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Southern Nevada Water Authority

Geologic Data Analysis Report for Monitor Well 182M-1 in Delamar Valley

October 2007

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SOUTHERN NEVADA WATER AUTHORITY

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SOUTHERN NEVADA WATER AUTHORITY
Groundwater Resources Department
Water Resources Division
snwa.com

CONTENTS

FIGURES

TABLES

ACRONYMS

API GR	American Petroleum Institute gamma ray unit
BLM	Bureau of Land Management
RGU	regional geologic unit
SNWA	Southern Nevada Water Authority
TD	total depth
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

ABBREVIATIONS

°C	degrees Celsius
amsl	above mean sea level
bgs	below ground surface (depth)
cps	counts per second
ft	foot
gpm	gallons per minute
gru	API gamma ray unit
I.D.	inside diameter (of casing)
in.	inch
lb	pound
m	meter
mi	mile
min	minute
µs	microsecond
mS	millisiemens
mV	millivolt
O.D.	outside diameter (of casing)
ppm	parts per million
psi	pounds per square inch
rpm	revolutions per minute

1.0

INTRODUCTION

In support of the Southern Nevada Water Authority's (SNWA) Clark, Lincoln, and White Pine Counties Groundwater Development Project, SNWA drilled 10 monitor wells in five hydrographic areas in Lincoln County, Nevada, between February and December 2005 (Figure 1).

Monitor Well 182M-1 is located in southwestern Delamar Valley in Section 18, T7S, R63E, at an elevation of approximately 4,580 ft amsl (Figure 2). The site is approximately 12 mi east of Alamo, Nevada, and is accessed from U.S. Highway 93 by the Alamo Canyon Road. This site is in the South Pahroc Range just north of the Delamar Lake playa.

1.1 PURPOSE AND SCOPE

The purpose of this report is to describe the geologic, geophysical, and hydrologic data collected for Monitor Well 182M-1. The scope involves evaluation and comparison of borehole cuttings, drilling statistics, borehole geophysical logs, and hydraulic properties of the well. Geophysical data are compared to the borehole lithology to evaluate the geophysical response to geologic and hydrologic conditions, including the geologic units, geologic structures (fractures and faults), and hydrogeology. The drilling statistics are also correlated with the borehole lithology and geophysical logs. A discussion of hydrogeology is included to describe water levels, groundwater flow into the well, and geologic units and structure that provide this groundwater flow.

1.2 OBJECTIVES OF THE MONITOR WELL PROGRAM

The objectives for the 10 monitor wells are to:

- Further refine the distribution of regional aquifers and interbasin flow interpretations of those aquifers through the collection of additional hydrologic and geologic data, general groundwater chemistry and water-quality data, and water-level data.

- Provide long-term monitoring points for baseline depth-to-water levels, observe future pumping influences and climatic effects, and provide an accurate and timely assessment of groundwater conditions.

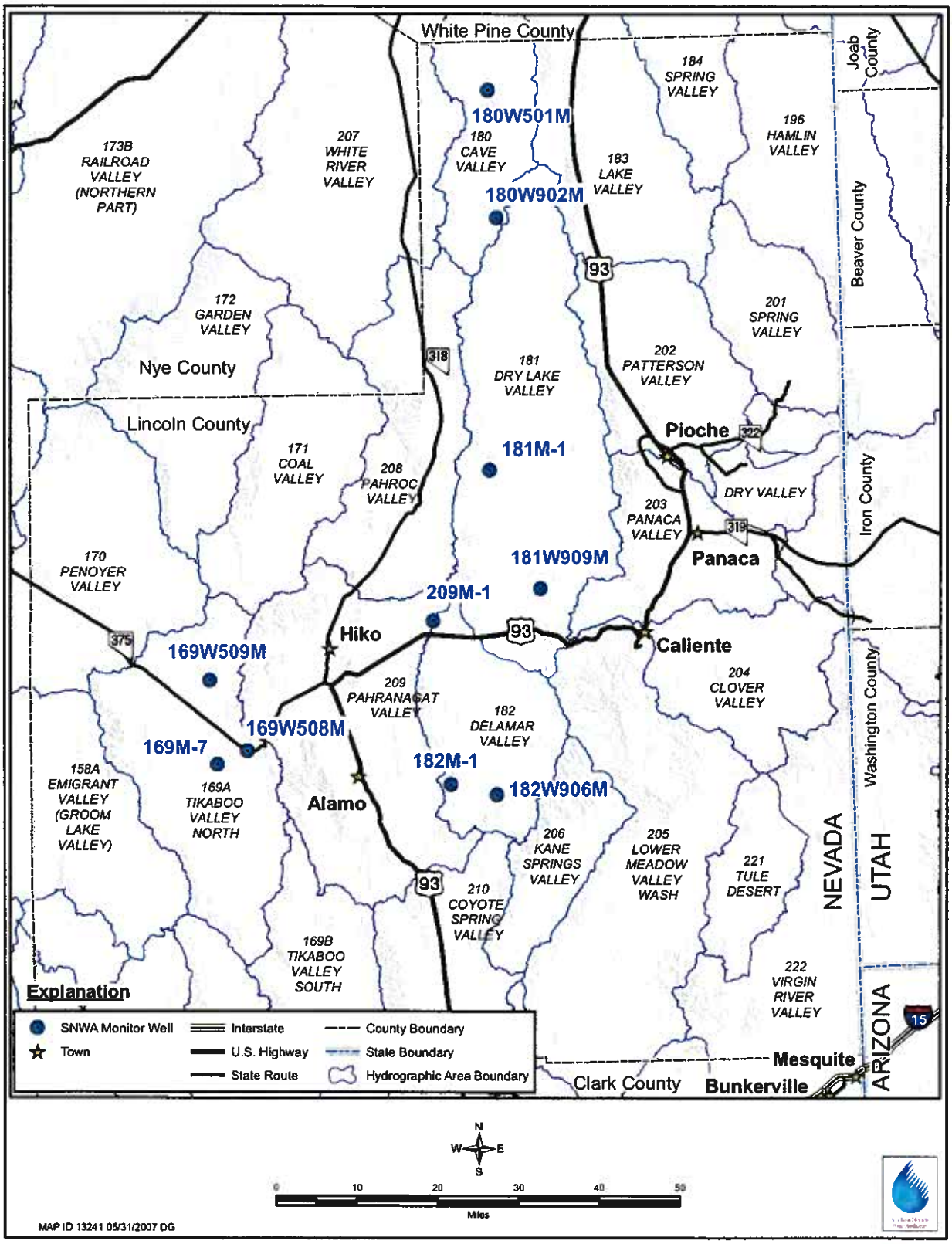
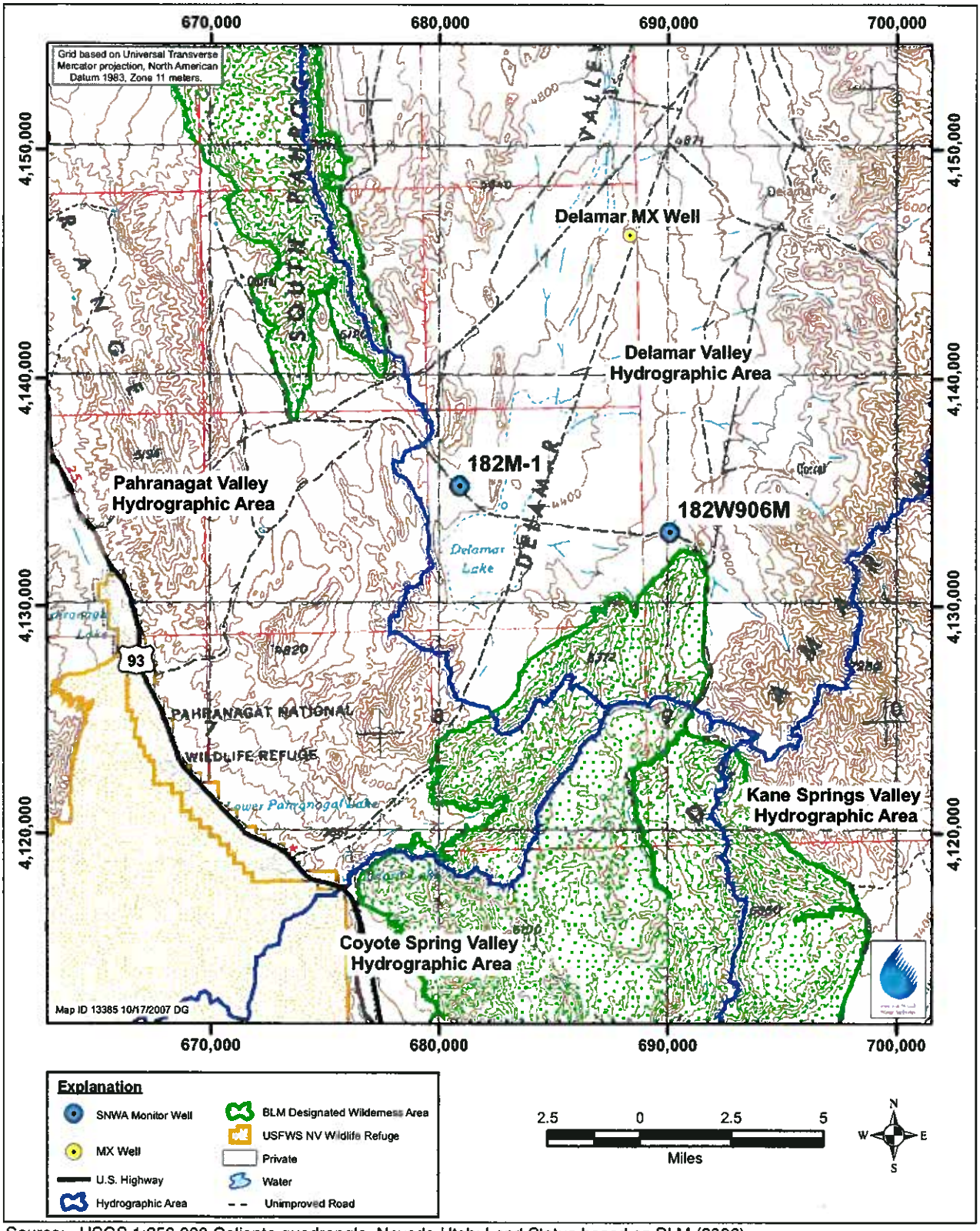


FIGURE 1
SNWA MONITOR WELL LOCATIONS, LINCOLN COUNTY, NEVADA



Source: USGS 1:250,000 Caliente quadrangle, Nevada-Utah; Land Status based on BLM (2006).

FIGURE 2
LOCATION OF MONITOR WELL 182M-1, LINCOLN COUNTY, NEVADA

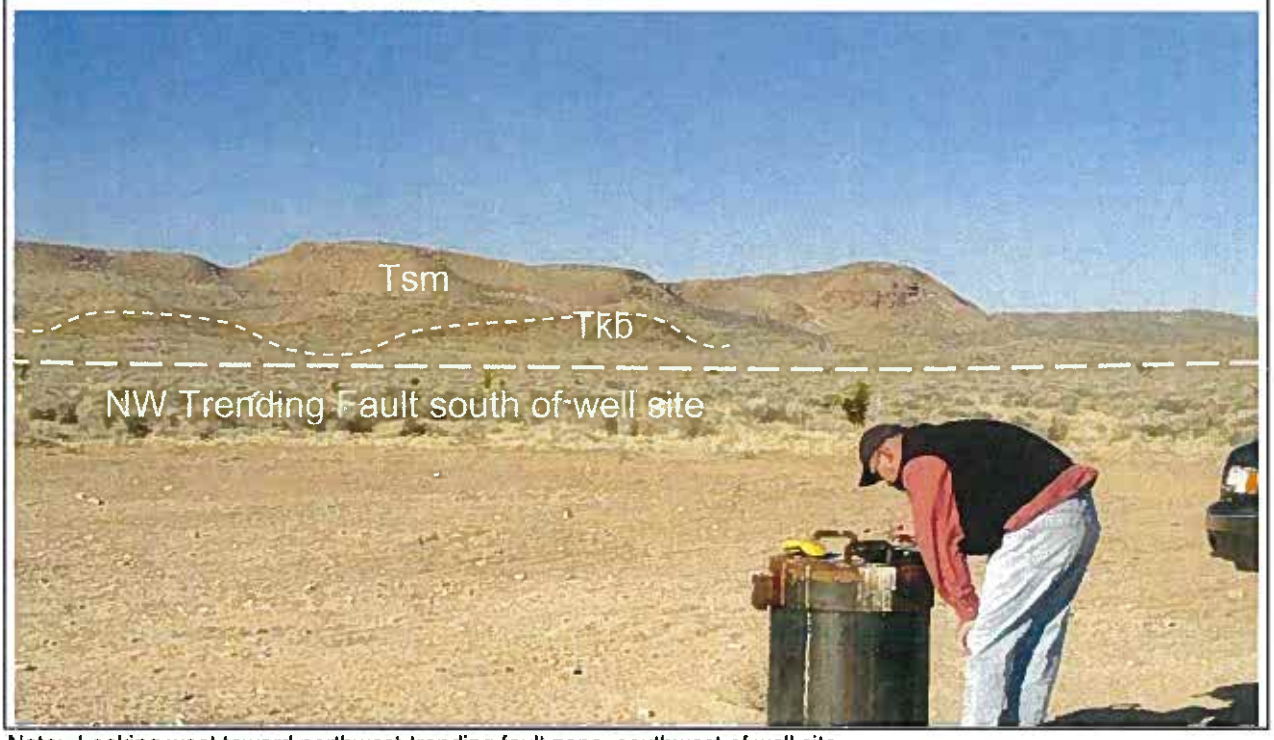
1.3 SUMMARY OF MONITOR WELL CONSTRUCTION

Monitor Well 182M-1 was completed in two stages. An initial (pilot) hole was completed on February 24, 2005, to a depth of 1,320 ft bgs as a 5.625-in. borehole inside 9.875-in. O.D. surface casing. The monitor well was drilled and completed from June 9 to July 11, 2005, to a depth of 1,345 ft bgs. The monitor well was completed with 20-in. O.D. conductor casing to a depth of 58 ft bgs and 12.75-in. O.D. (12-in. I.D.) well casing from 2.5 ft above land surface to 1,330.9 ft bgs. The monitor well was completed with 283 ft of slotted casing from 1,006.5 to 1,289.7 ft bgs.

The completion borehole was drilled using air-foam and flooded reverse circulation drilling techniques with a borehole diameter of 17.5 in. Due to sloughing hole conditions, at 170 ft bgs the borehole was cemented and reamed.

Figure 3 presents two photographs of the monitor well site taken on January 23, 2007. For additional information on the well construction, refer to Stoller (2006).

Note: Looking south with Delamar Lake playa on the left.



Note: Looking west toward northwest-trending fault zone, southwest of well site.
Tkb = Gregerson Basin member of the Kane Wash Tuff. Tsm = Sunflower Mountain Tuff. These units are to the right in the upper photograph, dipping eastward. Kane Wash Tuff and Sunflower Mountain Tuff are part of the Tt4 RGU (Dixon et al., 2007).

FIGURE 3
TWO VIEWS OF THE MONITOR WELL 182M-1 SITE

2.0

DATA ANALYSIS

This section analyzes the lithology, geophysical logs, and drilling statistics to evaluate the geology encountered in Monitor Well 182M-1.

2.1 GEOLOGIC SETTING

Delamar Valley is a fault-block basin within the Great Basin subprovince (Fenneman, 1931) formed during the regional extension during the late Tertiary Period (Rowley and Dixon, 2001). The southern end of the valley is marked by a northeast-trending Pahranagat shear zone that was formed by differential extension within the Great Basin region. To the east are the Caliente caldera complex and the Kane Springs Wash Caldera, both of which have expelled large amounts of volcanic material in the Delamar Valley area. These calderas appear to have formed during an earlier extensional phase during the Miocene where extension "was expressed more by the emplacement of voluminous calc-alkalic, shallow intrusions … than by faults" (Rowley and Dixon, 2001).

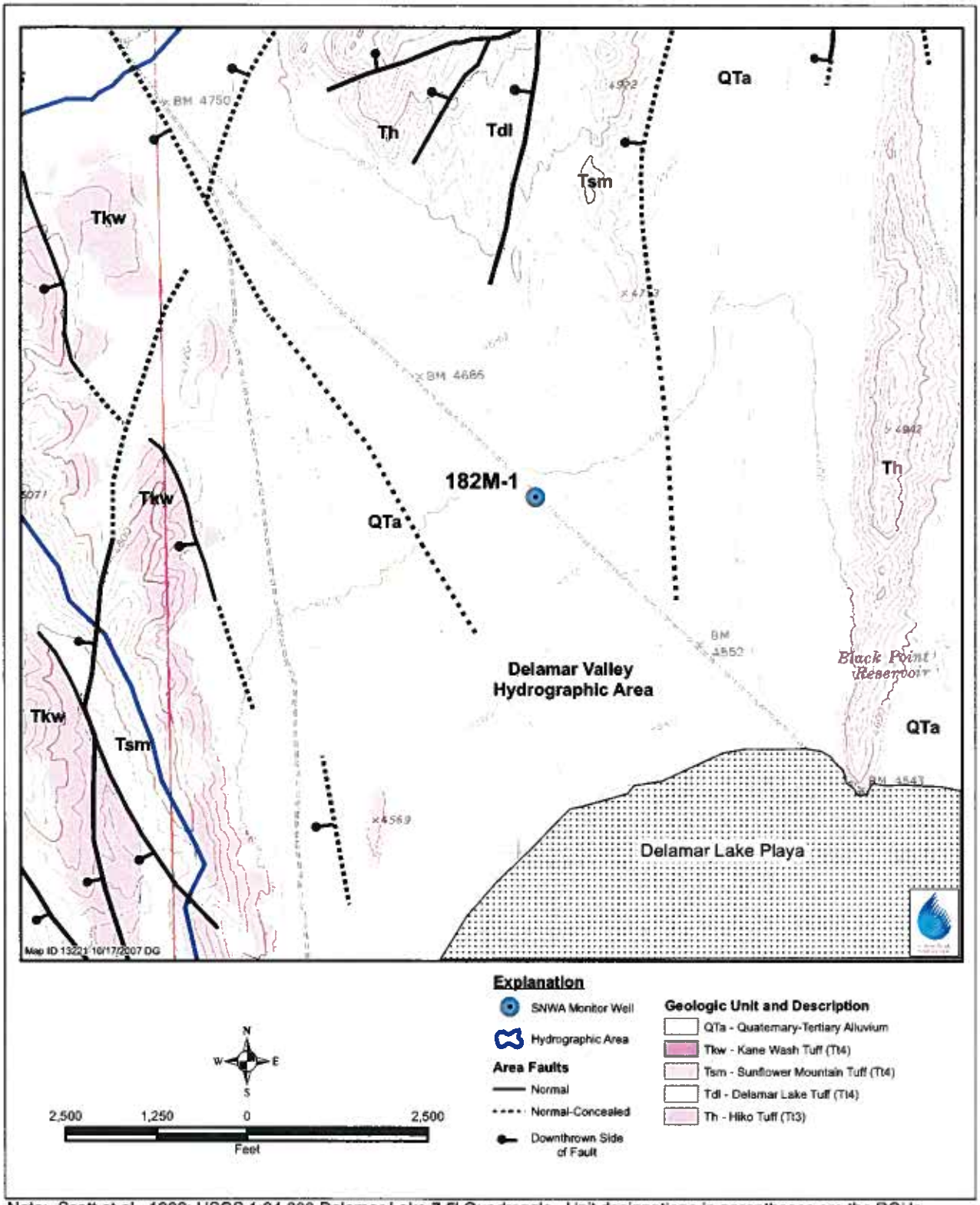
Monitor Well 182M-1 is situated near the southwestern end of the Delamar Valley Hydrographic Area near the western margin of the alluvial basin (Figure 1). The well site is in a northwest-trending valley at the intersection of a less prominent north-trending valley. The two valleys extend south and southeastward to the Delamar Lake playa (Figure 2). The surface geology at the well site is of Quaternary alluvium with Tertiary volcanic rocks of the Kane Wash, Sunflower Mountain, Delamar Lake, and Hiko tuffs to the west, north, and east of the well site (Scott et al., 1993, Figure 1-3). This surface geology is displayed on Figure 4.

2.1.1 GEOLOGIC UNITS ENCOUNTERED AT THE MONITOR WELL

The geologic units encountered in Monitor Well 182M-1 consist of alluvial material and Tertiary volcanics, including the Delamar Lake Tuff and the Hiko Tuff. The alluvial material consists of volcanic detritus eroded from the volcanic rocks to the west and north. This material is part of the "surficial alluvium and basin fill" (QTa) RGU (Dixon et al., 2007). The Delamar Lake Tuff is part of the "ash-flow tuff and interbedded airfall tuff unit 4" (Tt4) RGU, and the Hiko Tuff is part of the "ash-flow tuff and interbedded airfall tuff unit 3" (Tt3) RGU (Dixon et al., 2007).

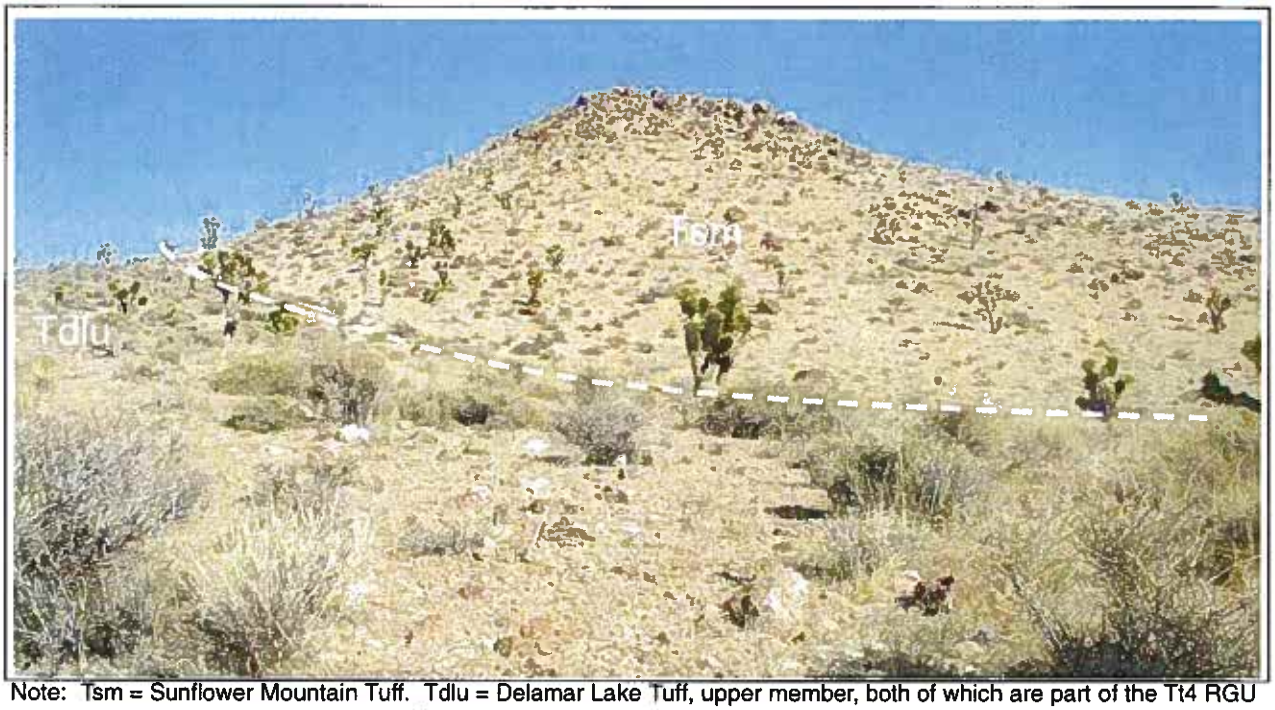
The Delamar Lake Tuff (Figure 5) is a poorly to moderately welded metaluminous tuff with phenocrysts of quartz and sanidine. The Delamar Lake Tuff has an abundance of elongated pumice fragments and lithophysae (Figure 6) and also has iron-rich mafic minerals such as hedenbergite and fayalitic olivine (Scott et al., 1995; Rowley et al., 1995). The upper and lower members of the Delamar Lake Tuff are weakly to moderately welded with abundant (up to 30 percent) pumice fragments. The combined thickness of these members is about 500 to 550 ft. The lowermost unit is a low-density nonwelded ash-fall tuff and is about 30 ft thick in the area of the monitor well site (Scott et al., 1993).

The Delamar Lake Tuff is underlain by the Hiko Tuff, which is a devitrified, nonwelded to densely welded ash-flow tuff with abundant (30 to 40 percent) phenocrysts. The phenocrysts are dominated by sodic plagioclase with lesser amounts of quartz and sanidine. Biotite, iron-titanium oxides (magnetite and ilmenite), and a minor amount of hornblende are also present, with traces of pyroxene



Note: Scott et al., 1993; USGS 1:24,000 Delamar Lake 7.5' Quadrangle. Unit designations in parentheses are the RGUs defined in Dixon et al. (2007).

FIGURE 4
GEOLOGIC MAP AROUND MONITOR WELL 182M-1, SOUTHWEST DELAMAR VALLEY



Note: Tsm = Sunflower Mountain Tuff. Tdlu = Delamar Lake Tuff, upper member, both of which are part of the Tt4 RGU (Dixon et al., 2007). Northwest of Monitor Well 182M-1, looking north. Fault contact, subparallel to bedding.

FIGURE 5
DELAMAR LAKE TUFF (GRAY) BENEATH THE SUNFLOWER MOUNTAIN TUFF (TAN)

Note: Gray patches are pumice fragments. Rock face is about 1.5 ft across, in outcrop northwest of Monitor Well 182M-1. Delamar Lake Tuff is part of the Tt4 RGU (Dixon et al., 2007).

FIGURE 6
DELAMAR LAKE TUFF WITH PUMICE FRAGMENTS TO TWO INCHES ACROSS

and sphene. The upper portion of the Hiko Tuff appears to have more mafic minerals than the lower portion (Scott et al., 1993). Plagioclase also appears more abundant in the upper portion. The Hiko Tuff is differentiated by a darker color and the presence of plagioclase and biotite, which are rare in the Delamar Tuff.

The Hiko Tuff is differentiated into four members: an upper moderately to densely welded tuff with about 40 percent phenocrysts and with pumice and lithic fragments, a lower unit of similar composition but less mafics, a vitrophyric unit similar to the lower Hiko Tuff, and a partly welded tuff with fewer phenocrysts and more lithic fragments (Figure 7). The approximate thicknesses of these units are, respectively, 250, 330, 150, and 200 ft near the well site (Scott et al., 1993) for a total formation thickness of about 930 ft.

Note: Darker clasts within the tuff are lithic fragments. View is about 3 ft across. Hiko Tuff (Thp) is part of the Tt3 RGU (Dixon et al., 2007).

FIGURE 7
PARTLY WELDED MEMBER OF THE HIKO TUFF, NORTHWEST OF MONITOR WELL 182M-1

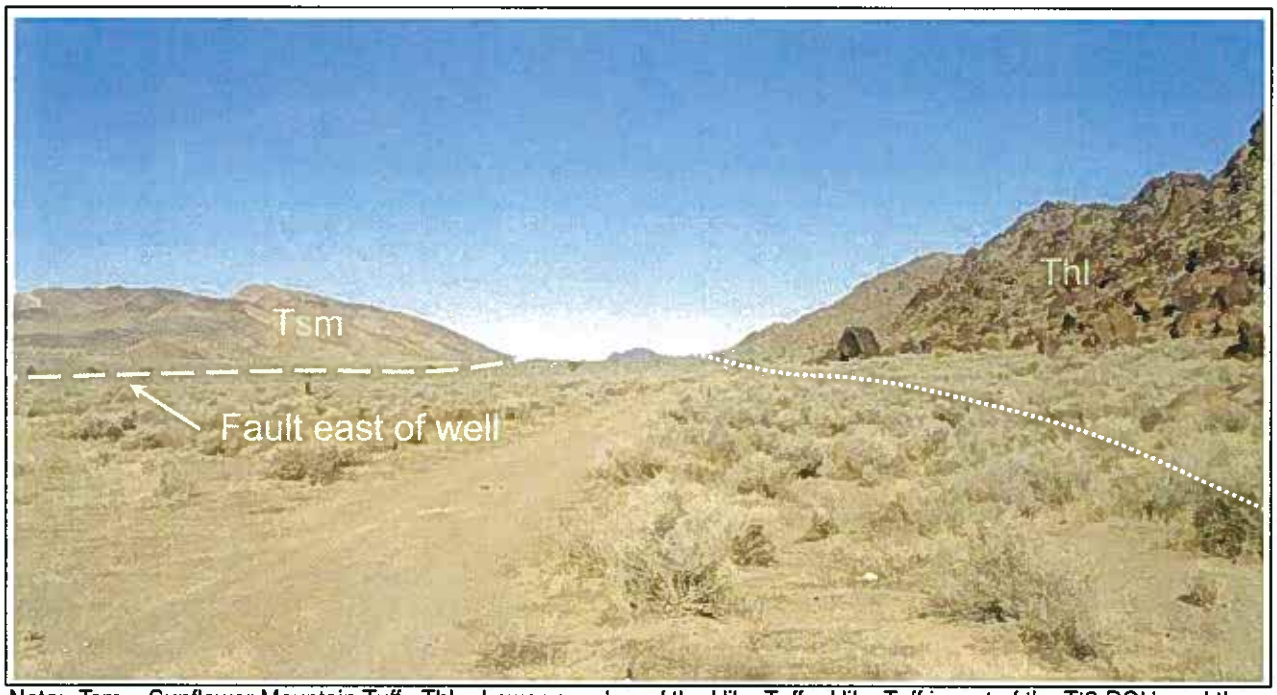
The geologic units in the vicinity of Monitor Well 182M-1 generally dip about 15 to 35 degrees east, averaging approximately 25 degrees east. At this dip, the apparent thicknesses of the various units and subunits identified in the borehole are:

Delamar Lake Tuff	585 ft
Upper and Lower Hiko Tuff	805 ft
Partly Welded Member Hiko Tuff	220 ft

The total thickness of the Hiko Tuff at the borehole was expected to be approximately 1,025 ft, barring any faulting that may either repeat or cut out portions of the geologic section. The thickness indicated for the upper and lower members of the Hiko Tuff is slightly greater than that indicated by the borehole cuttings, an indication of faulting or variations in the thickness of the unit (Section 2.2.1).

2.1.2 GEOLOGIC STRUCTURE AT THE MONITOR WELL SITE

Faults associated with the Pahroc Fault, a major north–south structure in the North Pahroc Range that splits into several strands southward into the South Pahroc Range (Tschanz and Pampeyan, 1970; Swadley and Scott, 1991; Scott et al., 1993), cut through the approximate location of the well site and extend southward toward the Delamar Lake playa (Figure 8). These faults trend north-south and northwest with a northwest structure trending south of the monitor well site (Figure 3, bottom view, and Figure 4). These structures trend along the alluvial subbasins or valleys that open onto Delamar Valley at the Delamar Lake playa. Few of the larger faults are present in outcrop in the vicinity of the well site.



Note: Tsm = Sunflower Mountain Tuff. Thl = Lower member of the Hiko Tuff. Hiko Tuff is part of the Tt3 RGU, and the Sunflower Mountain Tuff is part of the Tt4 RGU (Dixon et al., 2007). Looking north from a point southeast of the well site.

FIGURE 8
FAULTING IN VALLEY TO NORTHEAST OF MONITOR WELL 182M-1

2.2 MONITOR WELL 182M-1

Monitor Well 182M-1 was drilled in a single pass. An initial borehole was drilled near the completed monitor well and is considered in order to provide additional details, but the primary focus of this section is on the completed well. For this report, the well cuttings were logged and the geology encountered is discussed.

2.2.1 LITHOLOGY

Lithologic cuttings were collected for Monitor Well 182M-1 at 10-ft intervals during the drilling process using SNWA internal procedures. These cuttings were described and the lithologic units encountered by drilling were identified based on descriptions by Scott et al. (1993 and 1995) and Rowley et al. (1995) and from samples collected from nearby outcrops. A summary of the lithologic log is included in Table 1.

The Quaternary alluvium is about 40 ft thick and consists of two zones. The upper 20 ft is of sand and conglomerate, and the lower 20 ft is of sandy to silty clay. The lower zone is similar to playa sediments near the margin thereof. The well videos show bedrock below the bottom of the surface casing, at 60 ft bgs, and the base of the alluvium is within this 20-ft interval. The 40-ft depth is based on the initial hole as no cuttings are available from the completed well in this interval.

Below the alluvium, the upper part of the hole is in the Delamar Lake Tuff based on the cuttings from the initial and completed wells. The Delamar Lake Tuff is poorly to moderately welded with about 10 to 25 percent sanidine and quartz phenocrysts. The sanidine is often adularescent, and the quartz is often as euhedral beta quartz crystals. Mafics are generally 1 to 4 percent between 60 and 170 ft bgs and less than 1 percent below 170 ft bgs and are of pyroxene, hornblende, and iron oxides.

The contact between the Delamar Lake and Hiko tuffs is less distinct. In the initial hole cuttings, abundant biotite, about 4 percent of the rock, was present from 440 to 490 ft bgs. Biotite is not present in the Delamar Lake Tuff, so this material is identified as the Hiko Tuff where biotite may comprise up to 4 percent of the rock (10 percent of the phenocrysts) (Scott et al., 1993). In the interval of 490 to 540 ft bgs, biotite is absent, and the material is much more representative of the non-welded Delamar Lake Tuff.

In the completed well, cuttings from the interval between 420 and 490 ft bgs are missing, and the sample at 490 to 500 ft bgs is inadequate to ensure that it is a representative sample of that interval. Between 390 and 500 ft bgs, lost circulation was a problem. In Monitor Well 182M-1, the interval from 490 to 550 ft bgs appears to be Delamar Lake Tuff, based on the presence of vitrophyre, pumice fragments, and pyroxene, all of which are common in that unit. The short interval of Hiko Tuff within the Delamar Lake Tuff section indicates a concealed fault cutting the borehole.

Below 550 ft bgs, biotite is present in the cuttings and was common below 570 ft bgs. The top of the Hiko Tuff in this well is between 550 and 560 ft bgs, essentially in agreement with the initial hole. This tuff may be faulted into the sequence, and such a fault would explain the problem with lost circulation in this interval in the completed well.

The Hiko Tuff between 550 and 1,260 ft bgs is of moderately to densely welded ash-flow tuff with occasional zones only partly welded. Occasional lithic fragments are present, but there is no evidence of a vitrophyre. From about 1,260 to 1,345 ft bgs, the total depth of the hole, the Hiko Tuff appears to be a lithic tuff, often only partly welded.

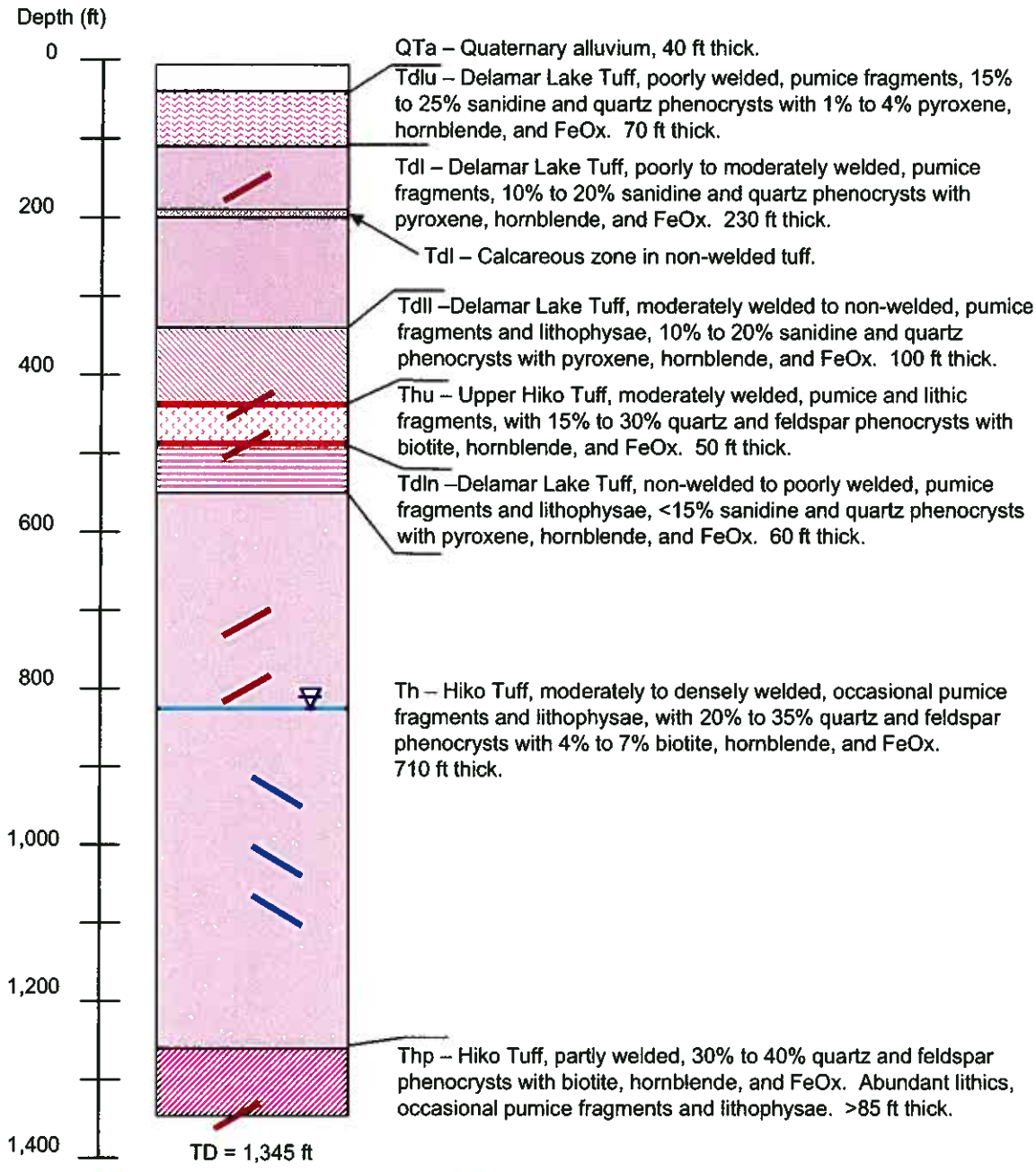
The well lithology is presented graphically on Figure 9.

TABLE 1
LITHOLOGY OF MONITOR WELL 182M-1

Interval Top to Base (ft bgs)	Geologic Unit	General Lithology	Description of Cuttings
0 to 20	QTa	Alluvium	Lt tan, occ pink or pinkish gray, coarse sand, gravel, and conglomerate, mod sorted, mod graded. Frags of devitrified volcanic tuff, ab mafics, fine to medium sand of quartz, sanidine, and mafic minerals. Calcareous coatings common on the larger frags.
20 to 40	QTa	Alluvium	Lt tan to tan-gray, clay, silt, and fine to medium grained sand. Poor to mod sorted, mod graded non-plastic.
40 to 110	Tdl (Tt4)	Poorly welded ash-flow tuff	Lt gray to reddish gray matrix, with sanidine and quartz phenocrysts, 15% to 25%. Sanidine is commonly adularescent (chatoyant). Pumice frags are present. Mafics, 3% to 5%, dominated by very dark pyroxene, hornblende, and FeOx (magnetite ± ilmenite), occ hornblende. No calcite. Occ pumice and lithophysae.
110 to 190	Tdl (Tt4)	Poorly welded ash-flow tuff	Lt gray to cream to pale orange matrix with sanidine and quartz phenocrysts, 10% to 20%, quartz crystals bipyramidal (beta-quartz). Sanidine as above. Pumice and lithophysae are common. Mafics generally less than 2%, often less than 1%, as above, often oxidized. Rare calcite, probably on fractures. Vitrophyric frags common as dark glass shards, to 160 ft bgs.
190 to 200	Tdl (Tt4)	Non-welded ash-flow tuff	Lt gray calcareous tuff, as above.
200 to 210	Tdl (Tt4)	Poorly welded ash-flow tuff	Relatively non-calcareous tuff as in the previous interval (110 to 190 ft bgs).
210 o 340	Tdl (Tt4)	Poorly to moderately welded ash-flow tuff	Lt gray to cream to pale orange matrix with sanidine and quartz phenocrysts as above. Pumice and lithophysae are common. Mafics generally less than 2%, often less than 1%, as above. Rare calcite on fractures.
340 to 440	Tdl (Tt4)	Non-welded to moderately welded ash-flow tuff	Lt gray to cream to pale orange matrix, percentage of sanidine and quartz phenocrysts variable but generally less than 15%. Mafics as above. Occ pumice frags, lithophysae.
440 to 490	Thu (Tt3)	Moderately welded ash-flow tuff, faulted	Yellow-white to orangish, occ reddish to red-brown frags with quartz and feldspar phenocrysts, 15% to 30%, with biotite as the dominant mafic, up to 4%. Pumice and lithic frags are present. Fine-grained groundmass is commonly flow-banded in appearance. This interval is missing in the completed well (missing interval 420 to 490 ft bgs).
490 to 550	Tdl (Tt4)	Partly to non-welded ash-flow tuff	Lt gray to creamy white, occ orange-reddish and brown-red frags. Sanidine and quartz phenocrysts, <15%. Vitrophyric, banded tuff, occ pumice and lithophysae. Mafics, including pyroxene, less than 3%.
550 to 1,260	Th (Tt3)	Moderately to densely welded ash-flow tuff	Generally pale pink to lt gray to orange, yellowish cream, orange cream matrix with quartz-sanidine-plagioclase phenocrysts, 20% to 35%. Biotite and FeOx, 4% to 7%. Red-brown to brownish gray lithics are common, occ pumice, lithophysae. Fine-grained groundmass. Calcite is rare. Upper and lower units not distinguishable.
1,260 to 1,345	Th (Tt3)	Partly to moderately welded ash-flow tuff	Lt gray-pink or orangish to orange, often pale yellow or creamy white matrix with quartz-sanidine-plagioclase phenocrysts, 30% to 40%. Mafics dominated by biotite, with FeOx, 3% to 5%. Lithics are common as above.

Common abbreviations for the above table:
ab - abundant
FeOx - iron oxides, principally magnetite, lesser ilmenite
frags - fragments
lt - light
mod - moderately
occ - occasionally

QTa includes the surficial Quaternary alluvium encountered in this hole. Tdl designates the Delamar Lake Tuff. Thu, Th, and Thp designate the Hiko Tuff and its identifiable submembers. Regional geologic unit (RGU) designations appear in parentheses where the unit is a subunit of the RGU. RGUs defined in Dixon et al. (2007).



Correlation of geologic units with regional geologic units (RGUs) (Dixon et al., 2007):
The surficial alluvium is part of the QTa RGU.
The Delamar Lake Tuff (Tdlu, Tdl, Tdll, Tdln) is part of the Tt4 RGU.
The Hiko Tuff (Thu, Th, Thp) is part of the Tt3 RGU.

FIGURE 9
BOREHOLE STRATIGRAPHIC COLUMN OF MONITOR WELL 182M-1

2.2.2 BOREHOLE GEOPHYSICS

A borehole geophysical survey was performed in the initial hole on February 24, 2005, to a depth of 839 ft bgs, at which point a bridge in the hole was encountered, just below the water level. As such, only a limited number of logs could be run. These logs are not presented in this report due to their limited depth and because a full suite of logs was created in July 2005 on the completed hole.

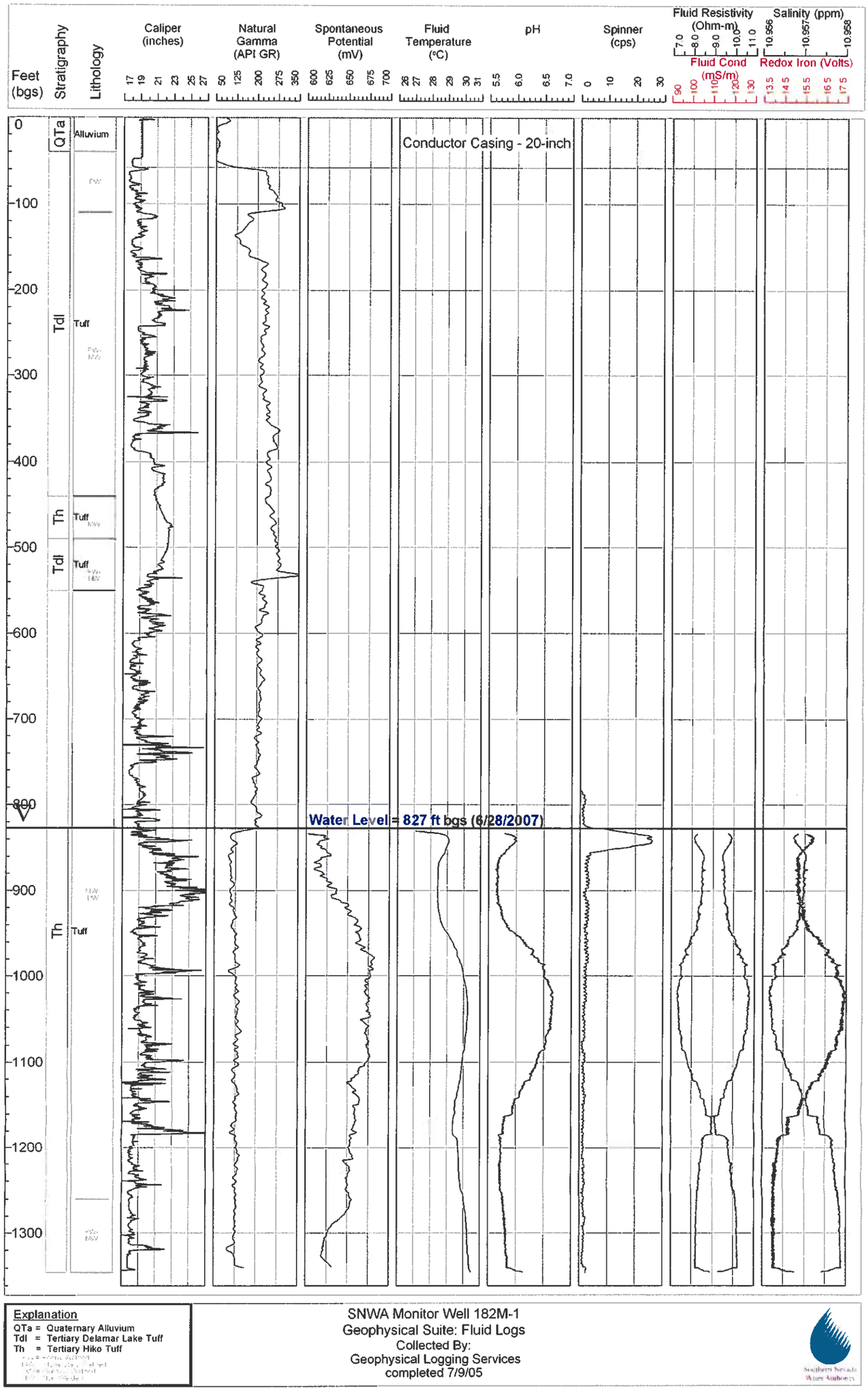
On July 9, 2005, following completion of the final hole, a full suite of geophysical logs was performed to the full depth of the well with minor exceptions. During the geophysical logging, the water level in the well was at about 830 ft bgs. On July 9, 2005, a well video was taken of the uncased hole to a depth of 850 ft, but below the water table, the water was too turbid and visibility ceased. On February 24, 2005, a well video was performed on the initial hole, but only to a depth of 117 ft. The following geophysical logs were performed:

- Natural Gamma Ray
- Deep Induction (Resistivity)
- Medium Induction (Resistivity)
- Short Guard
- Medium Guard
- Lateral Resistivity
- Spontaneous Potential
- Spectral Gamma – Potassium, Uranium, and Thorium (KUT)
- Total Spectral
- Neutron
- Density
- Sonic Delta T and Full Wave Sonic
- Fluid Temperature
- Differential Temperature
- Fluid Conductivity
- Fluid Resistivity
- Redox Iron Reduction (Volts)
- Salinity (NaCl)
- pH
- Spinner Log
- Caliper
- Deviation
- Pressure (psi).

These geophysical logs are presented on Figures 10 and 11.

Muller (2007a and b) evaluated the geophysical logs for Monitor Well 182M-1. The reliable logs for this well include Natural Gamma Ray (Gamma), resistivity logs (except the Short Guard log), Fluid Temperature, Fluid Conductivity, Fluid Resistivity, Salinity, pH, Deviation, Fluid Pressure, and Spectral Gamma. Both the Sonic and Spinner logs were considered questionable.

The Lateral Resistivity, Medium Guard, and Medium and Deep Induction logs are generally conformable and are discussed in this and subsequent paragraphs as Electric logs. These Electric logs indicate a conductive zone from about 1,240 to 1,320 ft (Figure 11). This conductive zone is in the



Note: Correlation with Regional Geologic Units (Dixon et al., 2007): The Delamar Lake Tuff is part of Tt4 ash-flow tuffs, and the Hiko Tuff is part of Tt3 ash-flow tuffs. Logs plotted by SNWA. Water level at time of geophysical logging was approximately 828 ft bgs.

FIGURE 10
MONITOR WELL 182M-1 GEOPHYSICAL FLUID LOGS

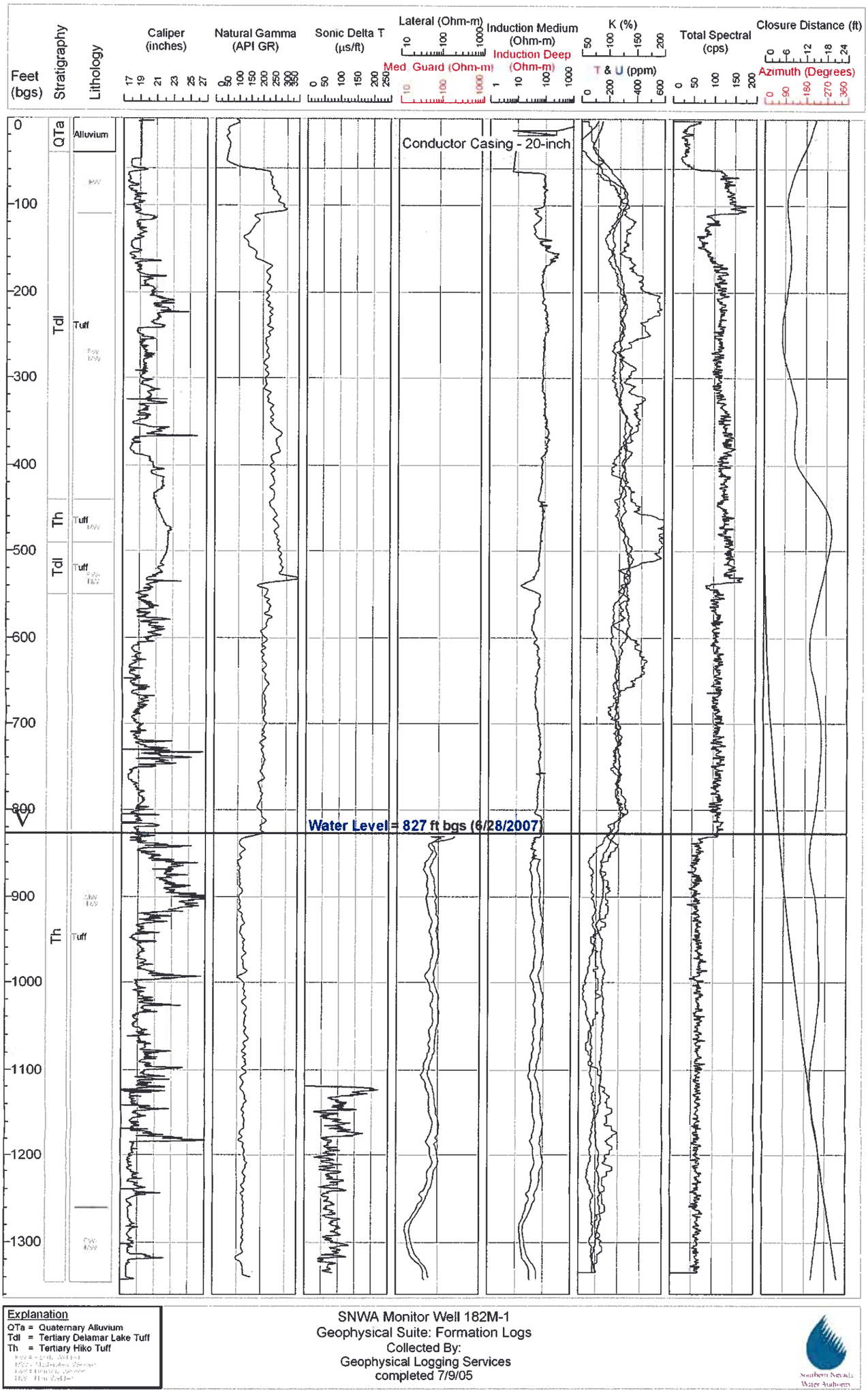


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FIGURE 11
MONITOR WELL 182M-1 GEOPHYSICAL FORMATION LOGS

same interval as the partly welded tuff member of the Hiko Tuff and is consistent with less permeable but more porous, clay-bearing material. A negative deflection is also present but less pronounced in the Spontaneous Potential log (Figure 10), where the negative deflection is also indicative of less permeable, clay-bearing material.

The Gamma log indicated a low activity in the surficial alluvium that increased to a high of about 250 gru immediately below the alluvial layer. Most of this change can be attributed to the presence of the surface casing above 60 ft bgs. A drop in the Gamma reading below 110 ft bgs corresponds to an increase in the degree of welding of the tuff. The lower Gamma readings between about 120 and 150 ft bgs are probably due to cement used to regain circulation in the well. The Gamma reading remained steady at about 200 to 250 gru to the base of the Delamar Lake Tuff. There is a small spike in the Gamma reading at the base of the Delamar Lake Tuff at 540 ft bgs. In the Hiko Tuff, the Gamma reading dropped to about 200 gru, and the count rate dropped to about 125 gru below the water table, suggesting a water attenuation of about 35 percent.

The potassium and uranium logs indicate little change throughout the ash-flow tuff units with little difference between the Delamar Lake and Hiko tuffs. Uranium generally followed potassium, as uranium is commonly present in potassic minerals, particularly biotite. Uranium appears to be less attenuated below the water table than potassium, which is most likely due to the higher energy of the uranium characteristic peak (Keys and MacCary, 1971). Thorium has peaks at 200 to 250 ft bgs, 460 to 510 ft bgs, and 600 to 660 ft bgs. These peaks may reflect variations in the mineralogy of the volcanic units, and the second peak roughly corresponds to the interval of Hiko Tuff faulted into the Delamar Lake Tuff. The third interval of high thorium corresponds to a repeated section of Hiko Tuff that produced the second thorium peak.

The Spontaneous Potential log increases from the water table to about 980 ft bgs and then decreases slightly below 1,100 ft bgs. The Fluid Temperature log represents a mixture of the drilling fluid (27.7°C) (Stoller, 2006) and the groundwater temperature (34.8°C) (Acheampong et al., 2007). The Fluid Temperature increased to 30°C between 990 and 1,100 ft bgs, which corresponds to a zone of groundwater interaction with the borehole. Inflections in the Fluid Temperature log at 1,180 and 1,250 ft bgs also indicate groundwater mixing with the borehole fluid at those depths.

Except just below the water level, the Spinner log is flat, indicating no groundwater flow, which is counter to indications by the Fluid Temperature log. The peak just below the water level was considered unlikely (Muller, 2007b).

Logs of pH, Fluid Resistivity, Fluid Conductivity, Salinity, and Redox Iron were derived from an Idronaut Water Quality Probe. The strong similarity of the logs indicate that they were all derived from one sensor (Muller, 2007b), so only the Fluid Conductivity log will be considered.

The Fluid Conductivity log indicates a lower fluid conductance, about 93 to 97 mS/m, between 1,000 and 1,100 ft bgs. This conductance supports groundwater interaction within this interval as indicated by the Fluid Temperature log. The step upward at 1,180 ft bgs also supports groundwater flux at this depth. However, the fluid temperature inflection at 1,250 ft bgs is not supported by a change in the fluid conductance, so any groundwater interaction at this depth is very minimal.

The Sonic log indicates two zones of higher effective porosity between 1,120 and 1,180 ft bgs. These zones correspond to moderately to densely welded lithic tuff, which is very similar to the tuff above

and below this interval. There are no sonic data above 1,120 ft bgs, so the higher effective porosity indication could continue uphole.

The Caliper log indicates a widened borehole at 400 to 540 ft bgs and at 860 to 920 ft bgs. The upper widening corresponds to a fault zone bringing in a slice of Hiko Tuff and the partly to non-welded lower part of the Delamar Lake Tuff. The lower zone is within poorly welded and fractured Hiko Tuff.

The Deviation (Closure Distance) log indicates that the borehole was essentially vertical to about 550 ft bgs. Moderately dipping, densely welded Hiko Tuff most likely caused the borehole to deviate to a final distance of approximately 21.5 ft S50W from the surface position.

2.2.3 DRILLING PARAMETERS

Stoller (2006) provided data on the drilling parameters as follows:

- Weight on Bit
- Pump Pressure
- Drill Bit Rotation
- Rate of Penetration
- Water Production.

These drilling parameters are presented on Figure 12.

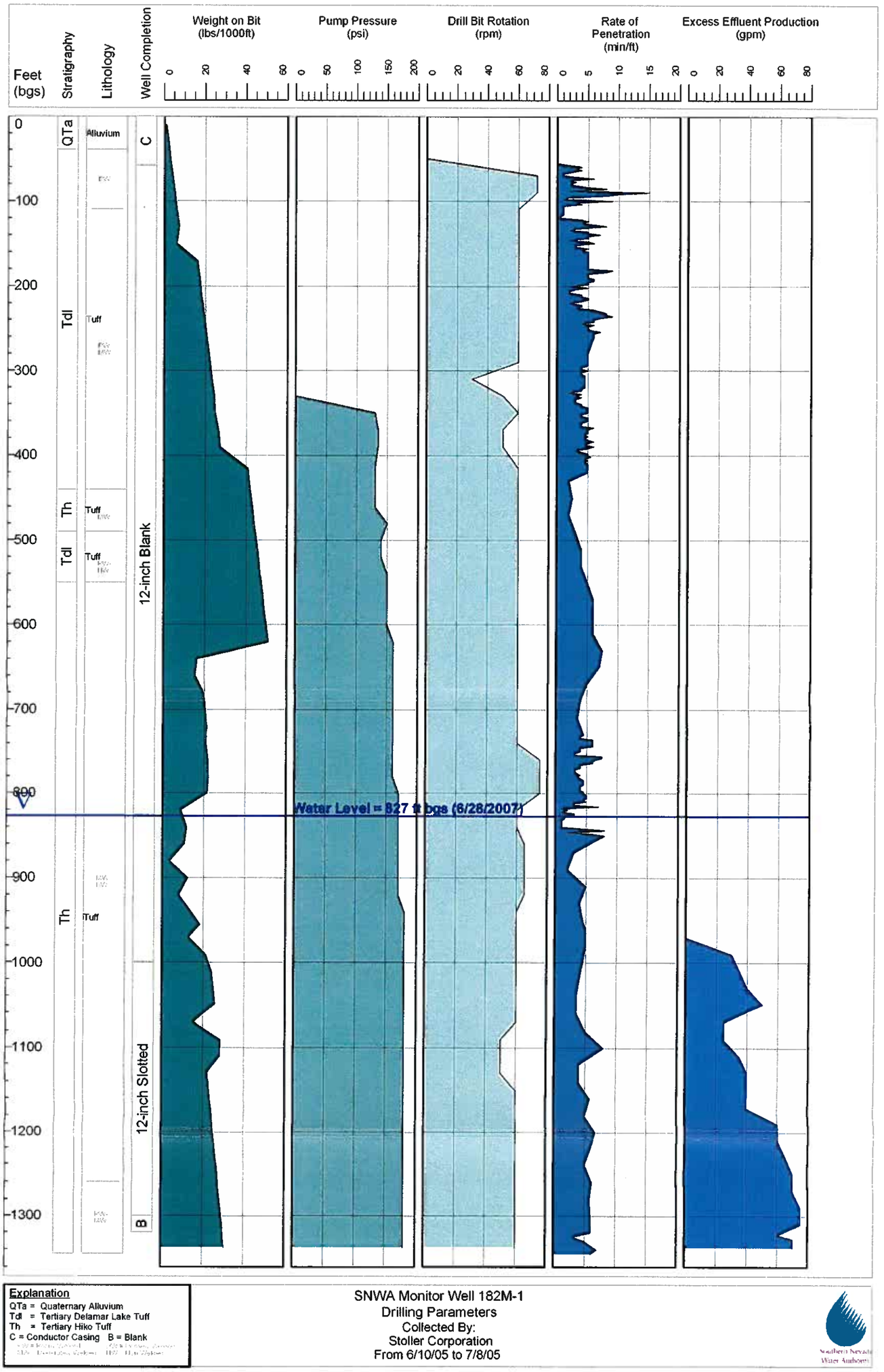
The rate of penetration is more variable within the Delamar Lake Tuff than in the upper Hiko Tuff, as indicated by the relatively smooth transitions within the Hiko Tuff. The slower penetration rate from 500 to 630 ft bgs indicates a geology that is difficult to drill, particularly as this rate is accompanied by a higher weight on the bit. Clay alteration and non-welded Delamar Lake Tuff are the most likely reasons behind this slow rate. The reduced penetration rate between 840 and 850 ft bgs may indicate a fracture zone at that depth and associated clay alteration of the Hiko Tuff.

The slower penetration rate between 1,080 and 1,120 ft bgs appears to be a zone of densely welded lithic tuff. A higher weight on the bit was used to improve the penetration rate in this interval. The penetration rate was lower below 1,150 ft bgs in densely welded and partly welded lithic tuff. The weight on the bit increased downhole in this interval. Partly welded tuff may have given problems with drilling near the base of the borehole due to the relatively soft nature of the material.

Except for an interval between 300 and 330 ft bgs, the drill bit rotation was fairly constant for the entire hole. In this short interval, the drill bit rotation was reduced, but this reduction did not affect the penetration rate. The pump pressure increased from 130 to 180 psi downhole. This increased pump pressure is most likely due to increasing hole depth.

2.3 HYDROGEOLOGY

Monitor Well 182M-1 was completed (screened) within the Hiko Tuff. During drilling operations for the initial hole, water seeps were encountered at 439, 608, and 715 ft bgs. In the completed well, an excess drilling effluent production of 30 gpm was first encountered at 980 ft bgs, increasing to 75 gpm at the total depth of the well (Figure 12) (Stoller, 2006). Geophysical evidence indicates that



Note: Correlation with Regional Geologic Units (Dixon et al., 2007): The Delamar Lake Tuff is part of Tt4 ash-flow tuffs, and the Hiko Tuff is part of Tt3 ash-flow tuffs. Logs plotted by SNWA. Water level at time of geophysical logging was approximately 828 ft bgs.

FIGURE 12
MONITOR WELL 182M-1 DRILLING PARAMETERS

most of the groundwater interaction with the borehole is between about 980 and 1,100 ft bgs and at 1,180 and 1,250 ft bgs. All of these zones represent depths at which drilling effluent increased during borehole drilling, as indicated in Figure 12.

A depth-to-water level of 827.62 ft bgs was taken at 12:00 (noon) on January 9, 2006, by SNWA (Stoller, 2006). The surface elevation at the monitor well is approximately 4,580 ft amsl, which gives a groundwater elevation of approximately 3,752 ft amsl. This site has not been professionally surveyed. In addition, eight water level readings have been taken since May 2006, ranging from 826.47 to 828.98 ft bgs and averaging 827.03 ft bgs or approximately 3,753 ft amsl. All of the readings vary by less than 1.5 ft from the average except the May 2007 reading. A complete set of water level measurements is provided in Table 2.

TABLE 2
WATER LEVEL MEASUREMENTS FOR MONITOR WELL 182M-1

Date	Time	Depth (ft bgs)	Elevation (ft amsl)	Data Collected By
2/23/2005	14:30	828.5	3,752	Stoller, on completion of the initial hole
7/11/2005	10:00	827.21	3,753	Stoller, on completion of the final hole
1/9/2006	12:00	827.62	3,752	SNWA
5/23/2006	12:00	830.0	3,751	Layne Christensen Co. (Yermo, CA) (SNWA, 2006)
10/24/2006	16:23	826.50	3,754	SNWA
12/8/2006	13:20	826.47	3,754	SNWA
1/22/2007	10:10	827.02	3,753	SNWA
2/26/2007	9:00	826.88	3,753	SNWA
4/2/2007	9:51	826.88	3,753	SNWA
5/14/2007	10:30	828.98	3,751	SNWA
6/20/2007	9:25	826.64	3,753	SNWA
6/28/2007	13:44	826.83	3,753	SNWA

Note: Groundwater elevations are rounded to the nearest foot to reflect the uncertainty in the surface elevation of the monitor well and the variability of the water level measurement procedures.

2.4 SUMMARY

Monitor Well 182M-1 was drilled in June and July 2005 for the purpose of collecting geologic, hydrologic, and geochemical data. This monitor well is located in southwestern Delamar Valley and was drilled to a total depth of 1,345 ft bgs with a slotted interval from 1,006.5 to 1,289.7 ft bgs.

The monitor well encountered 40 ft of alluvium and 1,305 ft of volcanic tuff. The hole penetrated nearly 500 ft of Delamar Lake Tuff, a non-welded to moderately welded ash-flow tuff with phenocrysts of sanidine, quartz, and iron-rich hornblende, pyroxene, and olivine. The Delamar Lake Tuff also contains abundant pumice fragments and lithophysae. A sliver of Hiko Tuff is present near the base of the Delamar Lake Tuff between 440 and 490 ft bgs, as indicated by the tuff mineralogy, and non-welded Delamar Lake Tuff is present between 490 and 550 ft bgs.

Below the Delamar Lake Tuff is at least 800 ft of Hiko Tuff, a moderately to densely welded ash-flow tuff with phenocrysts of plagioclase and sanidine feldspars along with quartz, hornblende, and biotite. The Hiko Tuff between 1,260 and 1,345 ft bgs contains zones of partly welded, lithic tuff, typical of the lowermost member of this unit.

Geophysical logs and drilling parameters provided additional data for analysis. In Monitor Well 182M-1, the Fluid Temperature and Fluid Resistivity logs indicate potential groundwater influx between about 1,000 and 1,100 ft bgs. Below 1,100 ft bgs and above 1,000 ft bgs, the borehole fluid is more representative of the drilling fluid. The drilling parameters indicate zones of densely welded tuff or partly welded tuff, with the higher drilling rates occurring in moderately welded tuff.

Water level measurements indicate a water-level elevation of approximately 3,752 ft amsl. The groundwater flow is indicative of fracture flow in moderately to densely welded Hiko Tuff.

3.0

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