with varying degrees of attraction. An extraction liquid or eluent then rinses through the column to move the ions down through the column packing. Because of the varying degrees of attraction the ions have to the resin, they have different retention times in the column. As they pass through the column at different rates they are separated from each other. The ions are identified by their retention times and quantified by the area under their respective peaks on the chromatogram.

F analysis can be affected by several things, one of which is called the water dip. Before a sample is run through the column, it is preceded by a slug of reagent water. This is detected as a negative conductivity and results in a dip in the chromatogram. Because F has the weakest affinity for the resin, it is first off the column. Potentially, the F peak can so closely follow the water dip that the two peaks overlap. On the resulting chromatogram, this interference slightly changes the spatial distribution of the area under the peak and can result in high bias. As part of the analysis, the peak area is calculated automatically and given a best fit, however, an analyst must go back and visually inspect the curve and adjust the reported concentration to account for the water dip. Thus, the analysts use their discretion on how best to correct the curve. This is most likely to affect samples with F concentrations of less than 1.5 mg/L. It is important to note that the concentrations of F in these samples are quite low, hovering at or very near the reporting limit. Because of possible differences in interpretation of results at these very low concentrations, and because the results are typically an order of magnitude smaller than the U.S. EPA National Primary Drinking Water Regulations, apparent lack of precision between the two laboratories does not affect the validity of the data set as a whole.

Review of the RPDs for analysis of radiological constituents, radioactive/radiogenic isotopes, and stable isotopes indicates good overall reproducibility. Laboratory duplicates conducted by Geochron indicated excellent reproducibility for analysis of Sr. For ^{18}O in SO_4 analyses, there appears to be a greater degree of variability between duplicates.

ANALYSIS OF POTENTIAL OUTLIERS

There are a number of times where concentrations of some constituents appear to spike from below reporting limit to well above it. The actual concentration changes may be exaggerated; the majority of these apparent jumps are attributed not to larger concentrations but rather to dropping reporting limits. Additionally, concentrations detected near the reporting limit may be expected to show variability inherent with very small concentrations. That being said, there are a few incidences where a value may not be representative of overall water quality at a sampling location.

The reported concentration of As in the sample collected from HRES-05 in August 2008 is 0.086 mg/L, about four times larger than those of previous and subsequent samples. In addition, the reported concentration of Se in this sample is elevated as well. The result of 0.0058 mg/L is in contrast with previous and subsequent results of <0.0020 mg/L. Review of laboratory QC showed no evidence of systemic analytical problems and the lab stands behind these data. With the exception of As, no other metals are elevated in this sample from HRES-05, indicating that sampling procedures were correctly followed. These values for As and Se may not be representative of overall water quality at HRES-05.

The reported concentration of Se in the sample collected from MJ-11 in August 2008 appears to be elevated. The reported Se concentration in the sample from MJ-11 is 0.02 mg/L. Previous results were all <0.0020 and no subsequent data are available. Review of laboratory QC showed no evidence of systemic analytical problems and the laboratory stands behind these data. With the exception of Se, no other metals are elevated in this sample from MJ-11, indicating that sampling procedures were correctly followed. This value for Se may not be representative of overall water quality at MJ-11.

The reported concentrations of Zn in three samples collected in December 2008 appear elevated. In the sample from Hackberry Windmill Well, the reported concentration of Zn of 0.31 mg/L is three times larger than previous and subsequent data. The other samples showing higher than expected Zn concentrations are a sample and duplicate collected from HRES-06. Reported Zn concentrations are two times larger than previous and subsequent data. Precision between the duplicates is excellent. Review of laboratory QC showed no evidence of systemic analytical problems and the laboratory stands behind these data. With the exception of Zn, no other metals are elevated in this samples from Hackberry Windmill Well and HRES-06 indicating that sampling procedures were correctly followed. These values for Zn may not be representative of overall water quality at Hackberry Windmill Well and HRES-06.

The reported concentration of Ni in the sample collected from HRES-07 in March 2009 appears elevated. While lower reporting limits exaggerate the Ni concentration in the March sample compared to previous data, the March result is about an order of magnitude larger than subsequent samples collected in June 2009 and during the long-term pumping test in October 2009. Review of laboratory QC showed no evidence of systemic analytical problems and the laboratory stands behind these data. With the exception of Ni, no other metals are elevated in this sample from HRES-07 indicating that sampling procedures were correctly followed. This value for Ni may not be representative of overall water quality at Hackberry Windmill Well and HRES-06.

Comparison of radiological results includes consideration of reporting limits and precision specific to each analytical run. A number of apparent inconsistencies in radiological analysis can be attributed to these factors.

The reported result of Ra-228 in the sample collected from Well HRES-06 in May 2008 appears to be elevated in comparison to previous and subsequent data. While other Ra-228 results were <1.3 pCi/L, the reported May result was 2.2 +/- 0.6 pCi/L. Taking error into account, the actual result could range from 1.6 to 2.8 pCi/L. This activity does appear to be larger than the rest of the data for HRES-06, but it is unclear how large. Because all of the other Ra-228 data from this well are consistent, it is likely that this result is an outlier.

The reported result of Ra-228 in the sample collected from Well HRES-07 in June 2008 appears to be elevated. Reported Ra-228 results in previous and subsequent samples are all <1.3 pCi/L. The reported June 2008 result is 1.8 +/- 0.58 pCi/L; the actual result is between 1.22 to 2.38 pCi/L. The Ra-228 result from analysis of the duplicate sample from HRES-07 is <0.85 pCi/L. The RPD between these results is poor. In consideration of the poor reproducibility of results and the possibility of a lower concentration fairly close to the other data, this value for Ra-228 may not be representative of overall water quality at HRES-07.

The reported Ra-228 result in the sample collected from Hackberry Windmill Well in June 2008 appears to be elevated. Previous and subsequent Ra-228 results are below 1.3 pCi/L; the June 2008 result is 2.8 +/- 0.85 pCi/L. The actual result is between 1.95 to 3.65 pCi/L but does not overlap with other data from this well. The laboratory used this sample for the matrix in the MS/MSD and both accuracy and precision were within method criteria. Review of sampling procedures and laboratory QC show no systemic problems. Because this elevated concentration has not been confirmed in subsequent samples, it is unlikely to be representative of water quality in Hackberry Windmill Well.