DOE/WIPP-07-3366

# Basic Data Report
# For Drillhole SNL-18 (C-3233)
# (Waste Isolation Pilot Plant)

January 2010

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# Basic Data Report
# For Drillhole SNL-18 (C-3233)
# (Waste Isolation Pilot Plant)

Dennis W. Powers
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140 Hemley Road
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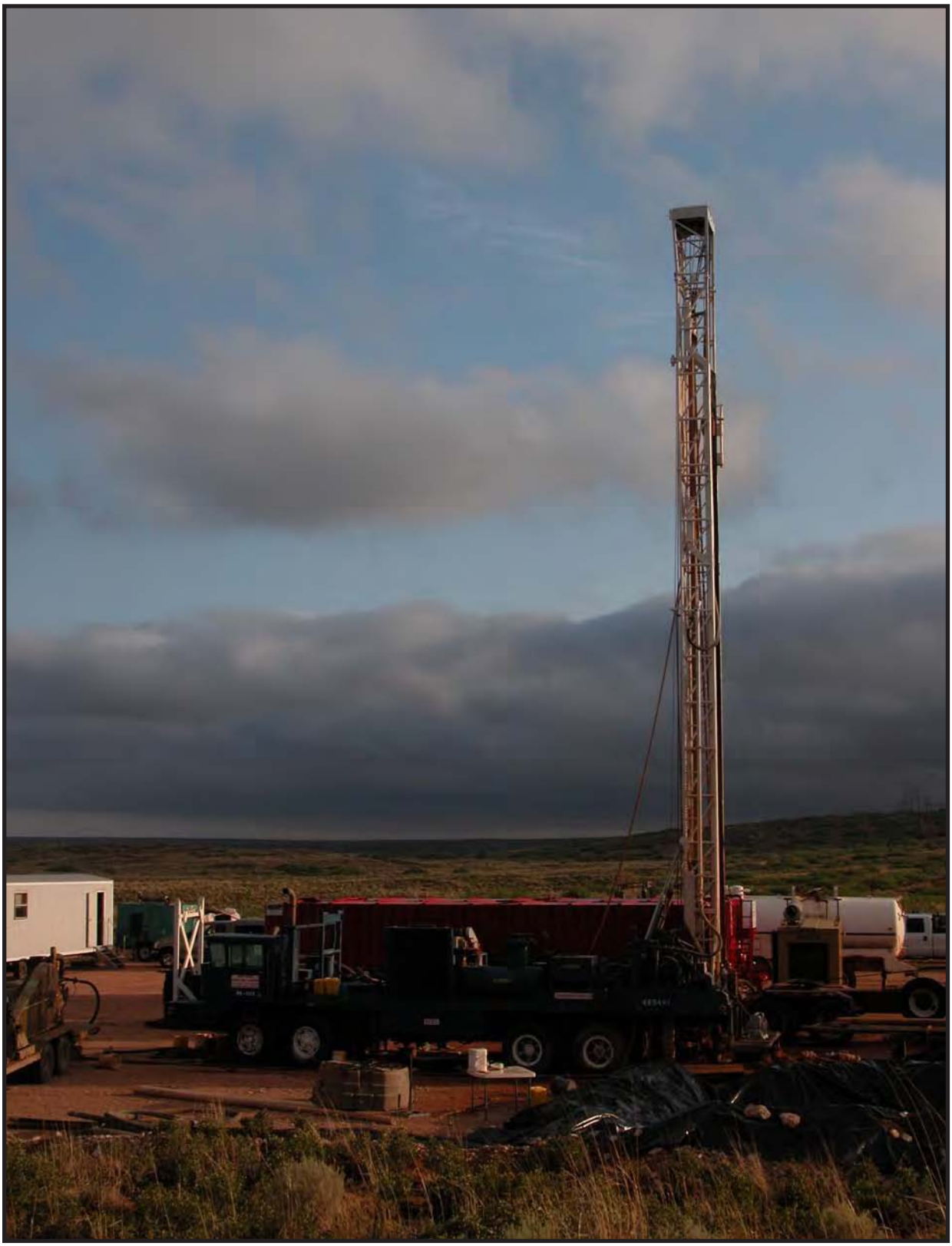
January 2010



West Texas Water Well Service Rig #15 at SNL-18 on June 23, 2006. Toward north, with the Nash Draw escarpment in the background on the right. Photo by Dennis W. Powers.

# EXECUTIVE SUMMARY

SNL-18 (permitted by the New Mexico (NM) State Engineer as C-3233) was drilled and completed during June 2006 to provide geological data and hydrological testing of the Culebra Dolomite Member of the Permian Rustler Formation along the margin of the northeastern arm of Nash Draw, north of the Waste Isolation Pilot Plant (WIPP) site. SNL-18 is in the area where upper Salado Formation halite has been dissolved and is in the mudflat facies tract of Rustler mudstone-halite units. Culebra transmissivity is expected to be relatively high. SNL-18 is located near the southeast corner of section 20, T21S, R31E, in eastern Eddy County, NM. SNL-18 was drilled to a total depth (TD) of 566 feet (ft) below ground level (bgl), based on driller's measurements. Below the caliche pad, SNL-18 encountered poorly consolidated sands, the Mescalero caliche, and the Gatuña, Dewey Lake, and Rustler Formations. The Santa Rosa and upper Dewey Lake have been eroded at SNL-18. The Rustler was cored from the lower Forty-niner Member into the upper Culebra Dolomite Member, with generally poor recovery. Geophysical logs were acquired from the open hole to a depth near TD. Water was encountered in the interval including lower Dewey Lake to Forty-niner Member.

SNL-18 was drilled to 307 ft (Dewey Lake) using air. Air and mist were used to drill and core from 307–496 ft. From 496 ft to TD, mud was used for drilling and coring with poor to no returns circulating to the surface. Coring was abandoned in the upper Culebra Dolomite due to hole conditions. Core recovery was variable, and cuttings are limited to lacking below 496 ft. Cement was pumped into the drillhole to control loss of circulation and fill during drilling.

The Los Medaños was drilled through mudstone 2 (M-2) and into the top of anhydrite 1 (A-1) based on geophysical logs and drilling rates. The thickness of M-2 is normal. No cuttings were obtained.

Core recovery from the Culebra was limited to the upper part of the unit, and no cuttings were obtained below that point. The thickness determined by drilling and geophysical logs (19 ft) is below normal. The recovered core shows bedding and possible organic-rich zones near the top of the member that are found elsewhere. The recovered core is highly fractured. Resistivity logs for the Culebra show relatively high values, possibly due to cement used to control the hole during drilling. Given the fracturing, the Culebra is expected to show relatively high transmissivity.

The Tamarisk has a normal stratigraphic sequence for the area west of the H-3 margin, but some units differ greatly in thicknesses from the WIPP site area. The basal sulfate (A-2) is gypsum that is 15 ft thick, with core displaying near-horizontal bedding and a siltstone unit recognized over a large area. The upper surface was likely exposed and eroded somewhat before mudstone deposition. At SNL-18, mudstone (M-3) of the Tamarisk shows sulfate clasts and possible intraclasts in reddish brown matrix with no upward sorting evident. Logs indicate 18 ft of M-3, which is slightly greater than in the WIPP site area. It may be partially dissolution residue after A-3 was dissolved, but facies relationships suggest thicker mudstone may exist more distal to the depocenter. The upper Tamarisk sulfate (A-3) is 5 ft thick, as measured by geophysical logging, and this is very different from unit thickness in the WIPP site area. No core was recovered. Cuttings are limited. Log data suggest it is gypsum, and it is likely the limited remains after dissolution of the remainder of the unit.

The Magenta Dolomite is 36 ft thick in logs, which is thicker than normal for the member. The very limited core recovered displays thin bedding and laminae at very steep dips. The calculated true thickness is ~6 ft, based on dip and apparent thickness measured at SNL-18 by geophysical logs.

Only the lower sulfate of the Forty-niner was apparently encountered at SNL-18. The basal gypsum (A-4) is 6 ft thick, which is less than normal. The limited cuttings show gypsum. Geophysical log data can be construed to show other Forty-niner units, but Dewey Lake cuttings were recovered to the change in lithology at 458 ft.

The Dewey Lake at SNL-18 is typical fine-grained, reddish brown siltstone, very fine sandstone, and silty claystone with common light gray reduction spots. The informal *basal bedded zone* appears to have been completely preserved, as is the informal zone of *fining upward cycles.* Upper Dewey Lake has been eroded. Moist cuttings were obtained from ~280 ft in the Dewey Lake, and the drillhole appeared to produce water from ~338 ft, also within the Dewey Lake.

The Gatuña at SNL-18 is 18 ft of brown, very fine to medium sandstone with laminar argillaceous siltstone and claystone. The Gatuña is very calcareous and moderately well indurated.

The Mescalero caliche is sandy limestone to calcareous sandstone, approximately 5 ft thick, at SNL-18. Cuttings exhibited laminar character, and the Mescalero is tentatively assigned as Stage IV development as a pedogenic calcrete.

The sand above the Mescalero is 33 ft thick, brown to reddish brown, rounded, and loose to slightly lithified. There is evidence of some different sand zones deposited at SNL-18.

SNL-18 was drilled (and reamed through cored intervals) with an original diameter of 11 inches to 566 ft for completion. Fiberglass reinforced plastic (FRP) casing (4.85 inches inside diameter) was placed in the hole, with a screen interval across the Culebra Dolomite from 557.0–530.3 ft below the top of the connector on the conductor casing. Blank casing with an endcap was added to bring the bottom of the casing to 559 ft. Approximately 2.5 ft of FRP casing was left above the connector. After drilling to TD of 566 ft, logging showed open hole to near TD. The annulus was filled with 4/10 gravel to 523 ft, above the Culebra. HolePlug® was placed from 523–518 ft. The base of HolePlug® is approximately at the contact between A-2 and overlying M-3. The annulus above the bentonite was cemented to the surface.

During drilling, water was encountered at a depth of ~338 ft (Dewey Lake). After drilling to 465 ft (into the uppermost Magenta Dolomite) and allowing overnight recovery, the water level was 301.8 ft below the connector on the casing. The average flow rate overnight was ~1 gpm. No other data on water inflow or water levels were obtained during drilling.

SNL-18 was completed June 29, 2006. The first Culebra water level recorded by Washington Regulatory and Environmental Services (WRES) was measured September 12, 2006; the initial depth to water was 300.44 ft below the top of casing.

# Table of Contents

## List of Figures and Tables



In keeping with practice at the WIPP site, the basic data for SNL-18 are reported in the inch-pound, or English, system; metric equivalents are given in one figure. The following conversion factors for metric equivalents may be useful:

| MULTIPLY ENGLISH UNIT | BY | TO OBTAIN METRIC UNIT |
|---|---|---|
| foot (ft) | 0.3048 | meter (m) |
| inch (in) | 25.4 | millimeter (mm) |
| inch (in) | 2.54 | centimeter (cm) |
| pounds (lb) | 0.4536 | kilogram (kg) |

Rig #15 in pre-dawn, June 23, 2006, at SNL-18 drillpad. Photo by Dennis W. Powers.

# 1.0 INTRODUCTION

SNL-18 was drilled near the southeast corner of section 20, T21S, R31E, in eastern Eddy County, NM (Fig. 1-1). It is located 39 ft from the south line (fsl) and 115 ft from the east line (fel) of the section (Fig. 1-2). This location places the drillhole near the escarpment of the northeastern arm of Nash Draw, north of WIPP. SNL-18 was begun on June 19, 2006, and was completed June 29, 2006. SNL-18 will be used to monitor groundwater levels of the Culebra Dolomite Member of the Permian Rustler Formation for WIPP in an area of expected high transmissivity.

SNL-18 was permitted by the NM State Engineer as C-3233. Official correspondence regarding permitting and regulatory information must reference this permit number.

Most drillholes at WIPP have been described after completion to provide an account of the geology, hydrology, or other basic data acquired during drilling and immediate completion of the drillhole. In addition, the basic data report provides an account of the drilling procedures and activities that may be helpful to later interpretations of data or for further work in the drillhole, including test activities and eventual plugging and abandoning activities. The basic data report also provides a convenient means of reporting information about administrative activities necessary to drill the hole.

## 1.1 Purpose of WIPP

WIPP is a U.S. Department of Energy (DOE) facility disposing of transuranic and mixed waste, byproducts of U.S. defense programs, as certified by the U.S. Environmental Protection Agency (EPA) and under a permit issued by the NM Environment Department. WIPP is located approximately 25 miles east of Carlsbad, NM, in eastern Eddy County (Fig. 1-1). Disposal panels are being excavated in the Permian Salado Formation at a depth of about 2,150 ft bgl.

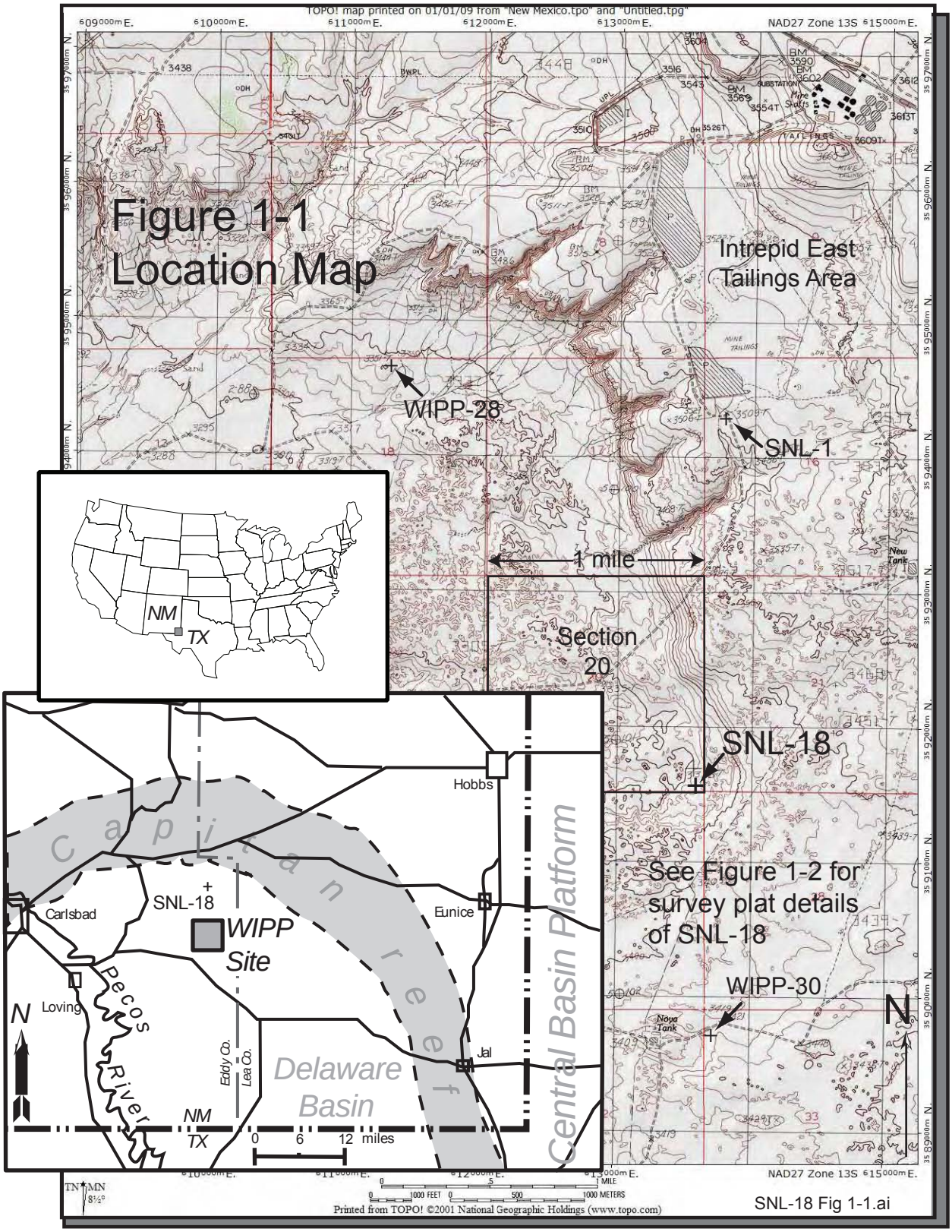
## 1.2 Purpose of SNL-18

SNL-18 was designed and located to provide information for the integrated hydrology program for WIPP (Sandia National Laboratories [SNL], 2003). Among the objectives of the integrated hydrology program, SNL-18 will help "… resolve questions related to observed water-level changes around the WIPP site, provide data needed for comprehensive modeling of WIPP groundwater hydrology, [and] construct a groundwater monitoring network that can be maintained throughout the operational period of WIPP …" (SNL, 2003, p. 1).

Culebra water levels in many of the wells monitored for WIPP have been rising in recent years, contrasting with the conditions used to calibrate models of the Culebra across the site area (SNL, 2003) for the Compliance Certification Application (CCA; U.S. DOE, 1996). Hydraulic properties of the Culebra vary spatially, and three factors (overburden, upper Salado dissolution, and Rustler halite distribution) appear to explain most of the variability in transmissivity (Holt and Yarbrough, 2002; Holt and others, 2005; Holt and Powers, 2002; Powers and others, 2003). The Compliance Recertification Application (CRA; U.S. DOE, 2004) submitted to the EPA models release scenarios through the Culebra using transmissivity fields based on these factors.

SNL-18 was located south of the tailings pile of Intrepid East (Fig. 1-1) mainly to test further the possibility that Culebra water level rises are related to infiltration from the tailings pile (Powers, 2006). SNL-18 provided a location for (Appendix A):

1. Testing confinement of the Culebra near the upper Salado dissolution margin,
2. Testing the potential for Culebra recharge through fractures paralleling the dissolution margin, and
3. Providing additional information on water level changes and flow directions in an area of uncertainty, given the higher fresh-water-equivalent heads at WIPP-27 and WIPP-30 compared to SNL-1.


TOPO! map printed on 01/01/09 from "New Mexico.tpo" and "Untitled.tpg"
NAD27 Zone 13S
Figure 1-1
Location Map
Intrepid East
Tailings Area
WIPP-28
SNL-1
1 mile
Section
20
SNL-18
See Figure 1-2 for
survey plat details
of SNL-18
WIPP-30
NM
TX
Hobbs
Carlsbad
SNL-18
WIPP
Site
Eunice
Loving
Pecos
River
Eddy Co.
Lea Co.
Delaware
Basin
Jal
Capitan reef
Central Basin Platform
N
0 6 12 miles
Printed from TOPO! ©2001 National Geographic Holdings (www.topo.com)
SNL-18 Fig 1-1.ai

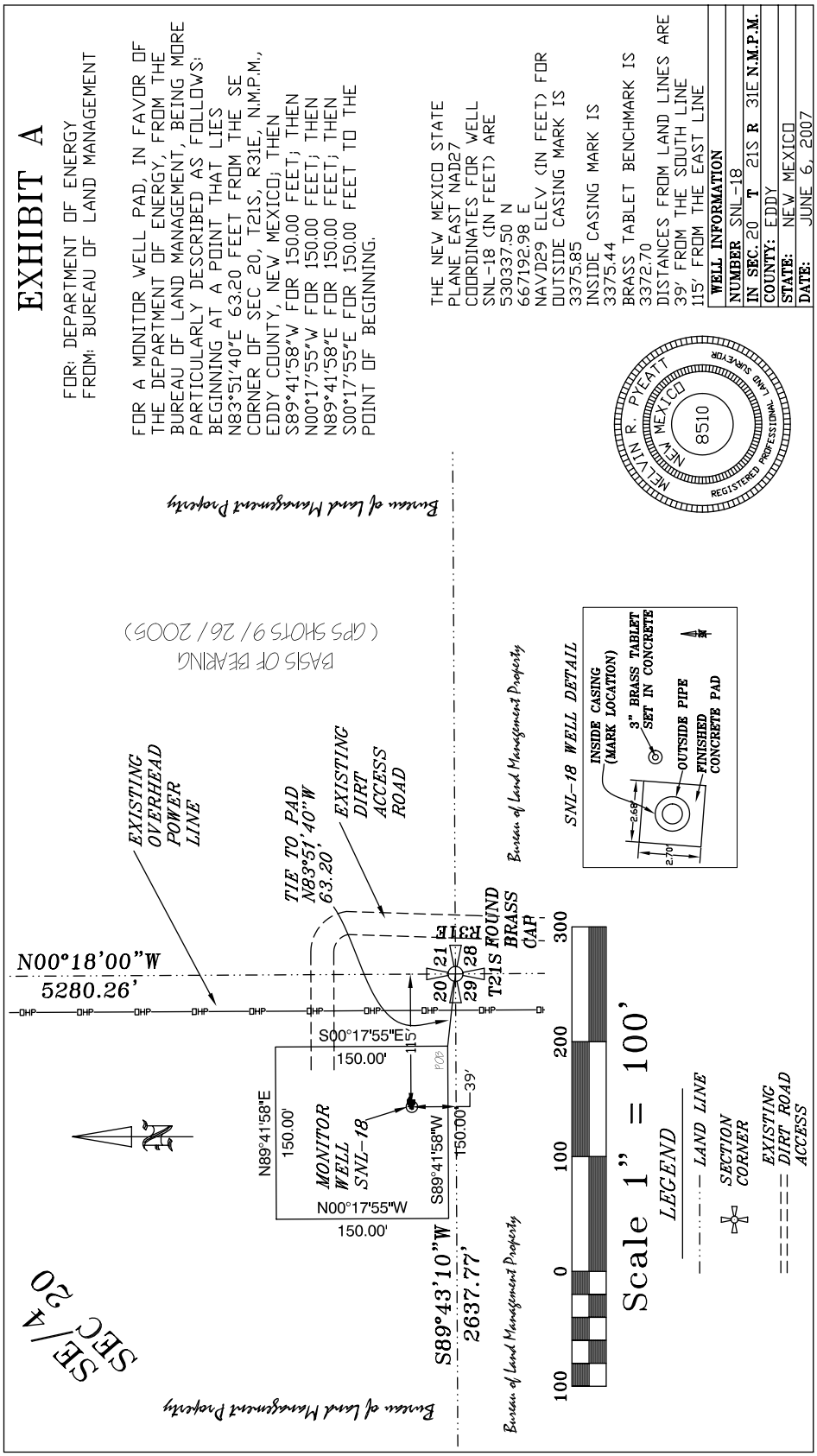



Figure 1-2
Survey Plat
for SNL-18

## 1.3 SNL-18 Drilling and Completion

The basic information about drilling and completion of SNL-18 is presented here in graphics (Figs. 1-3, 1-4, and 1-5) and in tabular form (Table 1-1) for ease of reference. Appendix B includes details based on daily drilling logs.

SNL-18 was rotary drilled and cored to a TD of 566 ft bgl (Fig. 1-3) as measured during drilling. Core recovery was generally poor (Table 1-1). The last recovered material from the middle Culebra was partial. There was limited to no circulation to the surface of drilling fluid from 496 ft to TD, and cuttings were limited from this interval. Geophysical logging prior to casing installation indicated that the drillhole was open to 548 ft, although casing was actually installed to 559 ft. SNL-18 was drilled to 307 ft using compressed air only; compressed air with mist was used to drill and core to 496 ft. Drilling and coring from 496 ft to TD were completed with fluid with bentonite and EZ-Mud®. Cement was pumped into the drillhole to control lost circulation zones encountered from 544 ft to TD.

Core recovery was variable and generally poor, with the average recovery ~34% (Table 1-1; Appendix C). Most of the Culebra was not cored due to loss of circulation. Complete core recovery is rare through the Culebra (e.g., Powers, 2002b; Mercer and others, 1998), although it is not common to stop coring because of lost circulation.

In keeping with recent practice at WIPP, SNL-18 was cased with FRP casing rather than steel to provide longer utility of the well for monitoring and testing. Steel-cased wells at WIPP are expected to be plugged and abandoned and, where necessary, replaced with wells completed with FRP casing (SNL, 2003).

SNL-18 was completed with a single screened interval for monitoring and testing of only the Culebra Dolomite (Fig. 1-4). With a single completion interval, some of the difficulties associated with multiple completions can be avoided: expense of buying, placing, and maintaining packers; loss of water-level data when packers fail; mixing of waters of differing qualities when packers fail; and the increased complexity of testing in a well completed to multiple intervals. No wells to other intervals have been proposed for the SNL-18 wellpad.

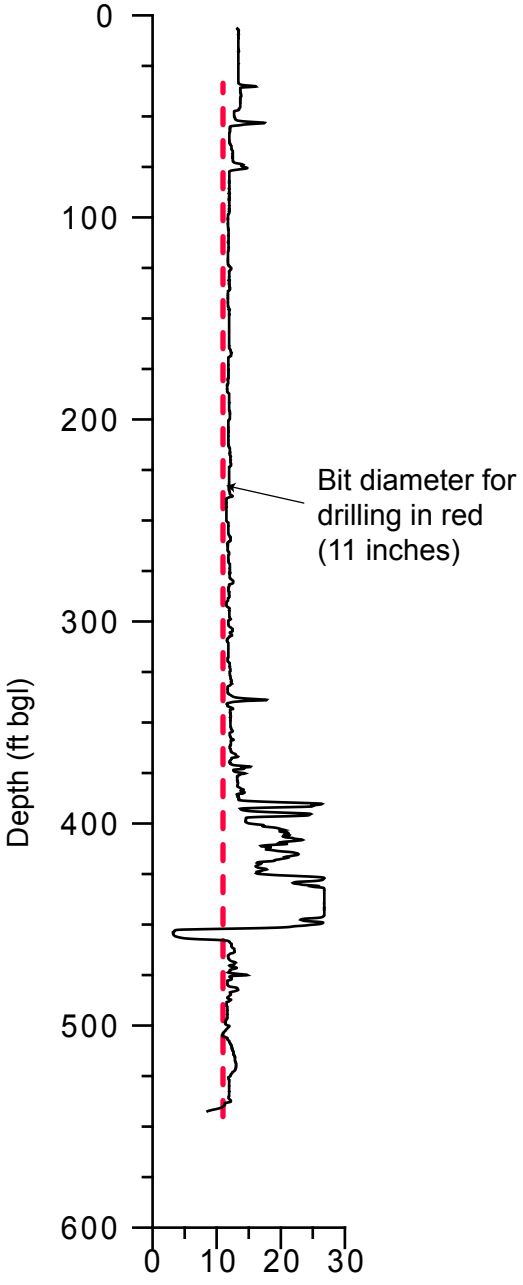
Geophysical logs, especially the natural gamma and caliper logs, were used to make the final decisions regarding completion of SNL-18 (Fig. 1-4) (Appendix D). The drillhole was stopped in an anhydrite below the Culebra to avoid circulation between Culebra and lower Rustler (Fig. 1-4). The bottom of the Culebra screen interval was placed at 557.0 ft, at the base of the Culebra. The top of the screen, at 530.3 ft, is above the top of the Culebra and includes part of the lower sulfate of the overlying Tamarisk Member. The top of the gravel pack (4/10 silica gravel) at 523 ft is near the contact between the lower sulfate and middle mudstone in the Tamarisk. Bentonite (HolePlug®) was placed to 518 ft, and the annulus above the bentonite was cemented to the surface. The caliper log (Fig. 1-3), run before the casing was placed, shows significant drillhole enlargement in the lower Dewey Lake Formation as well as a zone of diameter reduction between ~450–460 ft.

The surface configuration (Fig. 1-5) provides stability, security, and ready access to the casing for measurements, sampling, or testing. The benchmark is an accessible reference point for measurements if the well configuration is changed.

A steel surface conductor casing was cemented in place to a depth of 35 ft bgl, with the top of the cutoff conductor casing ~6 inches above the pad level (Fig. 1-5) serving as a common reference point for drilling; geophysical logging; and placing the screened interval, sand pack, bentonite seal, and cement. The top of the steel connector was estimated to have an elevation of 3,371 ft amsl (above mean sea level), based on a pre-drilling survey of the well pad (not shown). The benchmark placed at the drilling pad surface next to the completed well has an elevation of 3,372.70 ft amsl

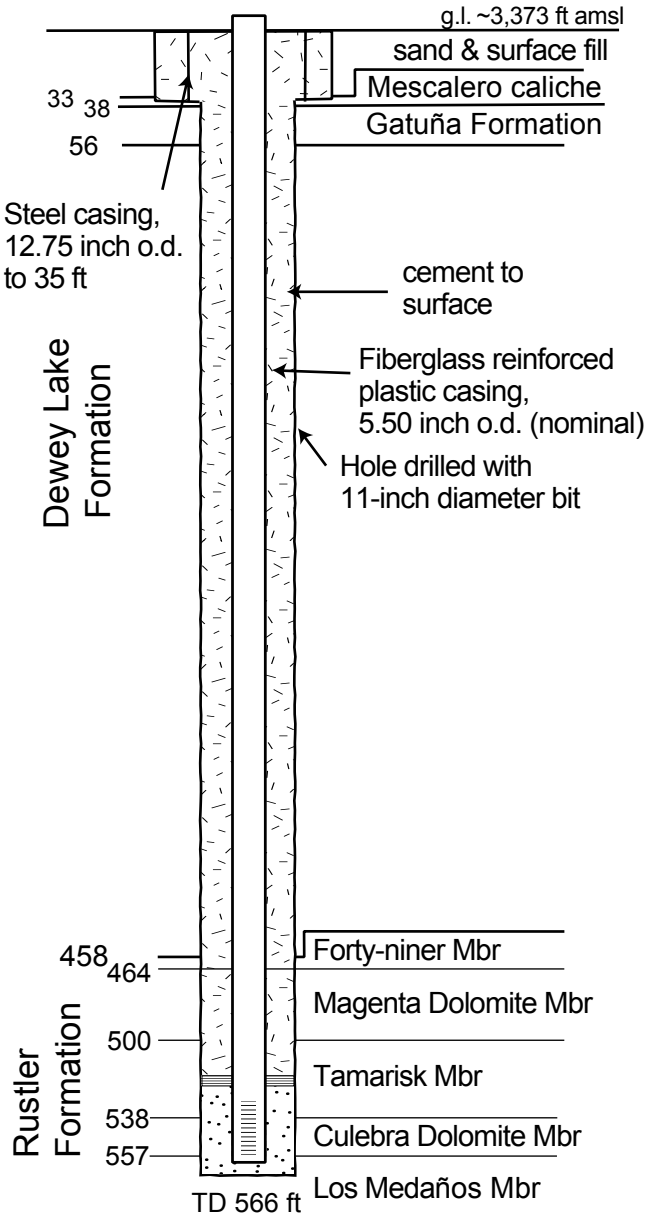
# Figure 1-3
# SNL-18 As-Built Diagram

## Pre-completion Caliper Log




SNL-18 Diameter (inches) (after drilling to 11 inches)
See Figures 1-4 and 1-5 for more details

## General Stratigraphy and Configuration




Note: Depths for drilling, geophysical logs, and completion are referenced to the top of the steel connector on the surface conductor casing, which is at the surface of the drilling pad at SNL-18 and is taken as 3,373 ft amsl.

## Table 1-1. Summary of Drilling and Well Completion Records for Hydrologic Drillhole SNL-18 (C-3233)

**LOCATION:** Southeast ¼, Section 20, Township 21 South (T21S), Range 31 East (R31E)

**SURFACE COORDINATES:** The well is located 39 ft from the south line (fsl) and 115 ft from the east line (fel) of Section 20. The New Mexico State Plane (NAD 27) horizontal coordinates in feet are 530337.50 North, 667192.98 East (Fig. 1-2 shows the survey plat). Universal Transverse Mercator (UTM) horizontal coordinates (NAD27, Zone 13) in meters were calculated for SNL-18 using Corpscon for Windows (v. 6): 613605.40 East, 3591529.06 North. Figure 1-1 shows 1,000-m UTM gridlines.

**ELEVATION:** All depths from geological and geophysical data used for completion were measured from the surface conductor casing just above the level of the drillpad surface (Fig. 1-5). Depths are reported as bgl, which is taken as 3,373 ft above mean sea level (amsl), the rounded value for the brass tablet benchmark (3,372.70 ft amsl) adjacent to the cement well pad. The primary datum for the completed well is 3,375.44 ft amsl (NGVD 29) for a mark on the fiberglass reinforced plastic casing inside the protective well pipe. Figures 1-3, 1-4, and 1-5 show the as-built configuration of SNL-18.

**DRILLING RECORD:**

**Dates:** Began drilling June 19, 2006; drillhole reached TD (566 ft) on June 28, 2006. Geophysical logging was conducted on June 29, 2006, after circulating and cleaning to TD. The drillhole was again cleaned and fluid circulated after logging and before casing. SNL-18 was cased and cemented June 29, 2006. SNL-18 was jetted on July 6, 2006, using 120 barrels of water; the well was airlifted for 40 minutes at approximately 20 gpm. A pump was installed July 17, 2006, and 29,368 gallons were pumped from the well from July 17 to July 19, 2006.

**Circulation Fluid:** SNL-18 was drilled to 307 ft bgl with circulating air, with damp cuttings from 280 ft. SNL-18 was drilled from 307 ft to 465 ft and cored from 465 ft to 496 ft using additional fresh water and Quik-Foam®. Because of water flow and fill, drilling from 496 ft to TD continued with circulating fluid (water, EZ-Mud®, and Aquagel®). Due to additional lost circulation while at a depth of 544 ft, 3 cubic yards of cement were pumped in the hole before continuing drilling. An additional 1.5 cubic yards were added to the drillhole due to lost circulation while drilling original cement.

**Cored Intervals:** 4.0-inch core was taken through these intervals (depths from drilling data):

465.0–541.0 ft bgl: lower Forty-niner to middle Culebra Dolomite Members

**Rig and Drilling Contractor:** Gardner-Denver 1500; West Texas Water Well Service, Odessa, Texas

## Table 1-1. Summary of Drilling and Well Completion Records for Hydrologic Drillhole SNL-18 (C-3233), continued

**Drillhole Record:**

| Size (inches) | From (ft bgl) | To (ft bgl) |
|---|---|---|
| 17.5 | 0 | 35 |
| 11 | 35 | 566 |

**Casing Record:**

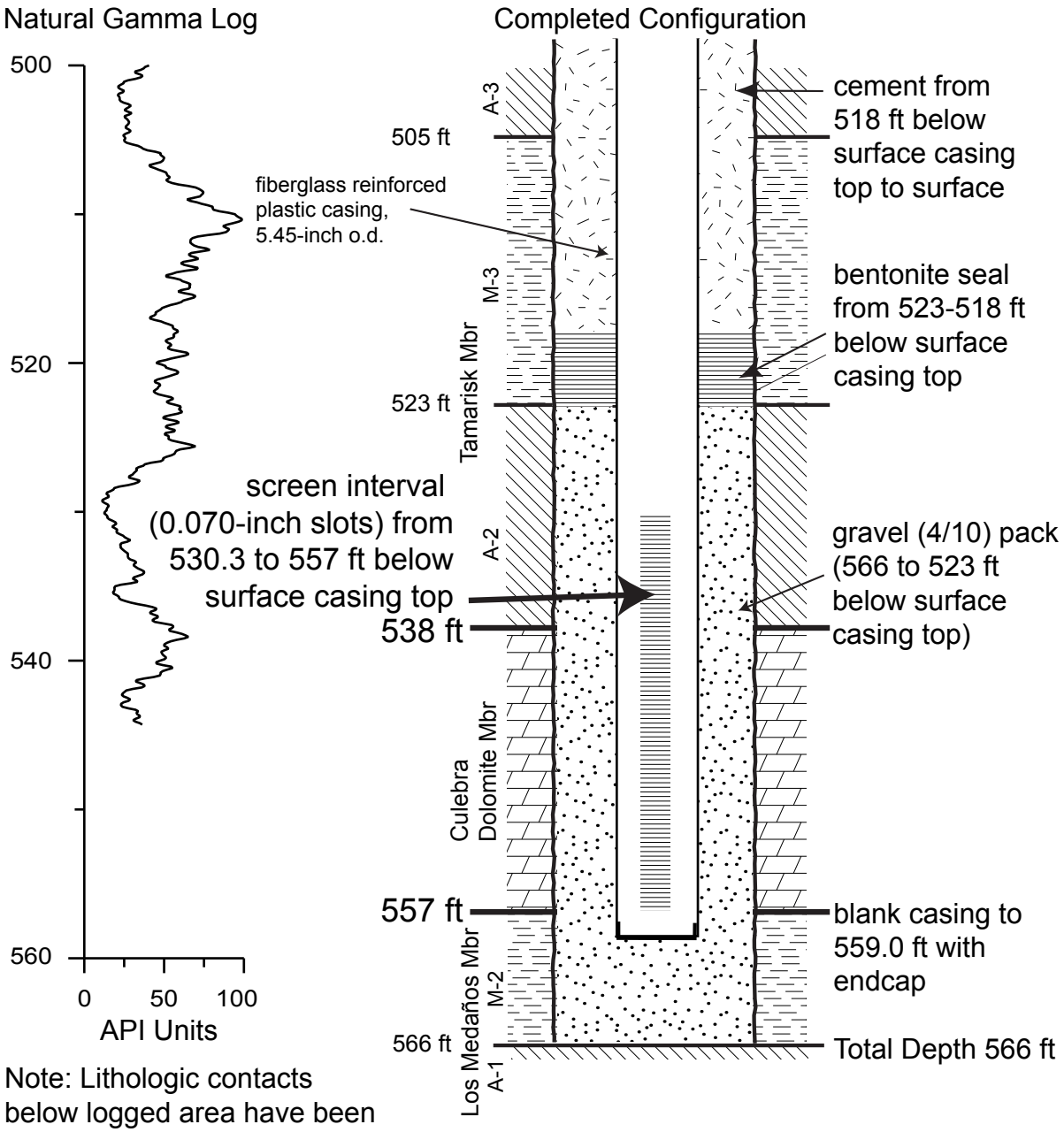
| Outside diameter (inches) | Inside diameter (inches) | Weight/ft (pounds) | From (ft bgl)* | To (ft bgl) |
|---|---|---|---|---|
| 12.75 | 12.25 | 48 steel | -3 | 35 |
| 5.45 | 4.85 | 3.20 FRP** blank | -2.5 | 530.3 |
| 5.45 | 4.85 | 3.20 FRP screen | 530.3 | 557.0 |
| 5.45 | 4.85 | 3.20 FRP blank | 557.0 | 559.0 |

*Top of the casing connector is the reference for depth denoted bgl. The FRP extends 2.5 ft (-2.5) above the steel casing connector.
**FRP: fiberglass reinforced plastic
Principal supplier and size: Centron® 5 1/2 DHC .300

**Coring Record:**

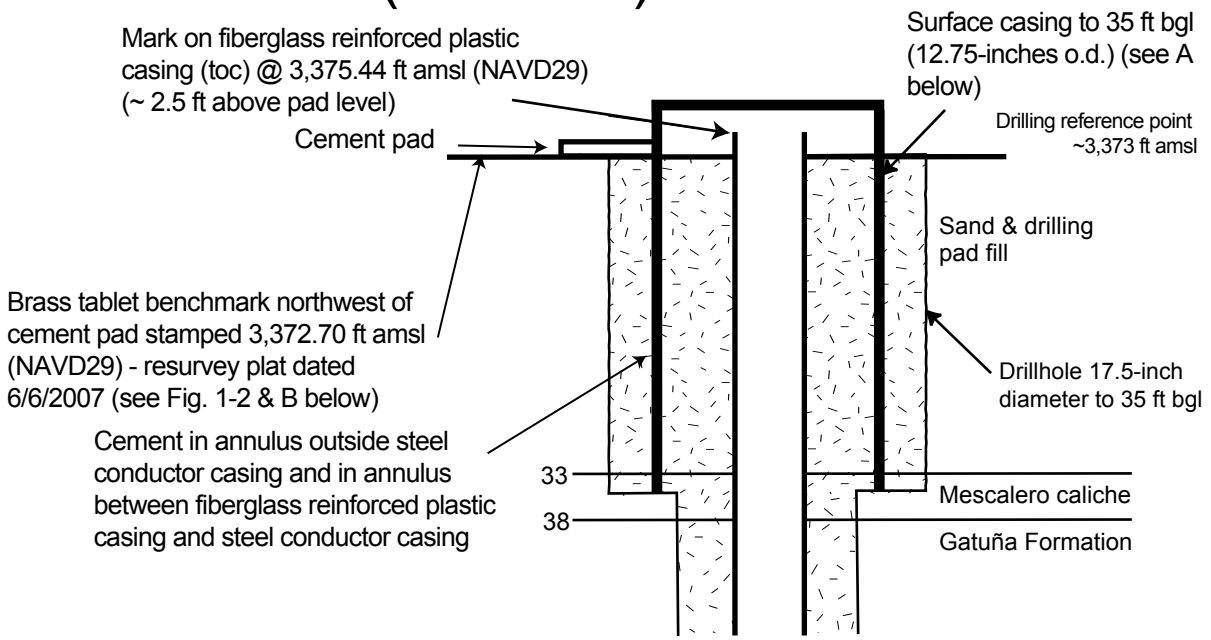
| Core Run No. | Depth Interval (ft) From | To | Interval (ft) Cored | Recovered | Recovered % |
|---|---|---|---|---|---|
| 1 | 465 | 495 | 30 | 1.5 | 5.00% |
| 2 | 495 | 496 | 1 | 0 | 0.00% |
| 3 | 496 | 526 | 30 | 12.3 | 41.00% |
| 4 | 526 | 537 | 11 | 8.5 | 77.27% |
| 5 | 537 | 541 | 4 | 3.5 | 87.50% |
| | | **Totals** | 76 | 25.8 | 33.95% |

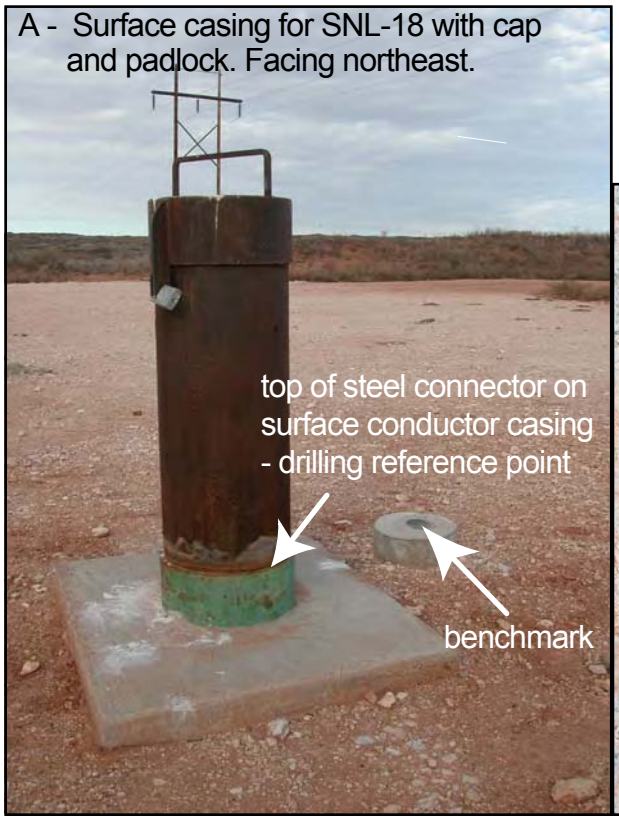
# Figure 1-4
# SNL-18 Completion and Monitoring Configuration (6/29/06)




Note: Lithologic contacts below logged area have been adjusted from depths determined during drilling to equivalent log depths.

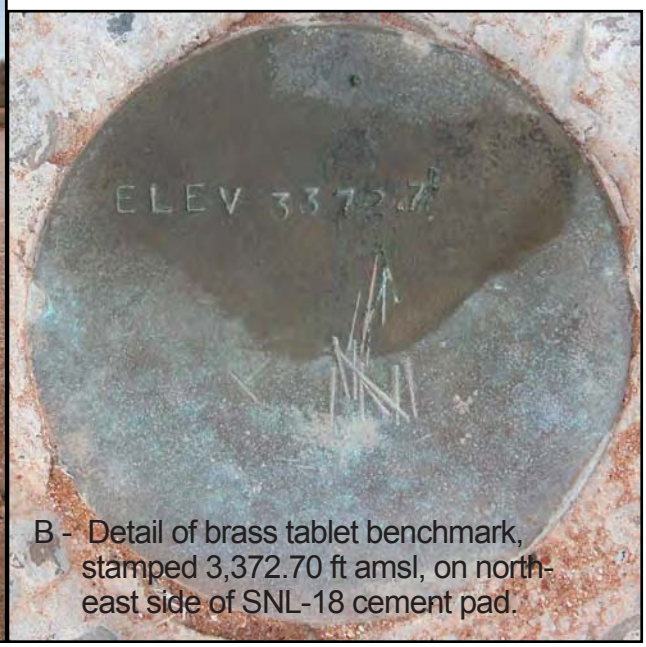
# Figure 1-5
# SNL-18 Surface Configuration and Elevation (12/17/07)




Note: Drawing is not to scale.

Photos by Dennis W. Powers 12/17/07.



(survey plat dated June 6, 2007; Fig. 1-2) and is very close to the elevation of the connector on the casing. *Other than water-level monitoring, depths are stated as bgl, and the top of the steel connector on the surface conductor casing is taken as a proxy reference point for ground level with an elevation of ~3,373 ft amsl (Figs. 1-3, 1-4, and 1-5).* The FRP casing projects ~2.5 ft above the steel connector on top of the conductor casing. This FRP casing point is surveyed (Fig. 1-5), and it provides the reference point and reference elevation (3,375.44 ft amsl) for monitoring water levels.

## 1.4 Other Background

SNL-18 was drilled and completed by the West Texas Water Well Service, 3410 Mankins, Odessa, TX, under contract from Washington TRU Solutions LLC (WTS). Coring was done by John Wood, Diamond Oil Well Drilling Co., Inc., P.O. Box 7843, Midland, TX. Geophysical logging was conducted by Al Henderson, Jet West Geophysical Services, LLC, 2550 La Plata Highway, Farmington, NM, 87499-3522, under contract to West Texas Water Well Service. Geological support was provided by Dennis W. Powers under contract to WTS. Well drilling wastes (cuttings) were removed from SNL-18 and disposed of at the Lea Land, Inc., landfill north of WIPP. Archeological clearances obtained from the U.S. Bureau of Land Management were based on field work and reports by Boone Archeological Services, Carlsbad, NM (Appendix E). Cores from SNL-18 were photographed with a digital camera, and a photo log is included in Appendix F. Electronic images can be requested from WTS.

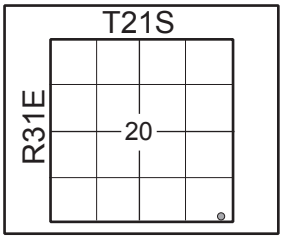
Formal color designations (e.g., weak red: 5YR5/4) included in the text and Appendix C are based on the 1971 edition of the Munsell Soil Color Charts. The names may differ from the general color observed; the rocks are compared when dry unless otherwise specifically noted.

## 1.5 Acknowledgements

Drafts of this document were reviewed by Wayne Stensrud, Rick Salness, Joel Siegel, Erik Powers, Tricia Johnson, and Rick Beauheim, and their comments improved the final report. Ron Richardson (Washington Regulatory and Environmental Services - WRES) provided field support during drilling, as did Ed Bielecki (Washington Group, International). Mark Crawley (WRES) provided field support and information on well development. Larry Keith and Luis Armendariz (West Texas Water Well Service) provided drilling data and daily drilling records. West Texas Water Well Service personnel were very helpful in providing access for sampling during drilling. Al Henderson (Jet West Geophysical Services) provided the printed and electronic files that were used to develop Figure 2-1. Vivian Allen (L&M) provided useful editorial guidance and management of the review process.

# Figure 2-1
# Well Record SNL-18 (C-3233)

Company: Washington TRU Solutions LLC
Well: SNL-18 (C-3233)
Section: 20 Twp: T21S Rge: R31E
Location: 39 ft from south line (fsl)
115 ft from east line (fel)




Reference point
Log measured from: top of connector on conductor casing (gl)
Drilling measured from: gl
Permanent Datum: benchmark

Elevation
KB:
DF:
GL: 3,373 ft amsl
(benchmark: 3,372.70)

Drilling contractor: West Texas Well Water Service
Coring contractor: Diamond Oil Well Drilling Co.
Geophysical logs: Al Henderson
Jet West Geophysical Services, LLC (NM)
Geologist: Dennis W. Powers
Spud date: June 19, 2006
Completion date: June 29, 2006
Total depth (TD): 566 ft bgl (driller log)

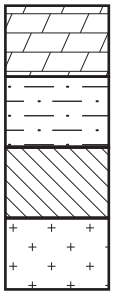
Casing Record
Conductor: 35 ft
12.75-inch o.d. steel
Casing: 5.45-inch o.d.
fiberglass reinforced
plastic to 559.0 ft bgl
Screened interval:
557.0-530.3 ft bgl

Geophysical Logs Date: June 29, 2006

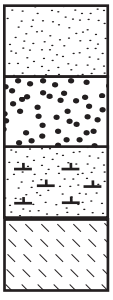
| | |
|---|---|
| Micro/Laterolog/SP: | 278-548 ft |
| Gamma | 0-544 ft |
| Caliper: | 0-542 ft |
| Density/Neutron: | 35-548 ft |

Type fluid in hole: top of drilling mud 278 ft bgl
Res mud: n/a
Res mud filtrate: n/a
Max. Rec. Temp.:
not recorded

## General Lithologic Symbols Used



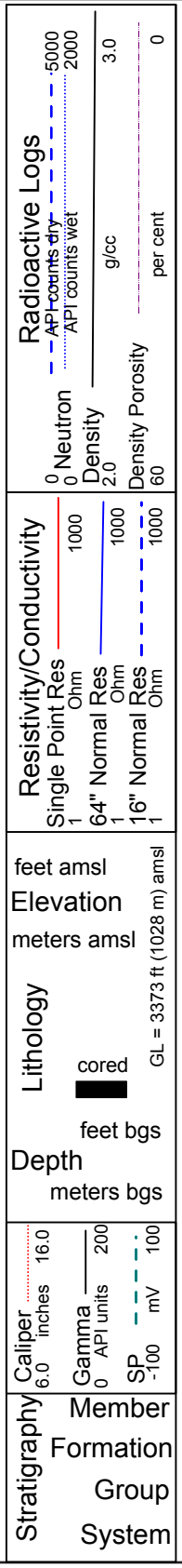
Dolomite
Mudstone/siltstone
Anhydrite
Halite

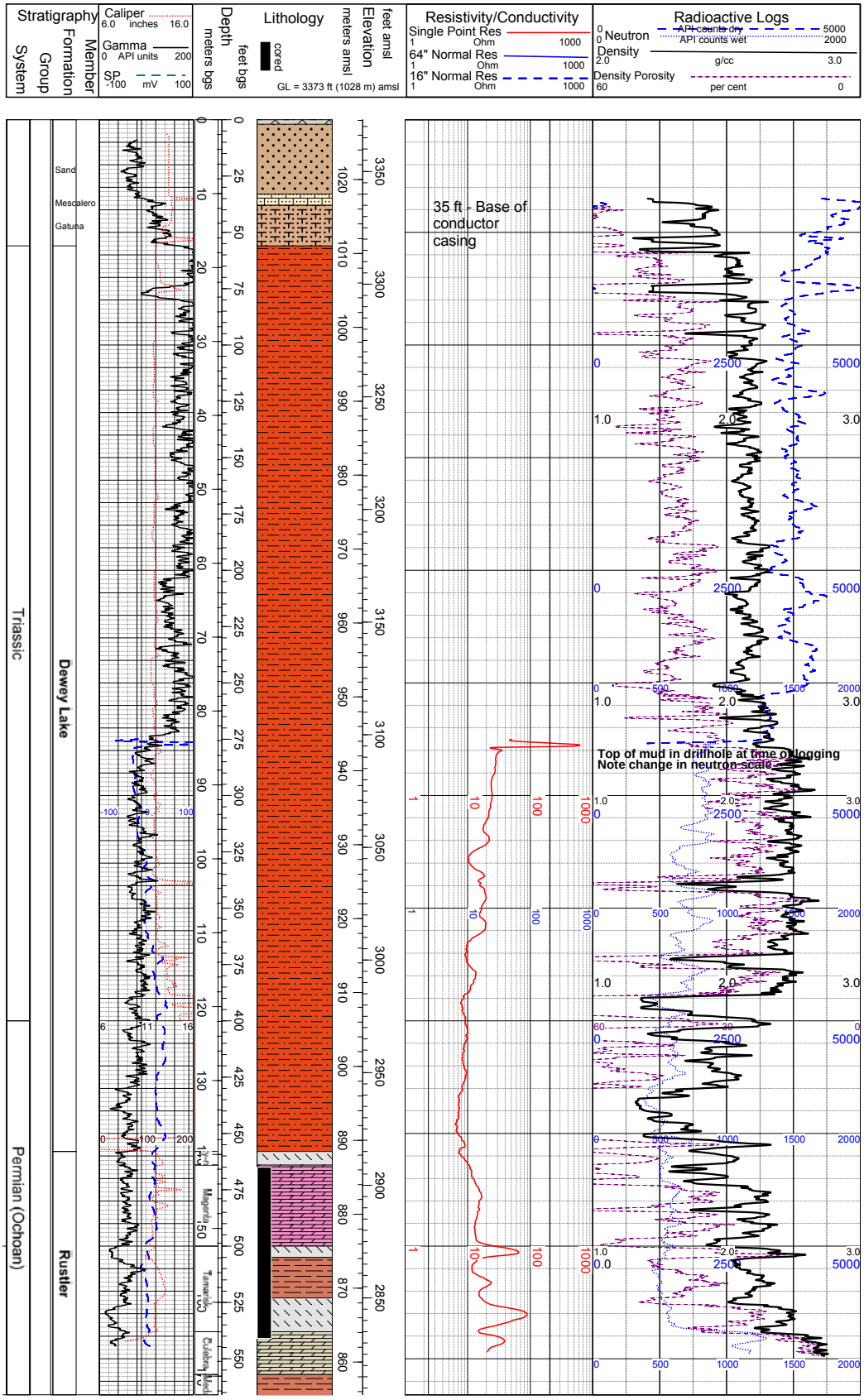


Fine sandstone & siltstone
Coarse sandstone
Sandstone w/caliche
Gypsum

Figure 2-1 Log Title & Header page.ai

## SNL-18 Well Log Headers






See end of Appendix G for larger format pdf version

**Table 2-1**
**Geology at Drillhole SNL-18**

| **System/ Period/**Epoch | | **Formation or unit** | **Member** *Informal units* | **Depth below surface (ft)**[1] *log depths* | *core marks* |
|---|---|---|---|---|---|
| **Cenozoic** | Holocene | surface dune sand and pad fill | | 0 - 33 ft | |
| | Pleistocene | Mescalero caliche | | 33 ft - 38 ft | |
| | Miocene-Pleistocene | Gatuña | | 38 ft - 56 ft | |
| **Mesozoic** | **Triassic** | Santa Rosa[2] | | eroded | |
| | | Dewey Lake[3] | | 56 ft - 458 ft | |
| **Paleozoic** | **Permian** | Rustler | Forty-niner<br>*A-5*<br>*M-4/H-4*<br>*A-4* | 458 ft - 464 ft<br>*dissolved*<br>*not detected*<br>*458 ft - 464 ft* | <br><br><br>*no core recovered* |
| | | | Magenta Dolomite | 464 ft - 500 ft | 493.5 ft - 495 ft |
| | | | Tamarisk<br>*A-3*<br>*M-3/H-3*<br>*A-2* | 500 ft - 538 ft<br>*500 ft - 505 ft*<br>*505 ft - 523 ft*<br>*523 ft - 538 ft* | 513.7 ft - 532.7 ft<br>*no core recovered*<br>*513.7 ft - 516.0 ft*<br>*516.0 ft - 532.7 ft* |
| | | | Culebra Dolomite | 538 ft - 557 ft | 532.7 ft - 541 ft |
| | | | Los Medaños[4]<br>*M-2/H-2*<br>*A-1*<br>*M-1/H-1* | 557 ft - 566 ft<br>*557 ft - 566 ft*<br>*top A-1 at 566 ft* | |

[1]Depths are based on measurements by geophysical logging; drilling and coring provided supplemental data to TD of 566 ft bgl by driller's log. Geophysical logs and drilling/coring depths begin at the top of the connector on the surface steel conductor casing. This reference point is taken as 3,373 ft amsl; it is near the elevation of the surface benchmark adjacent to SNL-18. Water level depths will be measured and reported relative to the surveyed point on the top of the fiberglass reinforced plastic casing (Fig. 1-5). Geological logs based on field descriptions (Appendix C) and markings on cores (Appendix F) vary modestly from log depths. Geophysical logs recorded data to near TD.

[2]The Santa Rosa Formation has been removed by erosion in this area.

[3]The Dewey Lake Formation has been considered part of the Permian System in the past. Recent work (Renne and others, 1996, 2001) indicates that lithologically equivalent rocks in Texas are mostly Lower Triassic, with some Upper Permian at the base.

[4]The Los Medaños Member was named by Powers and Holt (1999) to replace the informal unit "unnamed lower member" of the Rustler Formation. Depths are based on drilling information.

# 2.0 GEOLOGICAL DATA

## 2.1 General Geological Background

The geology and hydrology of formations at the WIPP site and surroundings have been intensively investigated since 1975, and the information and interpretations have been reported in numerous documents. The most thorough compilation is certainly the Compliance Certification Application (CCA) submitted in 1996 by the DOE to the EPA (U.S. DOE, 1996). Some salient features of the broader geological history, as well as more recent work on the geohydrology of the Rustler (e.g., Holt and Yarbrough, 2002; Powers, 2002a, 2003a; Powers and others, 2003), are relevant to understanding the geology and hydrology at SNL-18.

The Delaware Basin (Fig. 1-1) was a large structural feature that controlled deposition through much of the Paleozoic. By late Permian, the basin connection to the open ocean was restricted, and evaporite minerals were precipitated in abundance to fill the basin. Near the end of the Permian, circulation with the ocean improved, and some of the Rustler Formation, for example, was deposited in saline water rather than brine. As the Permian ended and Triassic began, significant redbeds were deposited in non-marine environments. Although surrounding areas accumulated variable thicknesses of later Mesozoic and Cenozoic age sediments, the WIPP area appears mainly to have been subject to erosion during an extended period. Some basin tilting from middle to late Cenozoic time exposed the evaporite beds to faster solution and erosion, and weathered material began to accumulate. The Pecos River drainage became integrated through the region during this period, and more recent deposits reflect such a sedimentary environment as well as sources of sediment from outside the local area. Although the region continues to be subject to some dissolution of evaporites and erosion, large areas have remained geologically stable for approximately the last half million years, resulting in the formation and preservation of pedogenic calcrete (caliche) deposits.

## 2.2 Geological Data From SNL-18

SNL-18 encountered a truncated stratigraphic sequence from ground level to TD, and this is anticipated for this location in the north central part of Nash Draw (Fig. 2-1; Table 2-1). Units encountered ranged from unconsolidated surface sand to the poorly consolidated Culebra Dolomite Member of the Permian Rustler Formation. Structural, sedimentological, and diagenetic features were examined during investigation using cuttings, cores, and geophysical logs. Details of the sedimentology of the Rustler will extend understanding of that unit. Moist cuttings and water were encountered while drilling the Dewey Lake, and drilling and coring were modified to use mist and, later, circulating drilling mud. From 496 ft, SNL-18 was drilled with mud, mostly without circulation to the surface.

The geologic units encountered in SNL-18 are described from TD to the surface, in the order in which they were deposited rather than in the order in which they were encountered in the drillhole. Cores and cuttings were described in the field using mainly drilling depths for depth control. Geologic logs detailing field observations of cuttings and cores are included in Appendix C. The difference between geophysical log and drilling depth is generally slight. Decisions about placing screen intervals and annulus fillings were based on depths indicated by geophysical logs (Appendix G).

*Note that the descriptions that follow use depths that correspond to core markings, with basic stratigraphic intervals provided by geophysical logs, as indicated.*

### 2.2.1 Permian Rustler Formation

The Rustler was drilled and cored into the upper Los Medaños Member. The contact between the Rustler and the overlying Dewey Lake Formation is at 458 ft (Fig. 2-2; Table 2-1), and 108 ft of the Rustler were penetrated at SNL-18 (Table 2-1).

#### 2.2.1.1 Los Medaños Member

The Los Medaños was named by Powers and Holt (1999) based on the rocks described in shafts at the WIPP site. For the area around WIPP, studies of the Rustler have commonly referred to this interval from the base of the Culebra Dolomite Member to the top of the Salado Formation as the unnamed lower member of the Rustler. Holt and Powers (1988) and Powers and Holt (1999) also informally subdivided the Los Medaños into five units: a bioturbated clastic interval at the base, a sandy transition zone, a lower mudstone-halite 1 (M-1/H-1), anhydrite 1 (A-1), and an upper mudstone-halite 2 (M-2/H-2). Halite margins for the Los Medaños below A-1 have been treated as a single composite unit (Powers, 2002a), called M-1/H-1, because halite below A-1 is not restricted to the thinner zone designated M-1/H-1 in these earlier publications.

None of the Los Medaños was cored in SNL-18. M-2 and the top of A-1 were penetrated, based on drilling rates. No cuttings were recovered from this interval due to loss of circulation.

The top of informal unit *anhydrite 1* (A-1; Fig. 2-2) was encountered at 566 ft.

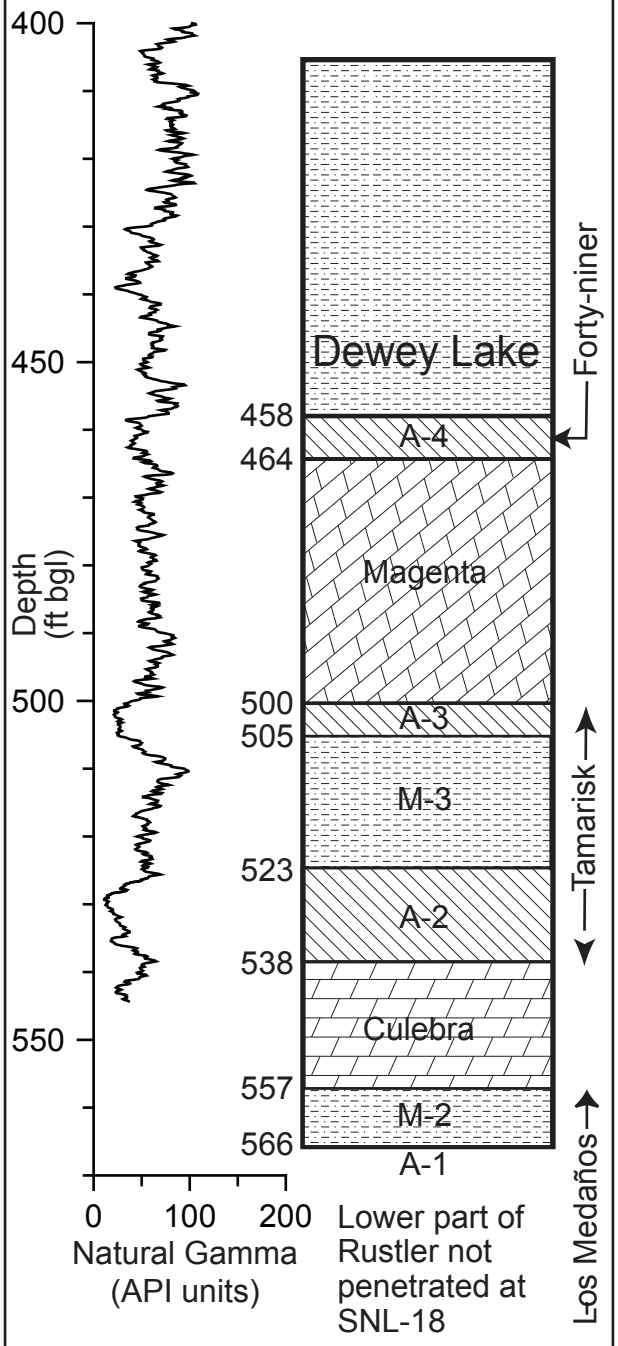
The informal unit *mudstone-halite 2* (M-2; Fig. 2-2) was encountered from 566–557 ft bgl.

#### 2.2.1.2 Culebra Dolomite Member

Based on drilling depths available at the time, the recovered Culebra core from SNL-18 was marked from 532.7–541 ft bgl (as used in information in Appendices C and F). The natural gamma log shows top of Culebra at 538 ft bgl (Fig. 2-2). The change in drilling rate indicates the base of Culebra at 557 ft, a thickness of 19 ft.

Holt and Powers (1988) found a range of 20–30 ft thickness in Culebra cores described from the WIPP Project, and a regional thickness exceeding 40 ft, based on geophysical log data. Significant core loss in the middle of the Culebra is common. The cored Culebra interval at SNL-18 was partly recovered, but coring was halted because of lack of circulation of drilling fluid.

Figure 2-2
Rustler Units at SNL-18




Formal and informal Rustler Formation units and depths at SNL-18 based on natural gamma log as well as drilling information.

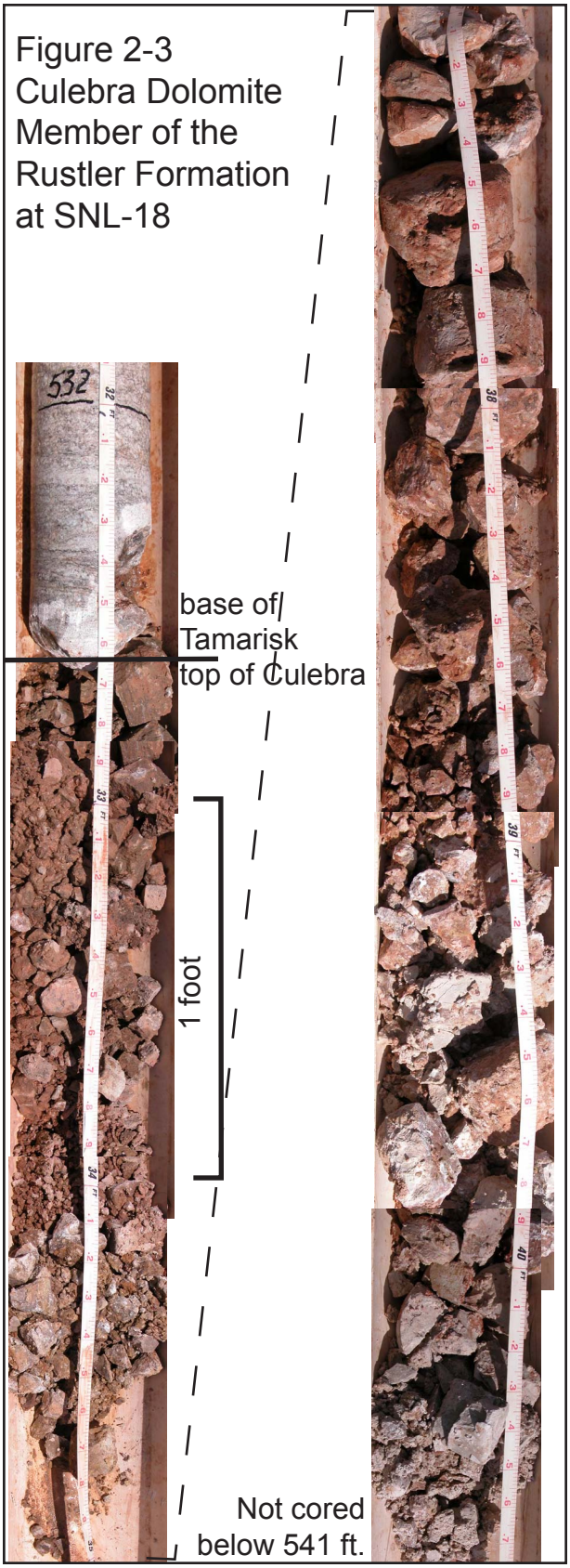



Figure 2-3
Culebra Dolomite
Member of the
Rustler Formation
at SNL-18

The recovered core (Fig. 2-3) is dark to light brown to light gray dolomite. There are some laminae and thin beds, and the uppermost laminae may be organic. The core is broken and fractured. Blocks with dimensions of 1-3 inches by 1 inch have been created by vertical fractures. Vuggy porosity is common, and there is possible calcite lining some pores. Some fractures and probable bedding planes exhibit darker staining.

The hydrostratigraphic units proposed for the Culebra by Holt (1997) are not generally assigned at SNL-18 because of the uncored section and poor preservation.

The geophysical logs (Figs. 2-1, 2-2) of the Culebra provide few additional details of the unit because they sampled only the uppermost part. The neutron log and density log values are relatively high compared to those of the overlying gypsum and mudstone, and these may reflect the cement pumped into this section to control lost circulation. Resistivity is low relative to the overlying sulfate of the lower Tamarisk. The natural gamma indicates a slight increase at the top associated with organic material. The log information is insufficient by itself through the Culebra to estimate relative transmissivity compared to the Culebra at WIPP.

### 2.2.1.3 Tamarisk Member

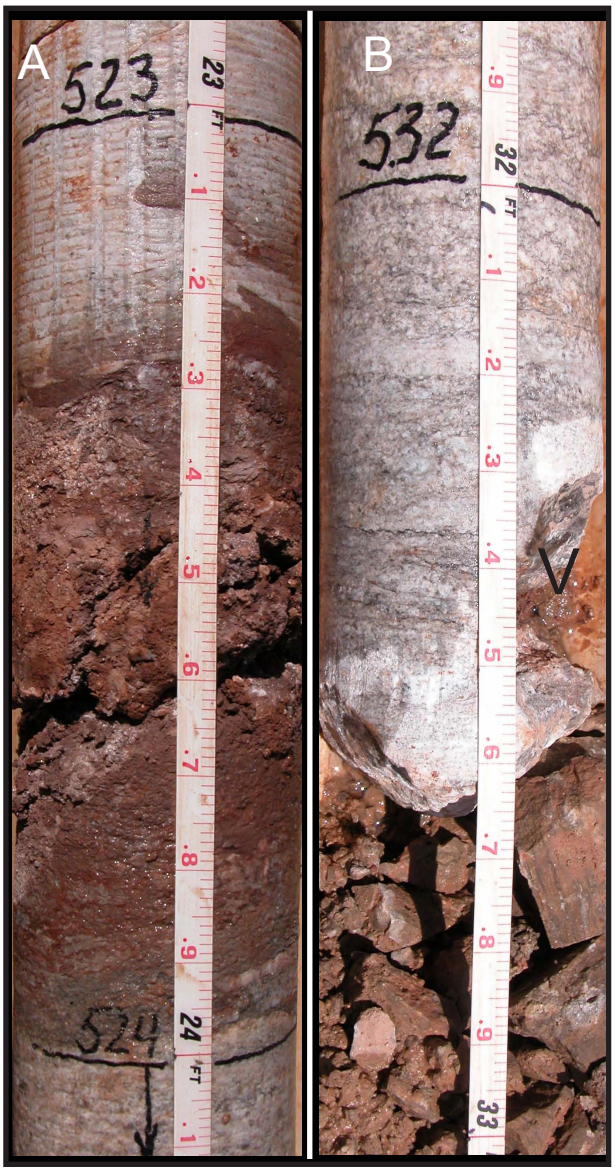
The natural gamma log of SNL-18 shows that the Tamarisk occurs from 538–500 ft bgl (core marked 532.7 ft at base). The Tamarisk comprises three basic subunits: a lower anhydrite, a middle halite and/or mudstone, and an upper anhydrite; all three are represented in geophysical logs. Cores are very limited. Powers and Holt (2000) labeled these A-2, M-3/H-3, and A-3, respectively, and showed that lateral gradation from mudstone M-3 to halite H-3 generally reflects lateral changes in deposition. SNL-18 is located in the M-3 facies (mudflats or saline mudflats), ~2-3 miles from the nearest H-3 margin (see Section 4.0). The lower part of M-3 and all of A-2 were cored; the

remainder of the unit is described on the basis of geophysical logs because cuttings are poor.

Informal Tamarisk unit *anhydrite 2* (A-2; Fig. 2-2) at SNL-18 is 15 ft thick, based on geophysical log data. Core markings are from 532.7–516.0 ft, indicating thickness of 16.7 ft.

A-2 is gray to brownish gray gypsum with some harder, possible anhydrite, zones, and it is subdivided by a siltstone from 523.3–524 ft (Fig. 2-4A). The upper 1.1 ft (517.1–516 ft) is light greenish gray, soft gypsum with fine laminae and thin beds, mainly horizontal near the base to some locally deformed beds dipping near-vertical in upper A-2 (above the siltstone). Gray to weak red gypsiferous siltstone occurs from 523.3–524 ft; reddish brown siltstone is marked 522.2–522.3 ft. The lower siltstone shows near-horizontal fine bedding at the base. The siltstone correlates with a zone found elsewhere ~10 ft above the base of A-2. An open vug, lined with calcite, was recovered at 532.5 ft (Fig. 2-4B).

Figure 2-4. Anhydrite 2 (A-2) at SNL-18.
A - Gypsiferous siltstone ~9 ft above base of A-2.
B - Calcite-lined vug (V) in lower recovered core from A-2.




Informal Tamarisk unit *mudstone 3* (M-3; Fig. 2-2) at SNL-18 is 18 ft thick (523–505 ft bgl), based on the natural gamma and caliper logs. The basal contact was marked 516 ft in core.

The cored interval of M-3 from 516–514.7 ft is dark reddish brown silty claystone and greenish gray claystone. There is some fine bedding as well as a sense of broader bedding, but most of the bedding appears smeared to discontinuous. Clasts near the base (Fig. 2-5A) are gypsum (angular to subround), and this interval includes clasts of medium brown argillaceous siltstone and greenish gray claystone. There are some small, clear gypsum crystals in this cored interval. The cored interval from 514.7–513.7 ft is dark reddish brown mudstone (Fig. 2-5B) and coarse crystalline gypsum. Bedding is near-horizontal. Some bladed gypsum crystals are preserved.

The geophysical log (Fig. 2-1) for M-3 shows somewhat lower natural gamma from 523–516 ft compared to the natural gamma above 516 ft. These differences may indicate stratigraphic units equivalent to subdivisions farther east, where the halite pan equivalents to M-3 show distinct lower and upper intervals.

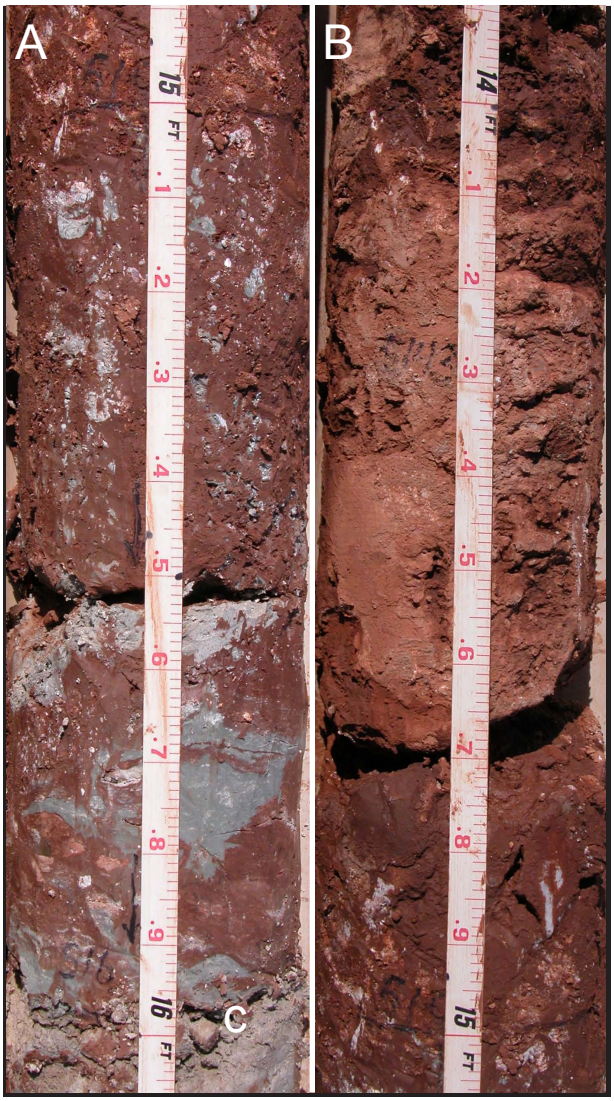
Informal Tamarisk unit *anhydrite 3* (A-3; Fig. 2-2) at SNL-18 is 5 ft thick (505–500 ft bgl) based on geophysical logs; no A-3 core was recovered.

The geophysical log data from A-3 indicate low natural gamma, increased resistivity near the

top, low neutron, and some increase in density compared to adjacent sections. A-3 is likely to be mainly gypsum, and the resistivity suggests a relatively nonporous segment in the upper part.

The thickness of A-3 is a small fraction of the thickness normally found for this unit in the WIPP site area. There is no facies change known of this magnitude for this unit, and it is interpreted as largely removed by dissolution after deposition of overlying beds (see next section).

Figure 2-5. Core from M-3 at SNL-18.
A - Gypsum clasts (c) at the base of M-3 at 516 ft below irregular clasts of siltstone.
B - Claystone-mudstone contact at 514.7 ft.




#### 2.2.1.4 Magenta Dolomite Member

Based on geophysical logs, the Magenta at SNL-18 is 36 ft thick (500–464 ft). This is considerably thicker than normal for the member. The core recovered from the Magenta is ~1.5 ft thick and steeply inclined (Fig. 2-6). The true thickness of the Magenta is thus undetermined.

The limited Magenta core recovered at SNL-18 is light gray (2.5Y7/2) sandy dolomite with thin beds to thin laminae and little gypsum. Ripple cross-laminae and erosional bases to features indicate upward direction (Fig. 2-6).

Geophysical log data from the Magenta show increased natural gamma compared to the underlying sulfate, but the magnitude of the natural gamma is reduced compared to most wells drilled near WIPP. Resistivity is low, but it is still higher than in overlying beds. Neutron increases slightly upward through most of the Magenta, with a lower neutron near the top. The density averages around 2.5 g/cc, with lower density intervals near the base, middle, and top of the Magenta.

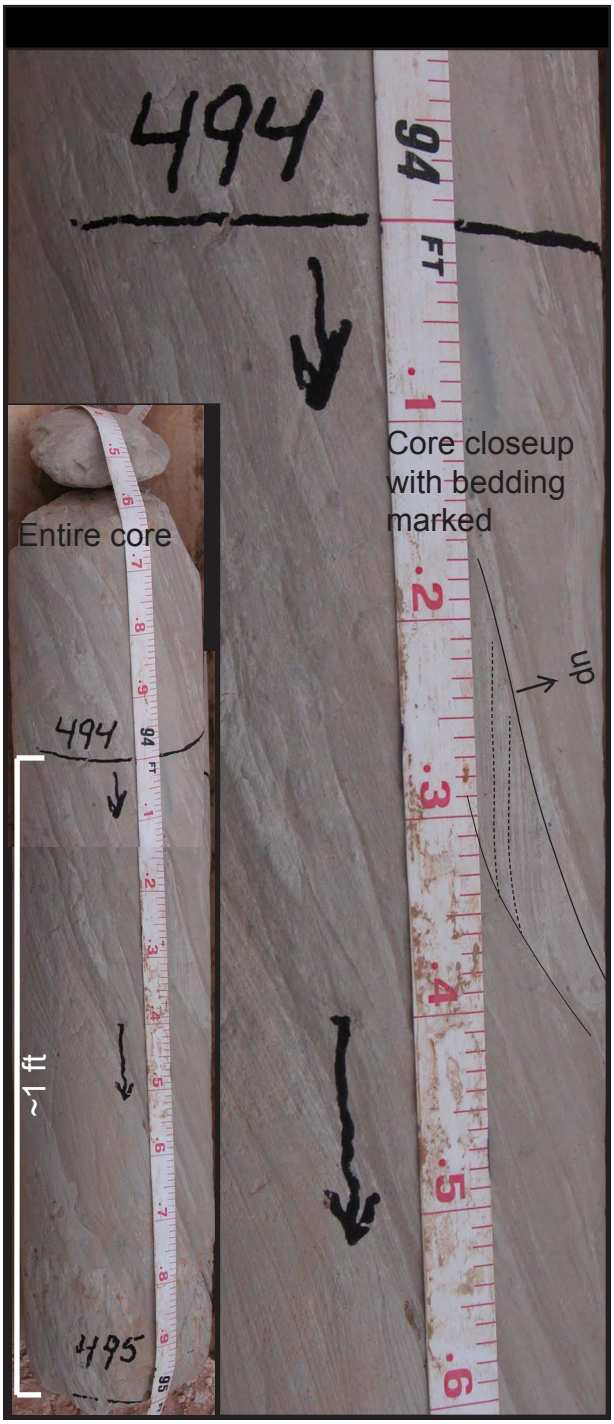
The steeply dipping bedding of the recovered Magenta, plus the greatly diminished thickness of underlying A-3, indicates collapse of this unit as the underlying unit was dissolved and removed.

#### 2.2.1.5 Forty-niner Member

Based on geophysical logs, the Forty-niner at SNL-18 is 6 ft thick (464–458 ft); no core was recovered from the Forty-niner and cuttings were limited or mixed. The Forty-niner is described on the basis of geophysical logs. Like the Tamarisk, intact Forty-niner consists of upper and lower anhydrites with a middle unit that is a mudstone or halitic unit. Powers and Holt (2000) informally designated these units as A-4, M-4/H-4, and A-5, from bottom to top. They attributed the lateral relationship between clastic beds (M-4) and halite (H-4) to depositional facies of mudflat–saline mudflat–saltpan environments.

The lower unit, *anhydrite 4* (A-4; Fig. 2-2), is 6 ft thick and is the only part of the Forty-niner

Figure 2-6 Magenta Dolomite Member of the Rustler Formation at SNL-18. Inset shows total recovered core (1.5 ft). Larger photograph displays closeup view of some of the dipping bedding with lines enhancing some structure.




apparently preserved at SNL-18; it is known from geophysical logs and minimal cuttings. The cuttings indicate gray sticky gypsite (possibly from grinding during drilling) and tan gypsum. A bit drop occurred from 458-459 ft. Natural gamma, density, and resistivity are slightly reduced compared to the Magenta; neutron is similar. These data are consistent with porous gypsum.

No other unit was assigned to the Forty-niner because cuttings were consistent with Dewey Lake to 456 ft. The caliper log is reduced through A-4 and indicates greatly enlarged diameter from ~452–390 ft. It is possible to interpret the natural gamma and caliper logs as indicating higher Forty-niner units between 456 ft and ~428 ft. An alternative interpretation is that Dewey Lake collapsed into, or filled, porosity in the Forty-niner as the sulfates were dissolved from the Forty-niner (and Tamarisk).

### 2.2.2 Permo-Triassic Dewey Lake Formation

The Dewey Lake Formation is 402 ft thick (458–56 ft) at SNL-18. It is known at SNL-18 from cuttings and geophysical logs.

It is red (2.5YR5/6-4/6) to dark red (2.5YR4/6-3/6) siltstone, very fine sandstone, and silty claystone with common small grayish green reduction spots. Zones along bedding can also be light gray (10YR7/1), similar to the reduction spots. A very fine to fine reddish brown (5YR5/4) sandstone with well-rounded quartz grains and ~1-2% opaque grains was encountered between ~130–120 ft. White sandstone was encountered from 75–78 ft. Some siltstone cuttings revealed fine laminae. Cuttings were calcareous down to ~190 ft, with carbonate absent or slight below ~190 ft. Small gypsum crystals were observed at 160 ft; gypsum was more apparent with depth, with gypsum-filled fractures at 350–360 ft. Gummy claystone cuttings were noted at 430 ft.

Geophysical logs from SNL-18 can be partially interpreted to indicate different basic

sedimentary regimes (e.g., Doveton, 1986). The following information follows the basic template developed for a study of the Dewey Lake hydrogeology (Powers, 2003b) and applied to other drillholes such as C-2737 (Powers, 2002b) and SNL-1 (Powers and Richardson, 2004).

The lowermost of three general depositional regimes, informally called the *basal bedded zone* (Powers, 2003b), for the Dewey Lake is not interpreted with confidence on natural gamma logs of SNL-18. The interval is normally ~100 ft thick in the WIPP site area. The natural gamma indicates a sandstone with a base at 346 ft that is similar to the expected top of the basal bedded zone, but the overall hole conditions are disrupted by increased diameter, rendering the log interpretation more difficult.

The interval from 346–56 ft bgl is marked by increasing natural gamma upward, consistent with the *fining-upward cycles* (Powers, 2003b).

The *coarsening upward sequence* found elsewhere at the top of the Dewey Lake was eroded prior to Gatuña deposition.

Cuttings were damp from 280 ft down, and drilling continued with soap and mist from 307 ft. The hole was apparently producing water beginning at ~340 ft. The caliper log shows enlargement at approximately this depth, and the density log decreases significantly from 344–336 ft.

### 2.2.3 Miocene-Pleistocene Gatuña Formation

The Gatuña is ~18 ft thick (56–38 ft) at SNL-18. The Gatuña is brown (5YR6/6-5/6), very fine to medium sandstone with laminar argillaceous siltstone and claystone. The Gatuña is very calcareous and moderately lithified, with some well-cemented fine sandstone.

Powers and Holt (1993) described Gatuña distribution, lithology, and depositional environments in the WIPP area.

### 2.2.4 Pleistocene Mescalero Caliche

The Mescalero is an informal soil stratigraphic unit defined by Bachman (1973). It is widespread in southeastern NM, and it is a continuous stratigraphic unit at the WIPP site. Uranium-disequilibrium ages indicate the Mescalero formed as a pedogenic unit between ~570,000 (±100,000) and ~420,000 (±60,000) years ago (Rosholt and McKinney, 1980). The age is further bounded by the Lava Creek B ash, which is ~600,000 years old and underlies the Mescalero along Livingston Ridge (Izett and Wilcox, 1982).

At SNL-18, the Mescalero is 5 ft thick (38–33 ft) based on cuttings. It is a white, sandy limestone to calcareous sandstone and is more sandy and reddish with depth. The upper part yielded cuttings showing some laminar fabric.

Bachman and Machette (1977) classified six useful stages of pedogenic calcrete development, ranging from I as the least developed to VI morphologies showing multiple generations of calcrete development. ("Pedogenic calcrete" is preferred by many geologists and pedologists over the term "caliche" because of the wide variation in use of the latter term.) The Mescalero is tentatively classified as Stage IV at SNL-18, based on the cuttings with laminar fabrics.

### 2.2.5 Surficial Deposits

Construction fill (2 ft) and sand up to 31 ft thick were encountered at the drillhole location.

Sand from 33–20 ft is light brown, very fine, and dry, and it contains ~1% opaque grains. The reddish brown sandstone equivalent to the Berino soil (Chugg and others, 1971) was not distinguished. From 20–12 ft, the sand is reddish brown, loose, and damp, and it forms clay balls while drilling. From 12–8 ft, the sand is calcareous, whiter than overlying sand, damp, and may include some gypsite. From 8–5 ft, the sand is reddish (2.5YR4/6), more argillaceous than overlying sand, and damp. From 5–2 ft, the sand is light brown (5YR5/6) and damp.

# 3.0 PRELIMINARY HYDROLOGICAL DATA FOR SNL-18

SNL-18 was drilled in part to test confinement of the Culebra along the margin of Nash Draw and monitor possible recharge in the area from a tailings pile. Water levels from the Culebra Dolomite Member of the Rustler Formation are being monitored.

## 3.1 Checks for Groundwater Above the Tamarisk

The hole was drilled with compressed air to 307 ft, which is in the Dewey Lake. Cuttings from 220 ft were damp, and drilling from 307 ft continued with soap and mist into the upper ~1 ft of Magenta Dolomite at 465 ft. The driller observed likely inflow to the drillhole at ~338 ft, within the Dewey Lake.

Water was blown from the hole from TD of 465 ft before a miniTroll was installed on June 20. A grab sample measured in the field had a specific gravity of 1.005. The depth to water at 07:20 on June 21, 2006, was 301.8 ft below casing connector. The estimated average flow rate over nearly 14 hours was 0.99 gpm. No data were recovered from the miniTroll.

SNL-18 was cored to 496 ft, in the lower Magenta, June 21, 2006. After the decision to change drilling techniques to use circulating mud, a miniTroll was installed at 350 ft on June 22, 2006; an obstruction at ~360 ft prevented a deeper installation. The miniTroll was removed June 23, 2006; no data were recovered.

## 3.2 Initial Results From the Culebra Dolomite

No miniTroll or Solinst (water level) data were acquired regarding the Culebra before completion. SNL-18 was completed with slotted FRP through the Culebra and a blank below the screen (Fig. 3-1).

A pumping test of SNL-18 was performed August 14-18, 2006 (U.S. DOE, 2007). WRES began monthly water-level monitoring of the Culebra on September 12, 2006; the initial depth to water was 300.44 ft below the top of casing (U.S. DOE, 2007).

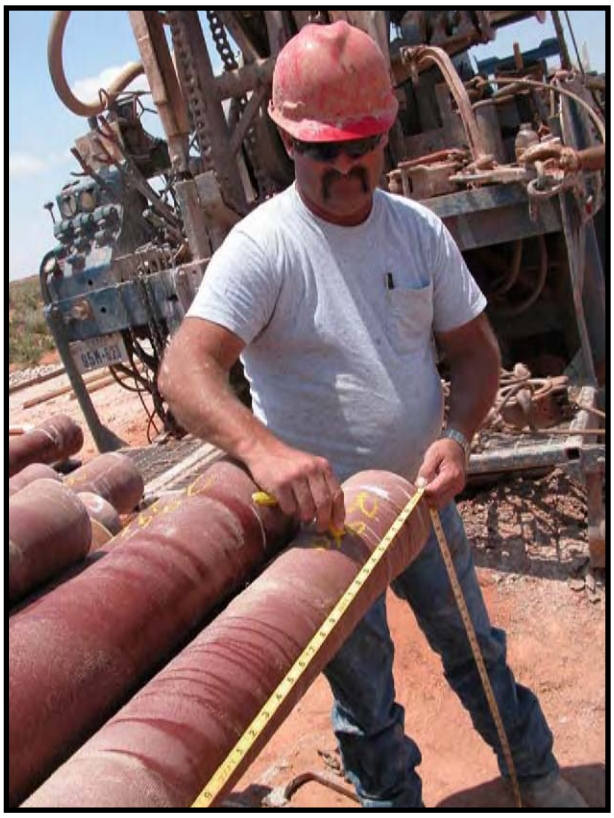
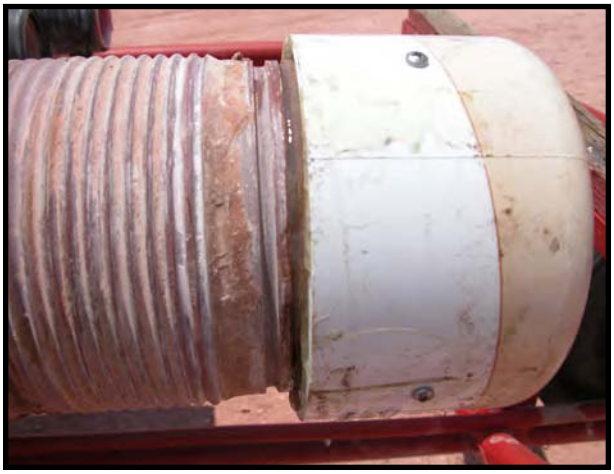


Figure 3-1 FRP used in completion of SNL-18.
Above: Ronny Keith (WTWWS) measuring and tallying FRP before installation.
Above right: Centralizer installed prior to running casing in hole.
Below right: Centron® label showing nominal 5½ inch outside diameter and wall thickness.
Below left: End cap to bottom of casing shown epoxied and screwed into blank.



## 4.0 SIGNIFICANCE/DISCUSSION

The materials used in completing SNL-18 are expected to be stable over a lengthy monitoring period, in contrast to steel casing in monitoring wells drilled before 1995. Newer monitoring wells provide construction experience for groundwater surveillance wells that may be drilled in the future.

SNL-18 penetrated only to the upper Los Medaños, and no cuttings were recovered from the Los Medaños due to lost circulation. No part of the Los Medaños was cored. Previous studies of thickness changes between the Culebra and Vaca Triste Sandstone Member of the Salado (Powers, 2002a, 2003a, 2007; Powers and others, 2003, 2006) indicated that SNL-18 is located west of the upper Salado halite dissolution margin (Fig. 4-1), and it is in the area where upper Salado halite has been dissolved. No halite was found in Rustler rocks, which is consistent with halite margins east of the SNL-18 location (Fig. 4-2).

Coring of the upper Culebra was limited to ~8 ft. The fractured nature of the recovered core suggests high transmissivity.

A-2 is the only unit well represented in core from SNL-18. It is within a normal range of thickness for the unit, shows evidence of horizontal bedding in much of the unit, and preserves a gray silty unit found elsewhere in similar stratigraphic position. The upper surface shows evidence of exposure and erosion (gypsum clasts) as the overlying mudstone was beginning to be deposited.

The lower part of M-3 was cored, revealing gypsum clasts and claystone intraclasts. Bedding is not well developed, and it shows signs of soft deformation. Some clear gypsum crystals were preserved. M-3 thickness is similar to elsewhere.

A-3 was not recovered in core or represented by cuttings. Geophysical logs indicate an interval of gypsum 5 ft thick. A-3 is 67 ft thick north of SNL-18 at SNL-1 (Fig. 1-1; Powers and Richardson, 2004). A-3 is interpreted to have been nearly dissolved at SNL-18, as the facies relationships for the Rustler do not indicate such changes are depositional. The degree of disturbance of the overlying Magenta is consistent with this interpretation.

The Magenta core recovery was limited to ~1.5 ft, attributed to the lower part of the member. Sedimentary structures preserved in this core are consistent with other Magenta cores. The core showed very steep dips, indicating deformation associated with dissolution of the underlying A-3. The true thickness of the Magenta is undetermined. If the log thickness (36 ft) is the full thickness of Magenta at 80º, the true thickness could be calculated to be slightly more than 6 ft. It is unknown whether the Magenta has been mostly dissolved or fractured so only a portion was encountered.

The Forty-niner is abnormally thin, and only the lower of three informal units was identified. A-4 is likely gypsum, based on log character. Cuttings were similar to Dewey Lake down to the encounter of A-4. The geophysical logs show some evidence of these two units (as discussed in the text), but borehole conditions limited effectiveness of the logs. As a consequence, the interpretation is that A-5 has been dissolved, and M-4 was not identified, possibly due to mixing with Dewey Lake sloughed from the borehole.

The Dewey Lake has been thinned by erosion at SNL-18, with the upper zone removed prior to Gatuña deposition. The lower zone is not clearly identifiable, partly because of hole conditions during logging. The middle *fining upward cycle* is indicated by natural gamma. Water was encountered in the Dewey Lake, and water levels measured during drilling were similar to those currently measured for the Culebra. Some gypsum remains in the Dewey Lake, but its effect on vertical movement of water is unknown. The borehole enlarged significantly during drilling through the lower Dewey Lake. The potash core hole on this location was abandoned due to lost circulation in the Dewey Lake.

## 4.0 SIGNIFICANCE/DISCUSSION

The materials used in completing SNL-18 are expected to be stable over a lengthy monitoring period, in contrast to steel casing in monitoring wells drilled before 1995. Newer monitoring wells provide construction experience for groundwater surveillance wells that may be drilled in the future.

SNL-18 penetrated only to the upper Los edaños, and no cuttings were recovered from the Los Medaños due to lost circulation. No part of the Los Medaños was cored. Previous studies of thickness changes between the Culebra and Vaca Triste Sandstone Member of the Salado (Powers, 2002a, 2003a, 2007; Powers and others, 2003, 2006) indicated that SNL-18 is located west of the upper Salado halite dissolution margin (Fig. 4-1), and it is in the area where upper Salado halite has been dissolved. No halite was found in Rustler rocks, which is consistent with halite margins east of the SNL-18 location (Fig. 4-2).

Coring of the upper Culebra was limited to ~8 ft. The fractured nature of the recovered core suggests high transmissivity.

A-2 is the only unit well represented in core from SNL-18. It is within a normal range of thickness for the unit, shows evidence of horizontal bedding in much of the unit, and preserves a gray silty unit found elsewhere in similar stratigraphic position. The upper surface shows evidence of exposure and erosion (gypsum clasts) as the overlying mudstone was beginning to be deposited.

The lower part of M-3 was cored, revealing gypsum clasts and claystone intraclasts. Bedding is not well developed, and it shows signs of soft deformation. Some clear gypsum crystals were preserved. M-3 thickness is similar to elsewhere.

A-3 was not recovered in core or represented by cuttings. Geophysical logs indicate an interval of gypsum 5 ft thick. A-3 is 67 ft thick north of SNL-18 at SNL-1 (Fig. 1-1; Powers and Richardson, 2004). A-3 is interpreted to have been nearly dissolved at SNL-18, as the facies relationships for the Rustler do not indicate such changes are depositional. The degree of disturbance of the overlying Magenta is consistent with this interpretation.

The Magenta core recovery was limited to ~1.5 ft, attributed to the lower part of the member. Sedimentary structures preserved in this core are consistent with other Magenta cores. The core showed very steep dips, indicating deformation associated with dissolution of the underlying A-3. The true thickness of the Magenta is undetermined. If the log thickness (36 ft) is the full thickness of Magenta at 80º, the true thickness could be calculated to be slightly more than 6 ft. It is unknown whether the Magenta has been mostly dissolved or fractured so only a portion was encountered.

The Forty-niner is abnormally thin, and only the lower of three informal units was identified. A-4 is likely gypsum, based on log character. Cuttings were similar to Dewey Lake down to the encounter of A-4. The geophysical logs show some evidence of these two units (as discussed in the text), but borehole conditions limited effectiveness of the logs. As a consequence, the interpretation is that A-5 has been dissolved, and M-4 was not identified, possibly due to mixing with Dewey Lake sloughed from the borehole.

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The Santa Rosa was completely removed by erosion at an undetermined time before Gatuña Formation deposition. The Gatuña showed some signs of interbedded sandstone, siltstone, and mudstone that are common to the formation.

The Mescalero caliche is moderately well preserved at SNL-18 and retains features of strong development tentatively assigned to Stage IV.

Sand above the Mescalero is thick in this location, and there are differences that indicate probable different stages of deposition.

Water level measurements taken during drilling when TD was in the upper Rustler do not differ greatly from measured water levels after the well had been completed in the Culebra.

Figure 4-1. Dissolution margin of upper Salado in the vicinity of SNL-18. From Powers (2005).

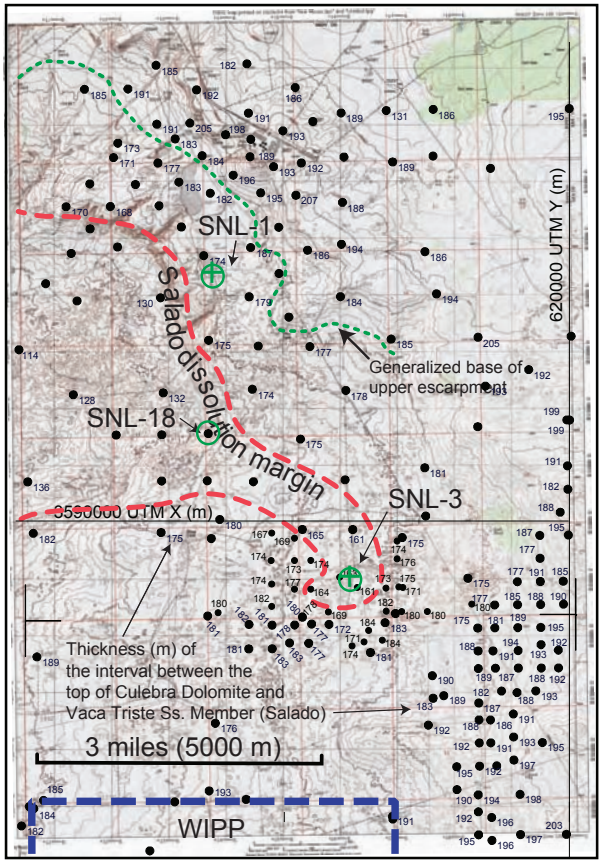
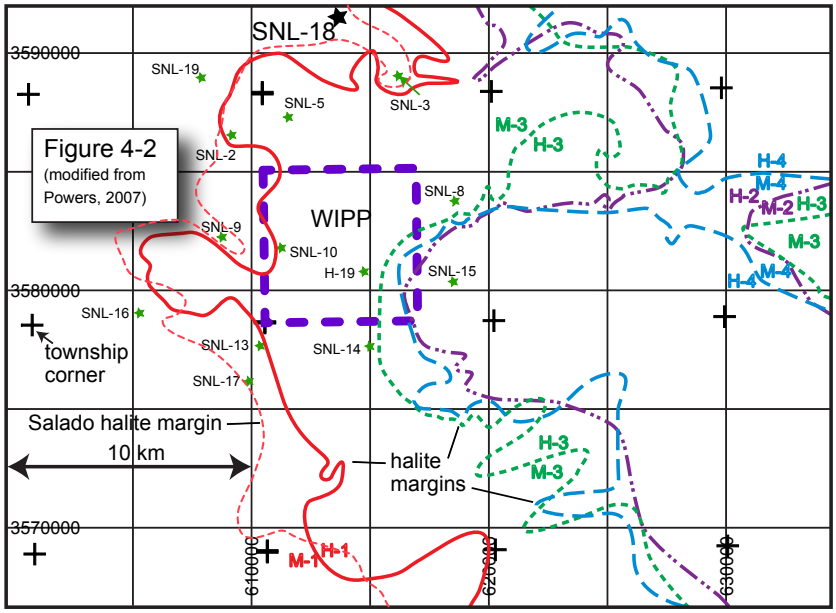



Figure 4-2. Halite margins in Rustler Formation relative to SNL-18. No halite was encountered in the Rustler at SNL-18, consistent with these margins.



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# Appendix A
## Drillhole Objectives

The basic document providing the basis for the drillhole and operations is the Program Plan WIPP Integrated Groundwater Hydrology Program, FY03-09 (Revision 0; Sandia National Laboratories, 2003). The main objectives are to resolve questions about water-level changes, provide data for modeling groundwater hydrology, and construct a network of wells to monitor groundwater through the WIPP operational period. Sections of this document relevant to this drillhole have been reproduced on the following pages, with the page number of the section preceding the extract and an ellipsis (…) following the end of the extracted section. A few figures have been included, but references and most figures are not included. The original document (Sandia National Laboratories, 2003) should be consulted for complete details and context for the program. Acronyms in the extracted text may not have a definition included.

SNL-18 was not designated as a location in the original groundwater hydrology program (Sandia National Laboratories, 2003). SNL-18 provides a location for testing for possible recharge of the Culebra from a potash tailings pile farther north and for testing Culebra hydraulic properties along the margin of Nash Draw.

The material selected here for SNL-18 has been excerpted from Sandia National Laboratories (2003) for general programmatic information and from Powers (2006) for specific objectives. Note that some pages reproduced here have been reduced in scale to fit the report page format.

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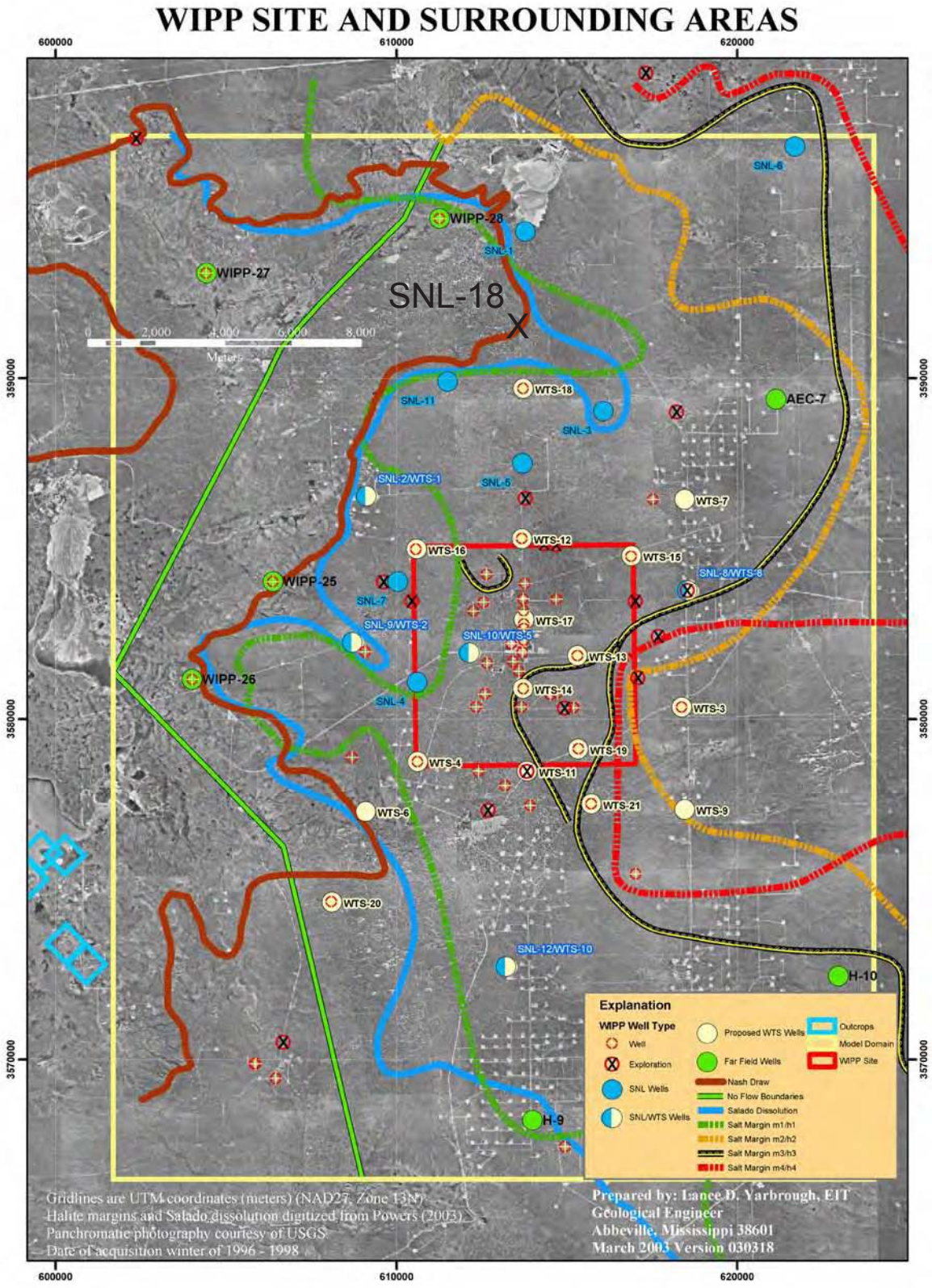
WIPP SITE AND SURROUNDING AREAS
600000
610000
620000
3590000
3580000
3570000
SNL-18
WIPP-28
WIPP-27
WIPP-25
WIPP-26
SNL-6
SNL-1
SNL-11
SNL-3
SNL-5
SNL-2/WTS-1
SNL-7
SNL-9/WTS-2
SNL-10/WTS-5
SNL-4
SNL-8/WTS-8
SNL-12/WTS-10
WTS-18
WTS-7
WTS-12
WTS-16
WTS-15
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WTS-13
WTS-14
WTS-3
WTS-19
WTS-4
WTS-11
WTS-21
WTS-9
WTS-6
WTS-20
AEC-7
H-10
H-9
0 2,000 4,000 6,000 8,000
Meters
Explanation
WIPP Well Type
Well
Exploration
SNL Wells
SNL/WTS Wells
Proposed WTS Wells
Far Field Wells
Nash Draw
No Flow Boundaries
Salado Dissolution
Salt Margin m1/h1
Salt Margin m2/h2
Salt Margin m3/h3
Salt Margin m4/h4
Outcrops
Model Domain
WIPP Site
Gridlines are UTM coordinates (meters) (NAD27, Zone 13N)
Halite margins and Salado dissolution digitized from Powers (2003)
Panchromatic photography courtesy of USGS
Date of acquisition winter of 1996 - 1998
Prepared by: Lance D. Yarbrough, EIT
Geological Engineer
Abbeville, Mississippi 38601
March 2003 Version 030318

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# 5. Description of Field Activities

A variety of field activities are planned to address the issues discussed in Section 3 and provide data needed for the modeling activities discussed in Section 4. To the extent possible, the activities represent an integrated approach to addressing all of the issues simultaneously, rather than a piecemeal approach that addresses each issue individually. The principal components of the field activities are drilling and logging of new and replacement wells, testing in individual wells, large-scale testing involving many wells, recompletion of existing wells, and plugging and abandonment of old wells. In addition, we anticipate that various ancillary activities will be necessary to collect information to support scenario evaluation and conceptual model development. The planned schedule for the field activities, as well as for the modeling activities, is described in Section 6. The activities described below represent our best current estimate of the work that will be needed. Clearly, the activities conducted in FY04 and later years are necessarily contingent on the results of previous years' field and modeling activities. As described in Section 11, a meeting of all parties involved in the hydrology program will be held annually to evaluate progress to date and develop final plans for the coming year.

## 5.1 New and Replacement Wells

Twelve locations have been identified where data from new wells are needed. These locations are designated with "SNL-#" labels in this document. Some of these wells are expected to provide information directly relevant to the scenarios under consideration, while others will provide information needed to support our conceptual and numerical models. In addition, a long-term Culebra monitoring network consisting of fiberglass-cased wells at potentially 21 locations has been designed to provide the data needed for compliance with the requirements of the WIPP HWFP. These wells will replace the existing network of steel-cased wells that are deteriorating and in need of plugging and abandonment. The 21 locations for the long-term monitoring network are designated with "WTS-#" labels. Well locations have been optimized so that five wells can serve as both SNL and WTS wells, reducing the total to 28 locations. Preliminary locations for the wells are shown in Figure 8. However, the final number and locations of the WTS wells will be optimized based on the modeling described in Section 4. Seven other existing well locations outside the extent of the HWFP network have been identified that will likely require replacement wells in the future to continue to provide data needed for Culebra modeling. New Magenta wells will be installed at six of the SNL- and WTS-designated locations to provide data needed for scenario evaluation and modeling. Five Dewey Lake wells are planned for locations north of the WIPP site where Dewey Lake water is encountered while drilling the Culebra wells. The justifications for the 12 SNL locations are given below, followed by the justifications for the WTS locations and the "far-field" replacement locations. Table 1 shows the roles to be played by each of the wells. The sequencing of drilling and testing in the new wells is described and explained in Section 6.

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*Consulting Geologist*

September 16, 2005

Ron Richardson
Field Lead
*WRES*

Rick Beauheim
Hydrology Lead
*Sandia National Laboratories*

**Initial Locations for Two Additional New Drillholes for FY2006**

Five drillholes are expected to be drilled during FY2006 to develop information in support of studies of the hydrogeology of the Waste Isolation Pilot Plant (WIPP). These studies provide information for modeling the hydrologic regime near WIPP and understanding processes behind continuing rises in hydraulic head for the Culebra around WIPP. Summary information and results are provided to EPA as part of periodic mandated recertification of WIPP by EPA (Sandia National Laboratories, 2003).

Here I summarize background information and justification for two additional drillhole locations so permitting and supporting activities can proceed. Although these wells have been located following three others in an earlier recommendation for drillholes for FY2006 (Powers, 2005), that does not imply that the locations will be drilled in numerical order.

## SNL-18

No well number has been assigned by the Office of the State Engineer (New Mexico) for this well because there has not been a previous permit application.

*Location*

SNL-18 is to be located on the drillpad of NMP-164 [no known OSE designation], used by New Mexico Potash for potash exploration in 1994. The stated location is near the southwest corner of section 21, T21S, R31E (Figure 1). Field UTM coordinates (NAD27, Zone 13) for this location were obtained 7/7/05: 613610 m Easting, 3591543 m Northing. These coordinates appear to plot in the extreme southeast corner of section 20 (Figure 1), and a field survey will be necessary to establish the legal description for a permit. Alternative locations are practical at drillpads for NMP-165 and NMP-166 or along the connecting road. These alternatives are located within the apparent extent of Nash Draw instead of on the margin. Ownership maps indicate the Bureau of Land Management is responsible for either of these sections.

No drillhole designated SNL-18 was included in the hydrological program plan (Sandia National Laboratories, 2003). Other drillholes in the general area were proposed for various purposes: a) replacing the plugged and abandoned WIPP-28 [C-2636], b) SNL-11 along Livingston Ridge (then moved further south after further modeling), c) WIPP-30 [C-2727] replacement well, and d) WTS-18 as a monitoring well approximately midway between SNL-1 [C-2953] and the middle of the WIPP site. The location of SNL-18 serves some of the functions of these wells, but it is located in a hydrogeologic setting that differs from these other wells proposed in the original hydrologic plan. For this reason, it has been given a different designation.

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Additional Drillhole Location for FY2006
September 16, 2005

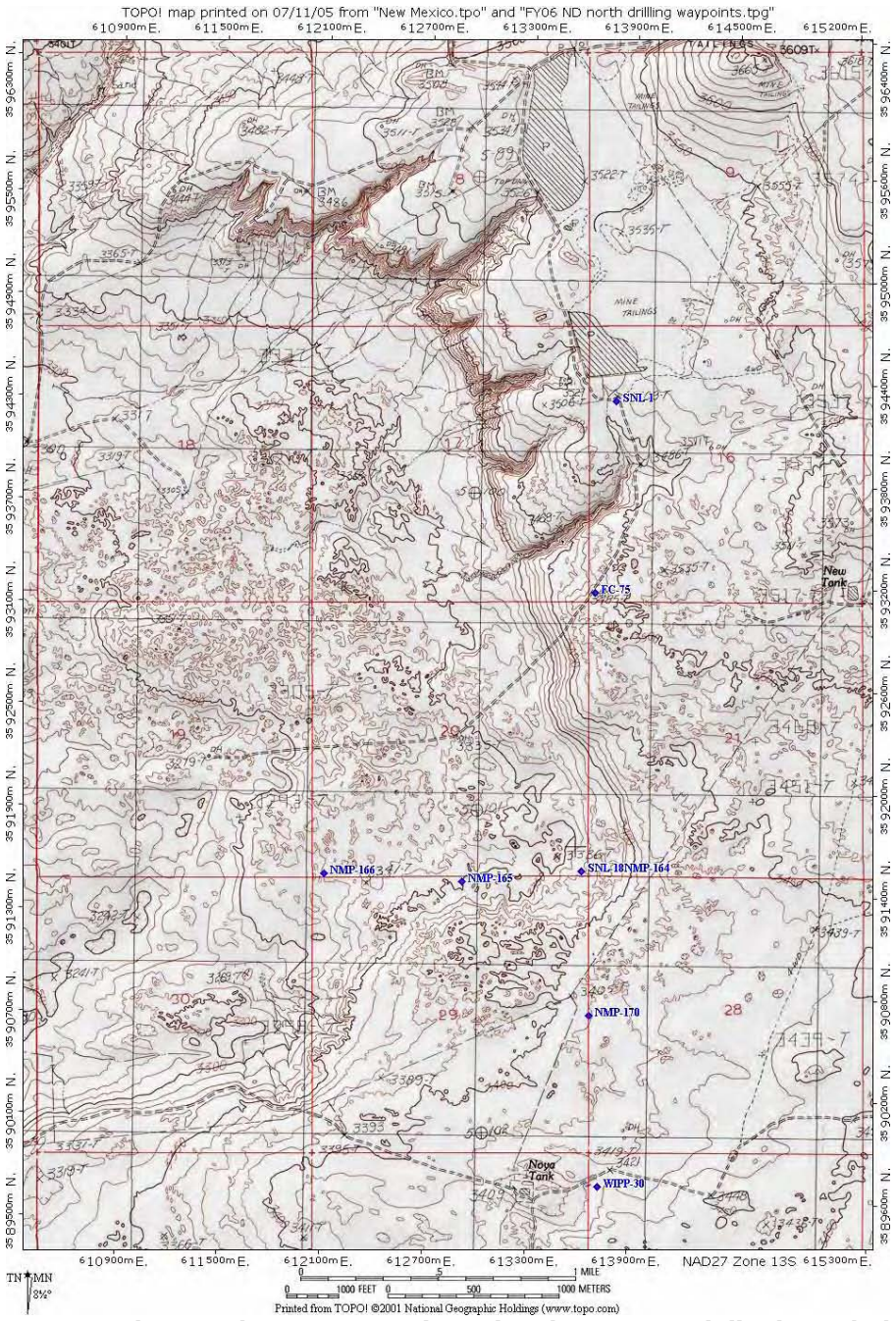


Figure 1. Topographic map showing SNL-18 located on the NMP-164 drillpad near the base of the escarpment marking the northeastern boundary of Nash Draw and between WIPP 30 and SNL-1. Alternative locations are at NMP-165 or NMP-166, west of NMP-164.

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Additional Drillhole Location for FY2006
September 16, 2005

*Background for SNL-18*

The principal objective of SNL-18 is to test further the potential for recharge of the Culebra by infiltrating potash mine tailings brines, creating the conditions leading to rising Culebra water levels (see Sandia National Laboratories, 2003, for further background). Well SNL-1 was an initial test of this hypothesis.

Well SNL-1 was located immediately south of the Intrepid East tailings pile to test the proposition that tailings water might be infiltrating, possibly through potash exploration drillholes, to recharge the Culebra and cause Culebra water levels to rise across the WIPP site (Sandia National Laboratories, 2003; Powers and Richardson, 2004). Sodium chloride brine was encountered in SNL-1 at a depth of about 30 ft, and this brine is consistent with a potash tailings source in its general chemistry (Powers and Richardson, 2004). The Culebra Dolomite, however, does not have a hydraulic head similar to this brine, does not have high solute content, and does not appear to be connected to a shallow source like the brine. In addition, the fresh-water-equivalent (FWE) head for the Culebra at SNL-1 is relatively high compared to the main site area, but it is lower than the FWE found at WIPP 27 [C-2722] in the northwest arm of Nash Draw and at WIPP 30 to the south.

Shallow brine at SNL-1 is derived from the tailings pile effluent, but the areal distribution and history of the brine movement are undetermined. My examination of the escarpment along the west side of the tailings pile revealed no lateral seepage at the surface consistent with the shallow brine at SNL-1. A shallow borrow pit adjacent to the SNL-1 drillpad was observed to have brine and halite deposits prior to construction of the SNL-1 drillpad and prior to any drilling. These are likely a relict of past overflows and surface seepage from the tailings pile. Since SNL-1 was drilled, some of the levees on the south side of the tailings pile failed and some brine flowed overland and along shallow arroyos to the south. There have been other significant breaks in the tailings pile levees in the past. Some alluvial surfaces in the drainage of Nash Draw 3–4 miles west-southwest of SNL-1 show slight efflorescent salt, presumably as a result of limited drainage noted around current levees and ponds. Overall, the surface evidence of brines seems to be related to recent failures of levees and some seepage or runoff from lower brine ponds. I have found no evidence of flow along the margin of Nash Draw indicating lateral movement of brine to the escarpment.

Three differing broad interpretations of the situation at SNL-1 are reasonable. One is that infiltration volume is much less than earlier estimates (Geohydrology Associates, Inc., 1978), causing little or no perturbation of the Culebra. Another is that vertical infiltration is simply slower than would be required to see the chemical effects at SNL-1. A third is that the pathway is more complex, and SNL-1 is not close enough to the path laterally or vertically to be affected chemically at this time. Only the third type of situation reasonably allows an association of Culebra water levels rises in the WIPP area with Intrepid East tailings pile infiltration. The other two situations require a different process to account for rising Culebra water levels. Nevertheless, additional testing is warranted to try to determine the role, if any, of the tailings pile brine in producing Culebra water level rises.

SNL-18 is located near the base of the (subdued) escarpment of Nash Draw south of well SNL-1. Previous wells such as SNL-1 and SNL-2 [C-2048] (Powers and Richardson, 2003) tested the

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*Consulting Geologist*



hydrogeologic parameters for the Culebra Dolomite at locations on the east side of the Nash Draw escarpment, east of the margin of upper Salado dissolution. Powers (2003a) and Powers and others (2003) found that the escarpment along Livingstone Ridge overlies closely the margin of upper Salado dissolution as demarcated by significant thinning of the Culebra to Vaca Triste interval. SNL-18 is located in a hydrogeological setting similar to the proposed well called SNL-17, located south of the WIPP (Powers, 2005).

SNL-18 is located in the area where Powers and others (2003) proposed that the upper Salado dissolution margin extends to the east-southeast from the edge of Nash Draw in an embayment (Figure 2). SNL-18 is not likely to improve knowledge of the embayment because it is located west of where the upper Salado dissolution margin already marks the edge of the draw. Possible structural lowering of the Culebra will be tested more directly by this location.

Aerial photographs of the margin along Nash Draw reveal fractures parallel to the margin in response to bending after dissolution of upper Salado halite. At the SNL-18 location, the margin of the draw is subdued in relief, more covered by sand, and does not obviously express these fractures as do other parts of the margin. The drilling report for NMP-164 indicates that it was abandoned at a depth of 240 ft because of lost circulation of drilling fluids in the "redbeds." The "redbeds" are expected to be the Dewey Lake Formation at this location, which do not commonly show such a degree of lost circulation, although lost circulation and local saturated zones in the Dewey Lake may be related to cement changes in the formation (Powers, 2003b). I infer that fracturing along the margin is a likely cause of the problem while drilling NMP-164. SNL-2 also showed fracturing in the Dewey Lake likely associated with the margin of Nash Draw and dissolution of upper Salado halite (Powers and Richardson, 2003). Such fracturing at SNL-18 is a part of the reason for drilling at the location.

If the tailings pile water encountered at shallow depths is bypassing SNL-1 and entering the Culebra elsewhere, the most likely pathway appears to be through the fractures paralleling the escarpment at the edge of Nash Draw. For the Culebra to be recharged along the margin, the Culebra would have to be effectively unconfined. SNL-18 will help determine how well confined the Culebra is near this margin.

*Justification for, and Scope of, SNL-18*

SNL-18 provides a location for

- testing confinement of the Culebra near the upper Salado dissolution margin,
- testing the potential for Culebra recharge through fractures paralleling the dissolution margin, and
- providing additional information on water level changes and flow directions in an area of uncertainty, given the higher fresh-water-equivalent heads at WIPP-27 and WIPP-30 compared to SNL-1.

Records from NMP-164 and surrounding drillholes yielded no information on Rustler geology and depths. From a slightly larger area, however, the data are reasonably firm, and the elevation of the top of Culebra at NMP-164 can be estimated at about 2820 ft amsl (Powers, 2003a). The surface elevation is 3385 ft amsl, and the depth to Culebra is estimated at about 565 ft. Based on unit thicknesses at SNL-1, the top of Rustler is estimated to be about 370 ft below ground level.

**Dennis W. Powers, Ph. D.**
*Consulting Geologist*

Additional Drillhole Location for FY2006
September 16, 2005

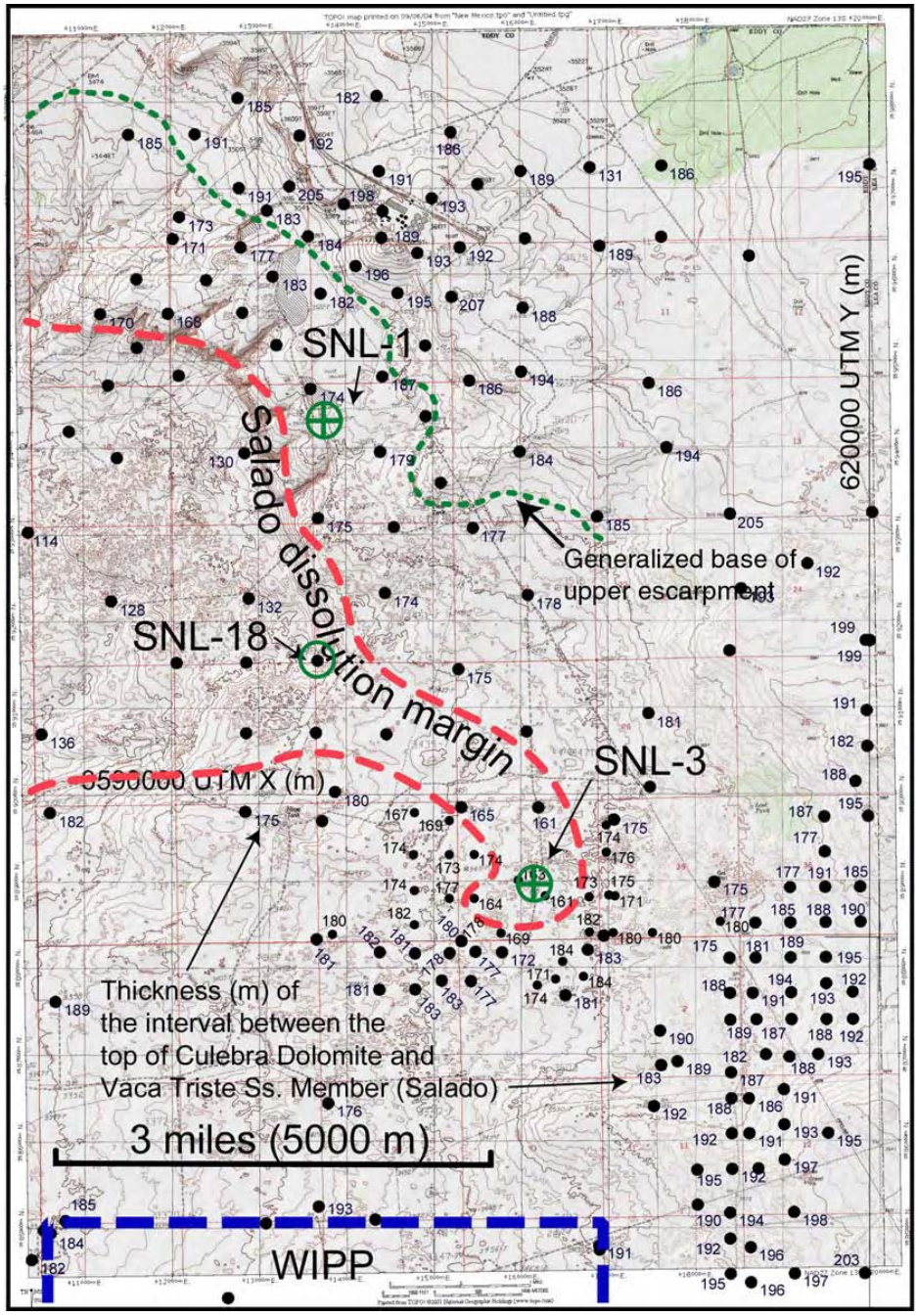



Figure 2. The proposed location of SNL-18 is on the subdued portion of Livingston Ridge south of SNL-1 and within a proposed embayment of the upper Salado dissolution margin (red line) along the ridge. Modified from Powers and Richardson (2004).

**Dennis W. Powers, Ph. D.**
*Consulting Geologist*

Additional Drillhole Location for FY2006
September 16, 2005

If the Culebra is 25 ft thick, the base of Culebra would be about 590 ft below ground level. Top of Salado should be about 700 ft.

Given the location and geohydrologic objectives, I recommend the following program of drilling, coring, and observations. Coring should include the Forty-niner mudstone through Magenta (about 60 ft) to determine the integrity of these units at the escarpment. Coring should continue from the Tamarisk mudstone to the upper Salado halite (~180 ft total). The well will be cemented back to a depth a few feet below the Culebra before completing a single screened interval across the Culebra. Where practical the upper part of the well through the Dewey Lake should be examined with a downhole camera to check fracturing and potential for infiltration. As practical, water-bearing zones above the Culebra should be sampled and observed to try to determine the degree, if any, of interconnection with the Culebra. It is especially important to monitor and sample groundwater within the Magenta to establish whether it is connected with the Culebra or the Culebra is confined.

*Much of this memorandum is not included because it does not concern SNL-18.*

**Dennis W. Powers, Ph. D.**
*Consulting Geologist*

Additional Drillhole Location for FY2006
September 16, 2005

## Summary

SNL-18 has been proposed to be drilled on the subdued margin of Livingston Ridge between SNL-1 and WIPP-30 to provide control on water level rises in the Culebra north of WIPP, investigate alternate pathways for tailings pile recharge, and provide a long-term monitoring location. The degree of confinement of the Culebra will be important to determining the possibility of infiltration from tailings or other surface water in the short time period they have existed in this area.

SNL-19 has been proposed to be drilled near the long axis of Nash Draw northwest of WIPP, between SNL-2 and WIPP-27. SNL-19 is expected to provide control on the assumption of a no flow boundary along the axis for modeling purposes, an assessment of the degree to which low surface areas around Red Lake may be providing recharge to the Culebra, and information on the degree of confinement of the Culebra in an area (Nash Draw) rather broadly thought to be modified by evaporite karst. It should also provide a long-term monitoring location for water levels northwest of WIPP.

## Comments on Drillholes

These two locations for drillholes to be completed during FY06 are part of the overall program to address two of the principal components of the hydrology program (Sandia National Laboratories, 2003):

- Resolution of water-level changes
- Enhancement of groundwater models

The locations focus more heavily on possible effects on the hydraulic system of the Culebra north and northwest of the site, including part of Nash Draw. One factor that may still enter into final drilling locations is the possibility of obtaining access to TUT well for monitoring in north central Nash Draw. TUT well is east of WIPP-27 and might temporarily supplement information now being obtained from WIPP-27 and SNL-1. Surface hydrology and geohydrology factors from this area have been outlined in this memo, especially regarding SNL-19 and potential recharge areas in the Red Lake area, that will likely be further investigated in the field in the near future. If those results are available in time, and have some potential to refine the locations of either well, they might be modified. This seems unlikely now, and the information now available has been used to make these location choices.

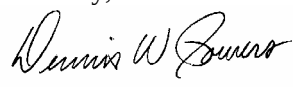
The coring and drilling projections for these drillholes have fewer local controls than for some wells. They are not, however, expected to differ grossly from projections. Coring is consistent with our recent practice.

As a last point, the five anticipated drillholes for FY2006 may be drilled in an order that differs from the order of proposing them or the numerical order because of the priority assigned to the information.

**Dennis W. Powers, Ph. D.**
*Consulting Geologist*

Additional Drillhole Location for FY2006
September 16, 2005

Sincerely,



Dennis W. Powers

References cited:

Bachman, G.O., 1981, Geology of Nash Draw, Eddy County, New Mexico: Open-File Report 81-31, US Geological Survey, Denver, CO.

Geohydrology Associates, Inc., 1978, Ground-water Study Related to Proposed Expansion of Potash Mining near Carlsbad, New Mexico: contractor report to Bureau of Land Management, Denver, CO, Contract No. YA-512-CT7-217.

Powers, D.W., 2003a, Addendum 2 to Analysis report Task 1 of AP-088, Construction of geologic contour maps: report to Sandia National Laboratories, January 13, 2003 (ERMS # 522085).

Powers, D.W., 2003b, TEST PLAN, TP 02-05 Geohydrological Conceptual Model for the Dewey Lake Formation in the Vicinity of the Waste Isolation Pilot Plant (WIPP): Sandia National Laboratories.

Powers, D.W., 2005, memorandum, subject: Initial Locations of Three New Drillholes for FY2006, to R.G. Richardson and R.L. Beauheim, dated July 7, 2005.

Powers, D.W., and Richardson, R.G., 2003, Basic data report for drillhole SNL-2 (C-2948) (Waste Isolation Pilot Plant): DOE/WIPP 03-3290, US Department of Energy, Carlsbad, NM.

Powers, D.W., and Richardson, R.G., 2004, Basic data report for drillhole SNL-1 (C-2953) (Waste Isolation Pilot Plant): DOE/WIPP 04-3301, US Department of Energy, Carlsbad, NM.

Powers, D.W., Holt, R.M., Beauheim, R.L., and McKenna, S.A., 2003, Geological factors related to the transmissivity of the Culebra Dolomite Member, Permian Rustler Formation, Delaware Basin, Southeastern New Mexico, *in* Johnson, K.S., and Neal, J.T., eds., Evaporite karst and engineering/environmental problems in the United States: Oklahoma Geological Survey Circular 109, p. 211-218.

Sandia National Laboratories, 2003, Program Plan WIPP Integrated Groundwater Hydrology Program, FY03-09, Revision 0: Sandia National Laboratories, March 14, 2003.

Ronnie Keith (WTWWS) measuring and marking each fiberglass-reinforced plastic casing for SNL-18 prior to installing at SNL-18 on June 29, 2006. Photo by Dennis W. Powers.

# Appendix B
## Abridged Borehole History

The abridged borehole history has been prepared by compiling information from driller's reports by West Texas Water Well Service (WTWWS) personnel, on-site reporting by Washington Regulatory and Environmental Services (WRES) personnel, and geologic logs by Dennis W. Powers. The main information is from WTWWS reports, which are reported as Central Daylight Time. For consistency, all information in the abridged borehole history has been converted to Central Daylight Time, regardless of source. Original files are maintained by WRES in the Environmental Monitoring and Hydrology Section.

**Note:** The abridged drillhole history provided here has been compiled mainly from the daily records produced by personnel of West Texas Water Well Service (WTWWS) and provided to Ron Richardson (Washington Regulatory and Environmental Services). The information has been reformatted and has been modestly edited. *Additions to the record from notes by Dennis Powers or other personnel are in italics.* All times reported in the abridged drillhole history are in CDT (Central Daylight Time) as recorded by WTWWS because they operate from Odessa, TX. Any additional notes included here (*in italics*) with times recorded in MDT (Mountain Daylight Time) at the site have been converted to CDT. Geologic logs (main body of text) have times as MDT, and times in the geologic logs commonly vary slightly from driller's log after allowing for the hour time difference.

**6-16-06** WTWWS crew moved equipment from SNL-10 to SNL-18 site from 06:45 to 12:30. Departed for Odessa, TX.

**6-19-06** WTWWS crew arrived on SNL-18 site from Odessa, TX, at 09:00. Finished rigging up by 10:00. *Cut surface conductor casing to 35' length. Performed fire hazard surveillance.* Broke air hose; Larry Keith to Carlsbad for replacement. Replaced air hose from 11:50 to 12:30. Changed out bit to 17.5" bit for surface casing. Drilled to 36' from 14:15 to 15:45. Pulled bit from hole and ran 35' of 12.75" surface casing in hole by 16:40. Southeast Redi-Mix on site at 16:40. Cemented surface casing and pad around casing with 2 cubic yards of cement by 17:00. Lea Land arrived on site with roll off at 17:00. Offloaded bin #1 and departed at 17:10. Completed site work and departed at 17:15.

**6-20-06** WTWWS crew arrived on SNL-18 site at 07:00 and held safety meeting. Set up drillbit and diverter to start drilling 11" hole. Started drilling 11" hole with air from 35' at 10:05. Slightly damp cuttings from about 280' and changed to air with mist and soap at 307'. Hole began producing some additional water during drilling from 338'. Tool drop from 458' to 459'. Reached 465' at 18:35 and stopped drilling at coring point. Tripped drillpipe and bit out of the hole. *Installed mini-Troll at depth of 450' below the top of the connector on the surface conductor casing at about 19:30. Departed site at 19:50.*

**6-21-06** WTWWS crew arrived on site at 06:50; held safety meeting. Mike Hillesheim (SNL) arrived on site at 06:50 with downhole video camera and prepared to run video. *Retrieved mini-Troll from drillhole by 07:00.* Completed video camera run by 08:15. Ran Solinst in hole at 08:20 and recorded water level at 301.8' below the top of the connector on the surface conductor casing. Pumped water out of roll off and lined pit with plastic. John Wood (Diamond Oil Well Drilling Company) arrived on site at 09:25 with core barrel and equipment. Rigged up to core. Lea Land arrived on site at 11:30, dropped bin #17 clean, and removed bin #1. Started tripping in hole at 11:30. Started blowing water from hole at 13:40 with 360' of core barrel and drilling pipe in hole. Set on bottom at 14:00 and began coring from 465'. Cut 30' to 495' by 14:24. Tripped out of drillhole by 15:25 and laid down 1.5' of core. Tripped back into hole by 16:30 to try second core. About 10' of fill in hole. Drilled 1' to 496' to try to retrieve any core left in hole. Tripped out by 17:10 and found about 1' of fill material in core barrel. Pulled up core barrel and changed out bit. Departed site at 17:30.

**6-22-06** Arrived at 07:00, and held safety meeting. Ran into drillhole with core barrel and drilling pipe to bottom while blowing water. Found about 30' of fill. Blew more water and fill from hole. Found 15' of fill in hole. Decided that drilling would have to continue with circulating fluid for hole stability. Tripped drilling pipe and core barrel out of drillhole by 09:40. Released John Wood (DOWDCO) for the day until rig is configured for drilling with water. WTWWS crew departed site at 09:40 for planned underground tour of WIPP site. Crew returned to site at 13:00. Moved equipment for drilling with water and mud. Completed rig activities at 17:45. *Installed mini-Troll at 350' at 17:00. Cable tension decreased at about 360' indicating some obstruction. Departed site.*

**6-23-06** Arrived on site at 07:00; held safety meeting. TFH delivered load of water for mud. Continued to rig up for drilling with mud. *Pulled mini-Troll from drillhole at 08:15.* TFH delivered another load of water. John Wood (DOWDCO) arrives on site at 09:45. Began mixing mud at 10:15 and began tripping into hole at 10:45. Stopped at 300'; established circulation to surface after putting ~50 bbls of mud into hole. Continued tripping into hole while circulating mud. Started coring from 496' at 13:07. Lost circulation while coring from 508' down at 14:00; stopped to mix more mud. Continued coring to 526' at 14:45. Tripped out with core barrel by 15:15. Used 1 gallon E-ZMud® and 78 bags of Aquagel®. Ten loads (130 bbls each) of water delivered total. Retrieved 3' of core; rest jammed in barrel. Laid barrel on cat walk and attempted to push remaining core out without success. Wood to Odessa for connection to allow pumping core out with pressure. Crew departed site 16:45.

**6-24-06** Arrived on site at 06:45; held safety meeting. Assembled connection to pressure core from barrel. TFH delivered first load of water. Mike Hillesheim (SNL) arrived on site. Retrieved 12.3' of core from barrel by 08:30. Core barrel reassembled. Waiting on crew from Lovington bringing more mud. Began tripping into hole at 10:10 while mixing more mud. Encountered ~50' of fill in hole; continued to bottom while circulating. Mixed more mud. Started coring from 526' at 12:45. Stopped coring at 537' at 13:25. Tripped out and retrieved 8.5'. Reassembled barrel and tripped back into hole while mixing mud; encountered 15' of fill. Continued to bottom and began coring at 15:55; reached 541' at 16:10 where advance stopped. Tripped out and laid down 3.5' of core. Used 99 bags Aquagel®. Six loads of water delivered total. Decided to terminate coring and start drilling in morning with objective of reaching 600' before completing well. Laid core barrel down, loaded, and released DOWDCO from site. Rigged up for drilling 11" hole. Crew departed site at 17:20.

**6-25-06** Arrived at site at 06:45 and conducted safety meeting. Began mixing mud. Tripped into hole with 11" drill bit and began reaming from 465' at 09:00. Stopped reaming at 515' at 10:00 to mix more mud. Started drilling at 10:30 and stopped at 540' at 11:00 to mix more mud. Started back at 12:30; lost 40' of hole. Drilled back down by 13:15; mixed more mud. Drilled to 540' by 14:00 and stopped because mud ran out. Tripped out of hole. Sent hands to Lovington at 15:00 for more mud and E-ZMud®. Used 154 bags of Aquagel® and 4 buckets of E-ZMud®. TFH hauled six loads of water. Departed site 16:45.

**6-26-06** Arrived at site at 06:45 and conducted safety meeting. Tripped out collars and confirmed bit was in good shape. Tripped back in hole with bit, collars, and some drill pipe. Mixed 90 barrels of mud in portable pit using bentonite, *small amount of mason's lime (~25 pounds),* and fresh water hauled by TFH Trucking. Tripped into hole to fill, about 60' above bottom (544'). Circulated down until mud ran out. Mixed another 90 barrels of mud using bentonite, lime, and fresh water. Circulated 90 barrels of mud into hole, with mud rising to ~3' below top of surface conductor casing and bit at 495'. Followed mud with ~70 barrels of fresh water and achieved temporary circulation at surface before drillhole began to take drilling mud again. R.L. Beauheim (SNL) concurred with WTWWS proposal to pump ~ 3 cubic yards of cement into drillhole to try to control fill and lost circulation. Tripped back into drillhole with drillpipe to pump cement. Southeast Redi-Mix arrived at 13:45, and 3 cubic yards of cement were pumped with bottom of drillpipe ~470' below the top of the surface conductor casing. Tripped out with drillpipe and washed cement. Departed site at 16:45. Used 4000 pounds of bentonite, 50 pounds of mason's lime, and 250 barrels of fresh water during drilling for day.

**6-27-06** Arrived at site at 06:45 and conducted safety meeting. *Ran Solinst into hole; stopped at 275' with probe sticking to side wall and no indication of fluid level.* Began tripping into hole with 11" bit at 07:00 and mixed mud. Started drilling cement at 460' at 09:00 with returns. Lost circulation at 500' at 10:00 and continued to drill to 10:15. Tripped out of hole by 11:45 and removed bit. Crew went to Carlsbad for Type II cement. Started setting up cement pump. Tripped drillpipe into hole to 500'. Mixed cement in tub and began to pump down ~1.5 cubic yards. Finished pumping at 14:20 and started mixing second batch. Pumped additional ~1.5 cubic yards cement by 14:47. Tripped out of drillhole with drillpipe. Mixed 90 more bbls of mud in steel pit and tripped collars back into hole by 17:00. Used 85 bags of Aquagel®, 35 bags of Portland, and 2 bags of lime. Departed site.

**6-28-06** Arrived at site at 07:00 and conducted safety meeting. Started tripping into hole with 11" bit at 07:15. Tagged top of cement at 495' at 07:45 with no immediate returns to surface. Reached 544' at 08:12 with intermittent returns to surface. Stopped drilling at 558' at 09:13 and made 90 bbls of mud thickened with lime. Used 2600 pounds of Aquagel®. Culebra base at 557'. Started drilling from 558' at 10:00 with about 4' of fill. Reached 566' at 10:33; harder drilling probably indicates top of A-1. Circulated on bottom to 10:53. Tripped out of drillhole by 11:30. Mike Stapleton (New Mexico Office of State Engineer) briefly on site to make sure of site location. Logistics for completion set. Departed site 12:55.

**6-29-06** Arrived at site at 06:55 with Al Henderson (JetWest) for logging. Set up to log and ran in hole; found considerable fill. Consulted with Rick Beauheim (SNL) and decided to mix up additional mud to circulate out fill and clean out small bridge in hole. Well screen will not have sump below end of screen pipe. JetWest completed logging by 09:30 and rigged down. Rigged up to go into hole with 11" drill bit to circulate and try to drill additional depth. Circulated hole to bottom with some returns and tripped out. Started running tremmie pipe into hole at 12:30. Started running casing in hole at 13:45 with centralizer at top of screen pipe. Casing to bottom at 15:00. Pumped about 90 bbls of fresh water down tremmie pipe to clean screen area. Started pumping sand pack at 16:17. Pumped 1 super sack (3000 #) of 4/10 and poured 3 bags of

HolePlug®. Cement truck on site at 17:45 and pumped ~ 8 cubic yards. Second truck on site at 18:45 and pumped additional 8 cubic yards. *Incomplete daily record.*

**07-06-06** *Arrived at site at 07:00. Performed rig maintenance. Crew to SNL-10 to pull pump. Back on site at 10:50. Set up pipe trailer and water truck. Began pumping fresh water into portable mud pit at 11:15. Added 7 gallons of Aquaclear® to source water (WIPP water hauled with WTWWS truck). Pipe was measured and tallied. Started running jet tool and pipe at 13:20. Water in mud pit still somewhat dirty colored. Bottom of tool reached depth of 555'. Started jetting well at 14:50. Jetted up from bottom and back down. Ran 120 bbls total, with good returns of very muddy water. Stopped jetting at 15:35 after water ran out. Tripped out of hole and removed jet tool. Tripped back into hole to airlift well. Began airlifting well at 16:40, with dirty water returns. At bottom of well at 17:00. Airlifted well continuously, making ~20 gpm of very dirty water. Stopped airlifting at 17:40 and pulled pipe from well by 18:00. Departed site 18:05.*

**07-17-06** *Arrived on site at 09:15 and started installing pump to 552' below top of casing. Pump installed by 11:30. Started pump at 11:50 at 12 gpm. Starting water level 301.4' below top of casing. Water was very muddy; stopped up pump and lines . Flow rated adjusted to 29 gpm at 12:15. Removed flow meter at 13:15 because it kept stopping up. Pumped wide open into mud pit. Flowed greater than 30 gpm and very muddy. Flow rate was steady at 14:00 at 30 gpm. Meter was reinstalled with discharge back into frac tank. Water was still muddy but getting cleaner. Flow rate at 15:00 was ~30 gpm; water was muddy. Could not measure water level because probe stuck. Flow rate steady at 15:30; water muddy. Flow rate 29.3 gpm at 15:40; water was muddy. Shut pump off at 17:00; total of 6,766 gallons pumped through meter. Departed site.*

**07-18-06** *Arrived on site at 09:00. Started pump at 09:09 with flow meter reading 188,386 gallons. Instant flow at 10:15 is 24 gpm; turbidity was improved but water was still cloudy. Instant flow was 27 gpm at 10:45; water cloudy. Flow meter cumulative reading 191,350 gallons at 11:09; average rate 24.7 gpm. Water was turbid. Instant flow at 11:45 was 26 gpm; water turbid. Instant flow at 12:45 was 26 gpm; water turbid. Cumulative reading at 13:09 was 194,467 gallons; average flow for two hours was 26 gpm. Water was still turbid but slightly clearer. Instant flow at 13:45 was 26 gpm; water as before. Instant flow at 14:45 was 26 gpm; water slightly cloudy. Specific gravity 1.008. Flow at 15:45 was 26 gpm; was as before with specific gravity of 1.009. Pump turned off at 16:30. Water was very cloudy during last 30 minutes. Cumulative flow meter reading is 199,667 gallons. Average daily pumping rate was 25.6 gpm. Departed site at 16:45.*

**07-19-06** *Arrived on site at 09:00. Started pump at 09:19 with flow meter reading 199,667 gallons. Initial pumping rate was 28.6 gpm; water very dirty after a few minutes of pumping. Flow rate at 10:05 was 28.6 gpm; water very cloudy. Pump off at 10:09 to allow WTC to take mudpit off site. Cumulative reading 201,073 gallons. Resumed pumping at 11:06 at 28.6 gpm; water muddy after minute of pumping. Pumping rate 28.6 gpm at 12:06; water cloudy, temperature 25.0°, and specific gravity 1.009. Pumping rate 28.6 gpm at 13:06; water cloudy,*

*temperature and specific gravity unchanged. Pumping rate 28.6 gpm at 14:06; water unchanged. Pumping rate at 15:06 and water unchanged. Pumping rate and water unchanged at 16:06. Pumping rate 28.6 gpm at 17:06; water slightly cloudy, temperature 25°C, specific gravity 1.010. Pump turned off at 17:07. Final cumulative flowmeter reading 210,988 gallons; 11,321 gallons pumped this day. Total pumped during development 29,368 gallons. Departed site at 17:15.*

**07-20-06** *Arrived on site at 08:45. WBS pump truck arrived on site. Started tripping out drop pipe from well at 19:30. Recovered water level probe. Pump removed from well at 11:10. Left site at 11:45.*

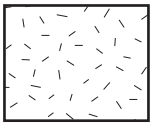
# Appendix C
## Geologic Logs

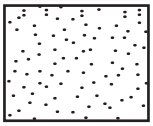
Note: The original field descriptions and graphic logs were prepared at differing scales, and the graphic logs for publication were generally produced at 10 or 20 vertical ft per inch, as indicated in the header for the log.

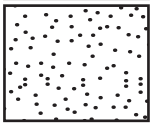
The field descriptions were related to depth based on drilling information and core recovery as best determined in the field. Core and sample footages are marked accordingly and can vary somewhat from depths determined for stratigraphic units based on geophysical logs (see Table 2-1 of text). Core depth markings have not been revised to reflect later geophysical log data. Depths used for completing the well are based on geophysical logs.

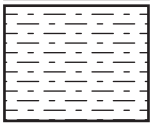
# *Explanation of Symbols Used in Lithologic Logs (Appendix C)*

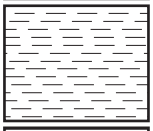
## Lithology

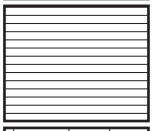

Construction fill

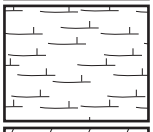

Fine sand or sandstone

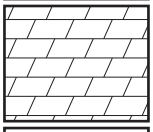

Medium or coarse sand or sandstone

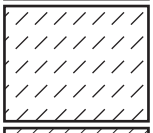

Siltstone

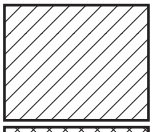

Claystone

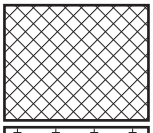

Organic-rich, claystone

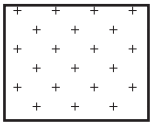

Carbonate (pedogenic calcrete)


Dolomite


Gypsum


Anhydrite


Polyhalite


Halite

## Features


Cross-cutting strata


Ripples


Bioturbation


Stylolite


Wavy bedding


Stromatolites, algal bedding


Vertical gypsum crystals


Gypsum nodules


Clasts, may show lithology as fill pattern


Brecciated, fractures

Fractures, filled or unfilled


Erosional boundary


Sharp lithologic contact


Gradational lithologic contacts

sl Slickensides

ns No cuttings sample

Symbols may be combined; not all symbols may be used

CORE LOG Sheet 1 of 8

Hole ID: SNL-18

Location: SE 1/4 SE 1/4, section 20, T21S, R31E, Eddy Co, NM

Drill Date: 6/19/2006

Drill Crew: West Texas Water Well

Drill Method: Rotary with air

Hole Diameter: initial 11 inches

Hole Depth:

Hole Orient: vertical downward

Drill Make/Model: Gardner-Denver 1500

Barrel Specs: 6 in o.d., 4 in. core

Drill Fluid: air

Core Preserv: box as is

Logged by: Dennis W. Powers, Ph.D., consulting geologist

Date: 6/19/2006 - 6/20/06

Scale: variable

| UTM NAD 27 (field) | Northing | Easting | Elevation |
|---|---|---|---|
| Survey Coordinate: (m) | 3591529 | 613605 | |

Comments:

| Run Number | Depth ( ) | % Recovered | RQD | Profile (Rock Type) | Description | Remarks |
|---|---|---|---|---|---|---|
| | | | | | | drilling with air |
| N/A | 0 | N/A | N/A | | 2’ Construction fill<br>Sand, light brown, damp (5YR5/6) | |
| | | C-1 | | | 5’ Becomes more argillaceous, slightly redder (2.5YR4/6) | |
| | | | | | 8’ more calcareous, whiter, possible gypsite, too | |
| | 10 | C-2 | | | | |
| | | | | | 12’ sandy, loose, with small clay balls developing, reddish brown | |
| | | C-3 | | | | |
| | 20 | C-4 | | | ~20’ sand, very fine light brown, dry, with ~1% opaques | |
| | | C-5 | | | | |
| | 30 | C-6 | | | | |
| | | | | | 33’ slightly harder, whiter. Limestone, sandy, white, laminar, well indurated, increasing sand, decreasing carbonate to ~38’; Mescalero caliche | stopped at 36’ |
| | | | | | ~38’ top of Gatuña from ~38’; calcareous brown sandstone, argillaceous siltstone. 5YR6/6-5/6. Very calcareous; cuttings include laminated (fine-1/16”) siltstone/claystone as well as cemented fine sandstone. | Begin 0904 MDT at 36’ 6/20/06 |
| | 40 | C-7 | | | | |
| | | C-8 | | | | |
| | 50 | | | | | |

Hole ID: SNL-18 CORE LOG (cont. sheet) Sheet 2 of 8

Logged by: Dennis W. Powers, Ph.D. Date: 6/20/06

| Run Number | Depth (ft) | % Recovered | RQD | Profile (Rock Type) | Description | Remarks |
|---|---|---|---|---|---|---|
| | 50 | | | | | |
| | 60 | C-9 | | | 63' Base of Gatuña Formation<br>Top of Dewey Lake Formation<br>hz Interbedded siltstones, argillaceous siltstones, red (2.5YR5/6-4/6), calcareous; with light gray (10YR7/1) thin (<1/2") interbeds and very small reduction spots. Harder drilling zones (hz). | |
| | 70 | C-10 | | | hz<br>75-78' white sandstone | |
| | 80 | C-11 | | | hz back to red siltstone, sandstone | |
| | 90 | C-12 | | | as above | |
| | 100 | C-13 | | | hz as above | |
| | 110 | C-14 | | | as above | |
| | 120 | C-15 | | | 121-128' sandstone, very fine to fine, well-rounded; quartz, ~1-2% opaques. Reddish-brown (5YR5/4), calcareous; brown matrix around grains. | |
| | 130 | C-16 | | | | |

Hole ID: SNL-18 CORE LOG (cont. sheet) Sheet 3 of 8

Logged by: Dennis W. Powers, Ph.D. Date: 6/20/2006

| Run Number | Depth (ft) | % Recovered | RQD | Profile (Rock Type) | Description | Remarks |
|---|---|---|---|---|---|---|
| | 130 | | | | Siltstone, argillaceous; red to dark red (2.5YR4/6-3/6); with interbedded sandy siltstone, and silty claystone; finely laminated; very tiny gray reduction spots (generally 1/16"); calcareous | |
| | 140 | C-17 | | | as above | |
| | 150 | C-18 | | | as above, more fine sandstone | |
| | 160 | C-19 | | | as above, few very tiny gypsum crystals, less sandstone | |
| | 170 | C-20 | | | similar to 150', more gypsum | |
| | 180 | C-21 | | | as above<br>drilling harder at 182-183' | |
| | 190 | C-22 | | | as above, less calcareous | |
| | 200 | C-23 | | | as above, gypsum increasing, slightly larger crystal size | |
| | 210 | C-24 | | | as above | |

Hole ID: SNL-18 CORE LOG (cont. sheet) Sheet 4 of 8

Logged by: Dennis W. Powers, Ph.D. Date: 6/20/2006

| Run Number | Depth (ft) | % Recovered | RQD | Profile (Rock Type) | Description | Remarks |
|---|---|---|---|---|---|---|
| | 210 | | | | | |
| | 220 | C-25 | | | as above<br>reduction in dust, cuttings feel slightly damp | |
| | 230 | C-26 | | | as above, noncalcareous?, cuttings less damp | |
| | 240 | C-27 | | | as above, slightly calcareous | |
| | 250 | C-28 | | | as above | |
| | 260 | C-29 | | | as above | |
| | 270 | C-30 | | | as above | |
| | 280 | C-31 | | | as above, more very fine sandstone | Sticking at 275';<br>moist cuttings from 280' |
| | 290 | C-32 | | | as above | |

Hole ID: SNL-18 CORE LOG (cont. sheet) Sheet 5 of 8

Logged by: Dennis W. Powers, Ph.D. Date: 6/20/06

| Run Number | Depth (ft) | % Recovered | RQD | Profile (Rock Type) | Description | Remarks |
|---|---|---|---|---|---|---|
| | 290 | | | | | |
| | 300 | C-33 | | | as above, less fine sandstone | |
| | 310 | C-34 | | | as above | ~307' began drilling with soap and mist; sticking ~275' |
| | 320 | C-35 | | | as above | |
| | 330 | C-36 | | | as above | |
| | 340 | C-37 | | | as above | hole is producing water (~5-10 gallons per minute) |
| | 350 | C-38 | | | as above | |
| | | | | | gypsum on fractures between 350' and 360' | |
| | 360 | C-39 | | | as above | |
| | 370 | C-40 | | | as above | |

Hole ID: SNL-18 CORE LOG (cont. sheet) Sheet 6 of 8

Logged by: Dennis W. Powers, Ph.D. Date: 6/20/06

| Run Number | Depth (ft) | % Recovered | RQD | Profile (Rock Type) | Description | Remarks |
|---|---|---|---|---|---|---|
| | 370 | | | | | |
| | 380 | C-41 | | | as above | |
| | 390 | C-42 | | | as above | |
| | 400 | C-43 | | | as above, no gypsum | |
| | 410 | C-44 | | | increasing greenish-gray downward. | |
| | 420 | C-45 | | | as above | |
| | 430 | C-46 | | | gummy claystone | |
| | 440 | C-47 | | | | |
| | 450 | C-48 | | | | |

Hole ID: SNL-18 CORE LOG (cont. sheet) Sheet 7 of 9

Logged by: Dennis W. Powers, Ph.D. Date: 6/20/06 - 6/24/06

| Run Number | Depth (ft) | % Recovered | RQD | Profile (Rock Type) | Description | Remarks |
|---|---|---|---|---|---|---|
| | 450 | | | | | |
| | | | | | ~456' Base of Dewey Lake Formation<br>Top of Rustler Formation<br>gray sticky gypsite, tan gypsum | drill bit drop 458-459' specific gravity 1.005 from grab sample of water blown from hole<br><br>end drilling 6/20/06, prepared for coring |
| | 460 | C-49 | | | | |
| 1 | | | | | | miniTroll placed to 450' at ~1830 6/20/06, removed ~0600 6/21/06 water level 301.8' below top of casing connector at 0720 MDT 6/21/06. |
| | 470 | | | | | |
| | | cut 30.0', recovered 1.5' | 1.5' in segments >4"; RQD = 100 | lost core zone | | |
| | 480 | | | | | |
| | 490 | | | | | |
| | | 495' | | | Dolomite, brown (2.5Y7/2; light gray); thin bedded to thin laminae, erosional bases and ripple cross-laminae indicate upward direction; mostly sandy dolomite, little gypsum apparent<br>Recovered fill material from core run 2 | 1.5' assigned to base of core interval attempted 1' run to see if any core left in hole. Recovered ~1' of fill material |
| 2 | | | | | | |
| 3 | | 496' | | | | |
| | 500 | | | | | |
| | | | | lost core zone | | 504-506' - no drop, fast drilling; made mud 506.5'; no returns to surface from ~508' to end of core run. |
| | 510 | | | | 513.7-514.7' Dark reddish-brown sandstone and coarse crystalline gypsum. Some bladed gypsum; bedding ~ horizontal.<br>514.7-516.0' Dark reddish-brown silty claystone and greenish-gray claystone (bedded and clasts) with medium brown argillaceous siltstone and gypsum clasts (angular to subround) near base. Broad and fine bedding, discontinuous to smeared. Small clear gypsum crystals are disseminated 516.0-517.1'. Fine gypsum, light greenish-gray, soft (gypsite); laminar bedding<br>517.1-533.0' Gray to brownish-gray gypsum (and anhydrite?) some bedding, locally deformed and dipping to ~90 degrees.<br>Reddish-brown soft siltstone at 522.2-522.3'; weak red gypsiferous siltstone 523.3-524.0', subhorizontal bedding; laminae near-horizontal 526.0-528.0', inclined 528.0-530.0', ~horizontal to 532.7'. Open vug with calcite 532.5'. | |
| | | cut 30', recovered 12.3' | 10.3' in segments >4"; RQD = 83.7 | | | Assigned core recovery to lower part of core run. |
| | 520 | | | | | |
| | 530 | | | | | |

Hole ID: SNL-18 CORE LOG (cont. sheet) Sheet 8 of 8

Logged by: Dennis W. Powers, Ph.D. Date: 6/24/06 - 6/25/06

| Run Number | Depth (ft) | % Recovered | RQD | Profile (Rock Type) | Description | Remarks |
|---|---|---|---|---|---|---|
| 4 | 530 | cut 11', recovered 8.5' | 6.5' in segments > 4"; RQD =76.5 | | 532.7' Dolomite, generally white (10YR8/2) to light brownish gray (10YR6/2); laminar to thin bedded, vuggy porosity with calcite lining some porosity; bedding plane separations and at least 2 ~vertical fracture planes created fractured blocks with long dimension 1-3" and other dimensions ~1". Darker surface stains common on fractures and bedding planes. Orientation lost during drilling and recovery. Dark brown (10YR3/3) organic zone near top. | stopped coring as the poor recovery and difficult drilling end 6/24/06 |
| 5 | 540 | cut 4.0', recovered 3.5' | No segments >4", RQD = 0 | No cuttings, lost core | 541' | 6/25/06 drilling blind to 544'. |
| | 550 | | | | cuttings 544-550' mainly cement and some Dewey Lake<br>cuttings 550-555' cement<br>drilling smoother at 557', possible base of Culebra; no circulation 558-559', ~40 bbls of mud to reestablish circulation<br>cuttings reduced, mostly cement at 560'<br>562' increase in pump pressure on rig<br>565': cuttings still reduced, smaller size, mostly cement, some Dewey Lake, scarce gypsum and tan dolomite.<br>566': harder drilling. Probable top of A-1. Ended drilling. | |
| | 560 | | | | | |
| | 570 | | | | | |
| | 580 | | | | | |
| | 590 | | | | | |
| | 600 | | | | | |
| | 610 | | | | | |

# Appendix D
## Permitting and Completion Information

A case file for SNL-18 (C-3233) containing official documents is maintained by the land management coordinator, Environmental Monitoring and Hydrology Section of Washington Regulatory and Environmental Services for the WIPP Project. Selected documents are reproduced here for ease of access. Originals have been reduced to fit page formats.

As noted in the text, all official correspondence concerning permitting and regulatory matters should refer to the New Mexico State Engineer permit number C-3233.

Information on management of well-drilling wastes for SNL-18 is not included.

**Dennis W. Powers, Ph. D.**
*Consulting Geologist*

July 5, 2006

**Ron Richardson**
Field Lead
*WRES*

**Rick Beauheim**
Hydrology Lead
*Sandia National Laboratories*

**Re: Drilling Decisions for SNL-18**

I am recording recent decisions regarding drilling SNL-18 because of changes in drilling conditions. This letter corrects some depths in the original letter dated June 26, 2006.

At a depth of ~307 ft (6/20/06), the drill pipe and bit started sticking while adding drillpipe. Air was being used to circulate cuttings from the drillhole. Drilling continued from 307 to 465 ft depth with air and mist to remove cuttings. It was apparent that the hole was producing water after reaching a depth of ~340 ft. A 1 ft tool drop was recorded from 458–459 ft. A Solinst reading the following morning indicated a water level 301.80 ft below the top of the connector of the surface conductor casing, consistent with depths recorded using the SNL video camera. A grab sample of this water blown from the drillhole along with added water and mist (soap) had a field specific gravity of 1.005.

The last cuttings recovered above 465 ft included soft off-white gypsum that is likely from the Forty-niner Member of the Rustler Formation. Because the contact between the Dewey Lake and Rustler Formations was deeper than I originally estimated, and because the upper Rustler rocks were in poor condition, I recommended coring from this point (465 ft). After coring to 496 ft, however, drilling with air and mist was not removing the cuttings and fill from the bottom of the drillhole. After WTWWS consulted with all of us, we decided to switch to drilling with bentonite mud. The rig was configured for drilling with mud, and coring proceeded on 6/21/06 from 496 ft, with mud circulating back to the surface.

During this core run (496–526 ft), the drilling rate was very high from ~504–506 ft, but there was no tool drop. From a depth of about 506.5 ft, mud no longer circulated to the surface, as the drillhole began taking mud faster than it could be pumped through the drillpipe. Only 1.5 ft of core was recovered from this interval, and the core is part of the Magenta Dolomite Member of the Rustler Formation, with near-vertical dip to the bedding.

Another core run from 526–537 ft was halted when no progress was being made. Lower Tamarisk Member and upper Culebra Dolomite were recovered in the core, although the Culebra was highly fractured. A solution cavity at least 2 inches across was intercepted in the lower most Tamarisk sulfate bed (A-2). During this drilling, thick bentonite mud was pumped through the drillpipe without any returns to the surface.

Another core run was attempted, cutting from 537–541 ft before no further advance could be made. All of the recovered core materials were of fractured, blocky Culebra, and came from the core barrel in pieces without certain orientations. At this point I recommended that no further coring be attempted and that reaming and drilling proceed to try to complete the well. Factors in this recommendation included:

- uncertain stability of the Culebra for coring and recovery,
- persistent fill (tens of feet) in the hole following each drilling or coring attempt,
- loss of large volumes of thick drilling mud, and
- limit of 90 barrels for mud mixing limits the time for trying to remove cuttings and drilling before having to stop to mix mud again.

140 Hemley Road, Anthony, TX 79821
Telephone: (915) 877-3929 E-mail: dwpowers@evaporites.com *CELL: (915) 588-7901*

**Dennis W. Powers, Ph. D.**
*Consulting Geologist*

On June 25, the cored interval from 465–541 ft was reamed, and the drillhole advanced to 544 ft before completely running out of bentonite to make mud.

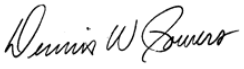
WTWWS drillers recommended that, in addition to making very thick bentonite mud, mason's lime be added in small amounts (~25 pounds per 90 barrels of thick bentonite mud) to further increase the viscosity of the drilling fluid. Additional bentonite was procured, and the drillhole was re-entered on 6/26/06. More than 60 ft of fill was encountered. 180 barrels of thick bentonite mud (with lime) were circulated into the drillhole, with mud levels reaching about 3 ft below the top of the conductor casing with the last of the mud. Approximately 70 barrels of fresh water were pumped in behind the mud, resulting in overflow at the surface. The initial overflow was of very fresh water (grab sample specific gravity 1.000), followed eventually by thicker drilling mud. [Fresh water pumped into the drillhole was at a depth well into the mud column, and the fresh water overflow sampled is believed to be from inflow from the lower Dewey Lake on top of the more dense drilling mud.] The drillbit was rotated and advanced to 495 ft while mud and water were pumped into SNL-18. As the drillbit reached this last depth, drilling mud/water ceased reaching the surface and began to be taken by the formation. Circulation was stopped, and the drill pipe and bit were removed from the hole.

After further discussion of options, WTWWS drillers recommended placing about 3 cubic yards of cement in the drillhole on top of the fill at or above 495 ft to attempt to limit water and mud intake as well as provide some possible control of fill. This cement would fill about 100 ft of borehole if there were neither enlargement nor intake of cement. The cement would then be drilled out, and the hole continued if possible. This recommendation was discussed among us, and we concurred on this option.

About 3 cubic yards of cement were delivered and pumped into the well by 15:00 (MDT), 6/26/06. The cement and water levels will be determined on 6/27/06, and it is expected that the cement in the drillhole will be drilled out. If appropriate, the interval just above the Culebra may also be cemented and redrilled.

I believe this letter summarizes the background for decisions to change drilling methods to deal with conditions at SNL-18.

Sincerely,



Dennis W. Powers

140 Hemley Road, Anthony, TX 79821
Telephone: (915) 877-3929 E-mail: dwpowers@evaporites.com *CELL: (915) 588-7901*

**Dennis W. Powers, Ph. D.**
*Consulting Geologist*

July 5, 2006

**Ron Richardson**
Field Lead
*WRES*

**Rick Beauheim**
Hydrology Lead
*Sandia National Laboratories*

**Re: Screen Interval for Culebra Dolomite Member in SNL-18**


Geophysical logs (6/29/06) and drilling data indicate that the best interval to screen the Culebra in SNL-18 is from 557.0–530.3 ft below the top of the surface conductor casing (see adjacent photo and log next page).

These are factors considered in this decision:

- The base of the Culebra, based on drilling rates and characteristics, is 557 ft. The top of the Culebra, based on geophysical logs, is at 538 ft. The Culebra is 19 ft thick, less than average around WIPP. Limited core was recovered from the Culebra.
- The gray to reddish brown silty claystone (upper M-2) below the Culebra was drilled, but cuttings were not obtained because of general loss of circulation and infill from the lower Dewey Lake Formation. The caliper log did not reach this interval because of fill.
- A-1 was intercepted at 566 ft, based on drilling rates and characteristics. Because of fill and lost circulation, I recommended drilling cease at this depth. A-1 confirmed the position of stratigraphic units, and the additional 9 ft below Culebra provided some volume to accommodate fill during casing. No halite was expected in the lower Rustler below A-1. A-1 was also not drilled to leave it as a potential barrier to vertical flow.
- At 307 ft depth (Dewey Lake Formation), we changed from air to air-mist to enhance cuttings recovery. The well began producing considerable water below this interval, and the overnight water level reached 301.80 ft below the top of the connector on the conductor casing. After coring to 496 ft, we switched to drilling with bentonite mud because of problems with fill. Circulation was lost at 506.5 ft and was only partially restored by cementing some intervals above the Culebra and using very heavy bentonite mud. There were no tool drops during drilling or coring of SNL-18. Electric logs indicate the fluid level during logging was at about 278 ft, mid-Dewey Lake.
- The base of the screen (26.7 ft long) will be at the base of the Culebra (557 ft) to maximize Culebra production. The top at 530.3 ft is ~ middle of A-2, in a zone with high resistivity. Lower A-2 includes small cavernous porosity. The gravel pack (4/10) will be run from the bottom of the drillhole to ~526 ft. HolePlug® is to be added from ~526 ft to ~521 ft. The annulus is to be cemented from the top of the bentonite seal to the surface. The blank casing and endcap below the screen interval are 2 ft long (to 559 ft).

I believe this letter summarizes the hydrological and geological justification for setting the screened interval and preparing SNL-18 for completion.

Sincerely,

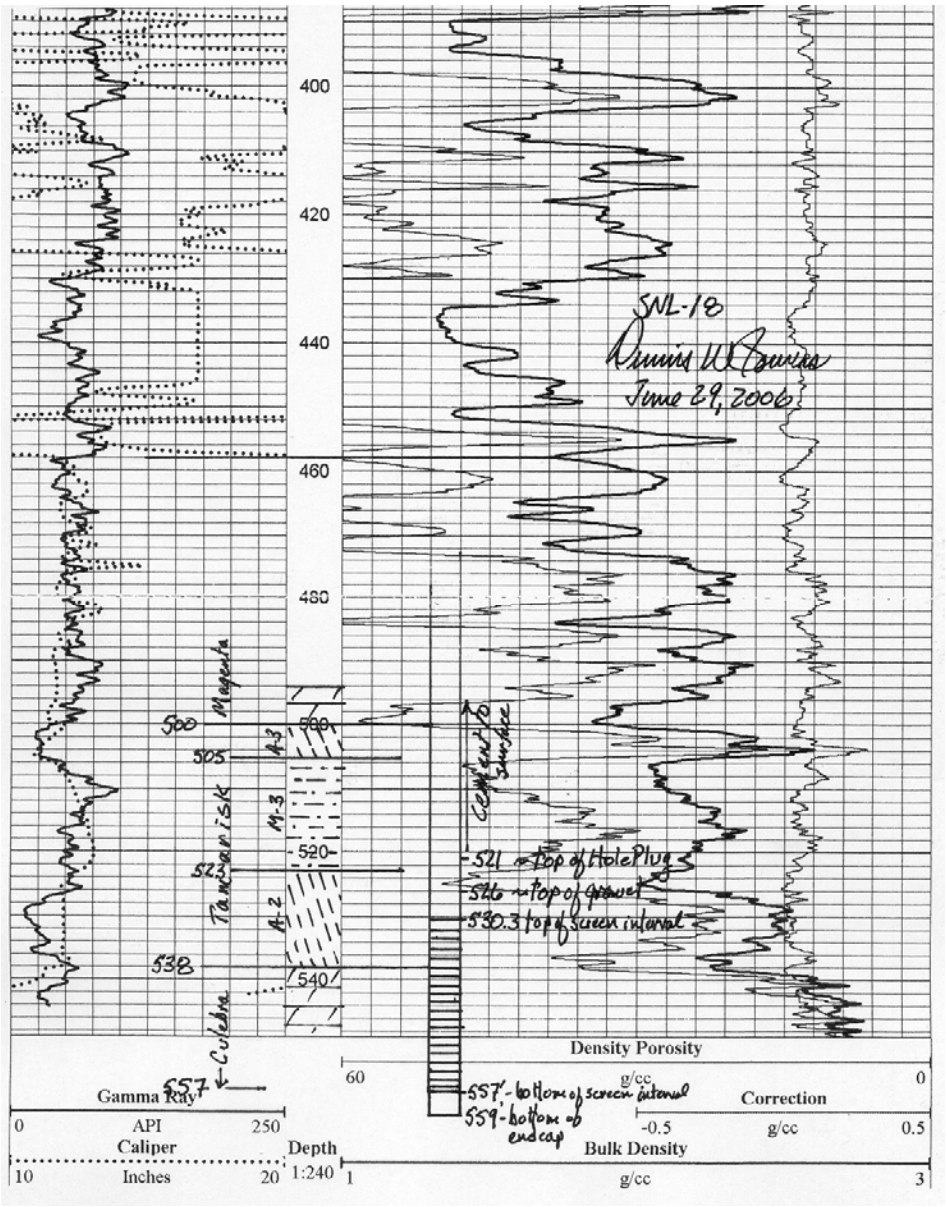
Dennis W. Powers

140 Hemley Road, Anthony, TX 79821
Telephone: (915) 877-3929 E-mail: dwpowers@evaporites.com *CELL: (915) 588-7901*

**Dennis W. Powers, Ph. D.**
*Consulting Geologist*

July 5, 2006

Partial Geophysical Log of SNL-18
Showing Completion Intervals
(scanned copy of marked field-log)

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**Dennis W. Powers, Ph. D.**
*Consulting Geologist*

July 5, 2006

**Rey Carrasco**
*Geotechnical Engineering*
Washington TRU Solutions
Carlsbad, NM 88220

**Storage and Retention of Cores and Rock Samples from SNL-18**

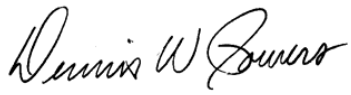
*Background*
Cores and cutting samples have been collected from drillhole SNL-18 in support of the drilling and testing program to investigate the hydrology of the Culebra Dolomite Member of the Rustler Formation as well as other units of hydrogeological significance to the program. These samples were collected under my supervision, and the chain-of-custody has been maintained by me or WRES personnel. SNL-18 is being drilled, completed, and tested under WTS contract provisions and under provisions in the hydrology program plan (SNL. 2003. Program Plan, WIPP Integrated Groundwater Hydrology Program, FY03-09, Revision 0. March 14, 2003. ERMS 526671).

*Core and Cuttings Storage Conditions*
There is no sample or core testing planned for SNL-18 requiring abnormal handling, preservation conditions, or immediate action to obtain test information. As a consequence, these samples and cores can be maintained in your current core storage facilities. Many of the cores obtained from SNL-18 are likely to be accessed in the next few months for further geologic studies to establish more details of stratigraphic, sedimentologic, and diagenetic conditions and events. These studies, if carried out, will be carried out under a formal plan, most likely developed under QA requirements of Sandia National Laboratories.

*Core and Cuttings Retention Periods*
It is recommended that cores obtained from SNL-18 be maintained indefinitely under normal storage conditions because of their relevance to hydrology and monitoring programs. The cores can be accessed for observations, and they can be removed for further laboratory study, including possible destruction, under a plan with appropriate management and QA approval.

It is recommended that cuttings samples be retained under normal storage conditions through the approval by EPA of the second CRA. Cuttings may be accessed for observation, and they may be removed for further laboratory study, including possible destruction, under a plan with appropriate management and QA approval.

*Supplemental Information*
Descriptive core logs and digital photographs of cores with a photograph log will be provided to you on CD-ROM format in accessible formats when the content has been reviewed for the basic data report for SNL-18.



Dennis W. Powers

Copy to:
Ron Richardson, *Environmental Monitoring*, WRES
Richard L. Beauheim, *Hydrology Lead*, Sandia National Laboratories

140 Hemley Road, Anthony, TX 79821
Telephone: (915) 877-3929 E-mail: dwpowers@evaporites.com *FAX: (915) 877-5071*

COPY

John R. D Antonio, Jr., P.E.
State Engineer

Roswell Office
1900 WEST SECOND STREET
ROSWELL, NM 88201

**STATE OF NEW MEXICO**
**OFFICE OF THE STATE ENGINEER**

SNL-18

Trn Nbr: 343280
File Nbr: C 03233

October 6, 2005

HAROLD JOHNSON
U.S. DEPART OF ENERGY
CARLSBAD FIELD OFFICE - WIPP
P.O. BOX 3090
CARLSBAD, NM 88221

Greetings:

Enclosed is your copy of the Exploratory / Monitoring Permit which has been approved. Your attention is called to the Specific and General Conditions of Approval of this permit.

In accordance with General Condition C, a well record shall be file d in this office ten days after completion of drilling. The well record is proof of completion of well. IT IS YOUR RESPONSIBILTY TO ASSURE THAT THE WELL LOG BE FILED WITHIN 10 DAYS OF DRILLING OF THE WELL.

This permit will expire on or before 10/31/06 unless the well has been drilled and the well log filed in this office.

Sincerely,

Mike Stapleton
(505) 622-6521

Enclosure

cc: Santa Fe Office

explore

| UNIQUE # | DOE UFC | DATE REC'VD | ADDRESSEES |
|---|---|---|---|
| 0503886 | 5487.00 | OCT 18 2005 | H Johnson w/o rgn. pkt. J Plum |

**NEW MEXICO STATE ENGINEER OFFICE**
**PERMIT TO EXPLORE**

**SPECIFIC CONDITIONS OF APPROVAL**

2 The well shall be constructed to artesian well specifications and the State Engineer shall be notified before casing is landed or cemented

4 No water shall be appropriated and beneficially used under this permit.

B The well shall be drilled by a driller licensed in the State of New Mexico in accordance with Section 72-12-12 New Mexico Statutes Annotated.

C Driller's well record must be filed with the State Engineer within 10 days after the well is drilled or driven. Well record forms will be provided by the State Engineer upon request.

C1 A complete and properly executed Well Record on the form provided by the State Engineer shall be filed not later than ten (10) days after completion of the well.
Test data shall be filed not later than ten (10) days after completion of the test(s).

LOG The Point of Diversion C 03233 EXPLORE must be completed and the Well Log filed on or before 10/31/2006.

**ACTION OF STATE ENGINEER**

Notice of Intention Rcvd: Date Rcvd. Corrected:
Formal Application Rcvd: 10/03/2005 Pub. of Notice Ordered:
Date Returned - Correction: Affidavit of Pub. Filed:

This application is approved provided it is not exercised to the detriment of any others having existing rights, and is not contrary to the conservation of water in New Mexico nor detrimental to the public welfare of the state; and further subject to the specific conditions listed previously.

Witness my hand and seal this 06 day of Oct A.D., 2005

John R. D Antonio, Jr., P.E. , State Engineer

By: Kenneth M. Freeman
fov Art Mason

Trn Desc: C 03233 MONITORING WELL File Number: C 03233
Trn Number: 343280

page: 1

Revised June 1972

**STATE ENGINEER OFFICE**

**WELL RECORD**

Section 1. GENERAL INFORMATION

A) Owner of well U.S. DEPARTMENT OF ENERGY - WIPP Owner's Well No. SNL-18
Street or Post Office Address P.O. BOX 2078
City and State CARLSBAD, NEW MEXICO 88221

Well was drilled under Permit No. C-3233 and is located in the:

a. SE ¼ SE ¼ ____ ¼ ____ ¼ of Section 20 Township 21 S Range 31 E N.M.P.M.

b. Tract No. ____ of Map No. ____ of the CARLSBAD DISTRICT

c. Lot No. ____ of Block No. ____ of the ____
Subdivision, recorded in EDDY County.

d. X= ____ feet, Y= ____ feet, N.M. Coordinate System ____ Zone in the ____ Grant.

(B) Drilling Contractor WEST TEXAS WATER WELL SERVICE License No. WD1184
Address 3410 MANKINS ODESSA, TEXAS 79764

Drilling Began 06-19-06 Completed 06-30-06 Type tools AIR/MUD ROTARY Size of hole 11 in.

Elevation of land surface or ____ at well is 3371 ft. Total depth of well 566 ft.

Completed well is ☐ shallow ☒ artesian. Depth to water upon completion of well ____ ft.

Section 2. PRINCIPAL WATER-BEARING STRATA

| Depth in Feet From | Depth in Feet To | Thickness in Feet | Description of Water-Bearing Formation | Estimated Yield (gallons per minute) |
|---|---|---|---|---|
| 301 | 460 | 159 | SOFT SILTSTONE BROWN(DEWEY LAKE) | |
| 505 | 515 | 10 | WHITE GYPSUM | |
| 538 | 557 | 19 | BROWN DOLOMITE | |
| | | | | |

Section 3. RECORD OF CASING

| Diameter (inches) | Pounds per foot | Threads per in. | Depth in Feet Top | Depth in Feet Bottom | Length (feet) | Type of Shoe | Perforations From | Perforations To |
|---|---|---|---|---|---|---|---|---|
| 12-3/4 | 33.41 | | 3' AGL | 35 | 38 | | | |
| 5-1/2 | 4.4 | 4 | 2.5 AGL | 559 | 561.50 | FIBERGLASS & PVC CAP | .070 SCREEN 530.3 | 557 |
| | | | | | | | | |

Section 4. RECORD OF MUDDING AND CEMENTING

| Depth in Feet From | Depth in Feet To | Hole Diameter | Sacks of Mud | Cubic Feet of Cement | Method of Placement |
|---|---|---|---|---|---|
| 0 | 35 | 17-1/2 | | 54 CU. FT. | TRIMIE - S.E.R.M. |
| 0 | 518 | 11 | | 648 CU. FT. | TRIMIE - S.E.R.M. |
| 523 | 518 | 11 | 3 BAGS BENTONITE HOLE PLUG | | |

Section 5. PLUGGING RECORD

Plugging Contractor ____
Address ____
Plugging Method ____
Date Well Plugged ____
Plugging approved by:
____
State Engineer Representative

| No. | Depth in Feet Top | Depth in Feet Bottom | Cubic Feet of Cement |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

FOR USE OF STATE ENGINEER ONLY

Date Received

Quad ____ FWL ____ FSL ____

File No. ____ Use ____ Location No. ____

Section 6. LOG OF HOLE

| Depth in Feet From | Depth in Feet To | Thickness in Feet | Color and Type of Material Encountered |
|---|---|---|---|
| 0 | 2 | 2 | CONSTRUCTION FILL |
| 2 | 33 | 31 | BROWN FINE-GRAINED SAND, LOOSE (DUNE SAND) |
| 33 | 38 | 5 | WHITE SANDY LIMESTONE AND CALCAREOUS SANDSTONE (MESCALERO CALICHE) |
| 38 | 56 | 18 | REDDISH BROWN CALCAREOUS SANDSTONE & ARGILLACEOUS SILTSTONE (GATUNA FORMATION) |
| 56 | 458 | 402 | REDDISH BROWN SILTSTONE WITH SMALL GRAY REDUCTIONS SPOTS; CALCAREOUS TO GYPSIFEROUS & WELL INDURATED (DEWEY LAKE FORMATION) |
| 458 | 464 | 6 | GYPSITE, SOFT, YELLOWISH WHITE; INTERMEDIATE REDDISH BROWN SILTSTONE NO DETECTED (FORTY-NINER MEMBER OF RUSTLER FORMATION) |
| 464 | 500 | 36DIPS | LIGHT GRAY TO GRAYISH BROWN DOLOMITE WITH LAMINAR TO WAVY BEDDING; -75°; LIMITED SAMPLING (MAGENTA DOLOMITE MEMBER OF RUSLTER FORMATIO |
| 500 | 538 | 38 | GYPSUM, WHITE TO GRAY, BEDDED, VUGGY AT BASE; INTERMEDIATE REDDISH-BROW FROM 505-523 FT (TAMARISK MEMBER OF THE RUSTLER FORMATION) |
| 538 | 557 | 19 | LIGHT TO DARK BROWN DOLOMITE; CORE LIMITED TO UPPER PART (CULEBRA DOLOMITE MEMBER OF THE RUSTLER FORMATION) |
| 557 | 566 | 9 | CLAYSTONE; NO CUTTINGS DUE TO LOST DIRCULATION, BASED ON DRILLING RATE (UPPER LOS MEDANOS MEMBER OF THE RUSTLER FORMATION) |
| | 566 | | GYPSUM; BASED ON DRILLING RATES (UPPER LOS MEDANOS MEMBER OF THE RUSTLER FORMATION) |

Section 7. REMARKS AND ADDITIONAL INFORMATION

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described hole.

Larry Keith
Driller

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the appropriate district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1(a) and Section 5 need be completed.

# Appendix E
## Archeological Clearance Report

The report from Boone Archeological Services on the following three pages was converted from an original Word document to an Acrobat (pdf) file and reduced in size slightly to fit page formats. The original signed document is maintained by the land management coordinator, Washington Regulatory and Environmental Services, for the WIPP Project.

**TITLE PAGE/ABSTRACT/**
**NEGATIVE SITE REPORT**
**CFO/RFO**

**1/03**

| | | |
|---|---|---|
| 1. BLM Report No. | 2. Reviewer's Initials/Date_____<br>ACCEPTED ( ) REJECTED ( ) | 3. NMCRIS No.: 95193 |
| 4. Type of Report: Negative (X) Positive ( ) | | |
| 5. Title of Report:<br>Class III archaeological survey of a pad for monitor well No. SNL-18.<br>Author(s): Ann Boone and Danny Boone | | 6. Fieldwork Date(s):<br>from 22 October, 2005 to<br>7. Report Date: 25 October, 2005 |
| 8. Consultant Name & Address:<br>Boone Archaeological Services<br>2030 North Canal, Carlsbad, NM 88220<br>Direct Charge: Danny Boone<br>Field Personnel Names: Danny Boone<br>Phone: (505) 885-1352 | | 9. Cultural Resource Permit No.:<br>BLM: 190-2920-05-G<br>STATE: NM 05-157<br>10. Consultant Report No.<br>BAS 09-05-57 |
| 11. Customer Name: Washington TRU Solutions, LLC<br>Responsible Individual: Ron Richardson<br>Address: P.O. Box 2078<br>Carlsbad, NM 88221<br>Phone: (505) 234-8395 | | 12. Customer Project No.:<br>SNL-18 |

| 13. Land Status: | BLM | STATE | PRIVATE | OTHER | TOTAL |
|---|---|---|---|---|---|
| a. Area Surveyed (acres) | 1.01 (+/-) | 0 | 0 | 0 | 1.01 (+/-) |
| b. Area of Effect (acres) | 0.52 (+/-) | 0 | 0 | 0 | 0.52 (+/-) |

14. a. Linear: Length; N/A Width; N/A
b. Block: 150' x 150' [Survey 210' x 210'] See. 16 b.

15. Location: (Maps Attached if Negative Survey)
a. State: New Mexico
b. County: Eddy
c. BLM Office: Carlsbad
d. Nearest City or Town: Carlsbad, NM
e. Legal Location: T 21S, R 31E, Sec. 20, SE¼ SE¼.
f. Well Pad Footages: N/A
g. USGS 7.5 Map Name(s) and Code Number(s): LIVINGSTON RIDGE, NM (Prov. Ed. 1985) 32103-D7

16. Project Data:

a. Records Search: Date(s) of BLM File Review: 19 October. 2005 Name of Reviewer (s): Ann Boone

Date(s) of ARMS Data Review: 20 October. 2005 Name of Reviewer (s): Ann Boone

Findings (see Field Office requirements to determine area to be reviewed during records search):

LA 104727 is within 500 ft.

b. Description of Undertaking:

This project is staked as a 150 by 150 feet square. One additional transect around the outer perimeter was added for the 1.0 acre minimum. Access will be from an existing caliche capped road that dead ends at the survey area. Impact acres are unknown and are estimated. A plat for the project is attached to this report.

c. Environmental Setting (NRCS soil designation; vegetative community; etc.):

Topography: Rolling dunal plain.

Vegetation: Overall groundcover is approximately 25% consisting primarily of mesquite, sage brush, yucca cactus, broom snakeweed, sand burrs, assorted grasses and other flora.

NRCS: Kermit-Berino association: Sandy, deep soils from wind-worked mixed sand deposits.

d. Field Methods: (transect intervals; crew size; time in field, etc.):

Transects: A parallel grid spaced 15 meters or less apart.

Crew Size: One

Time in Field: 1.0 hour.

e. Artifacts Collected (?): None

17. Cultural Resource Findings:

a. Identification and description: None

b. Evaluation of significance of Each Resource: None

18. Management Summary (Recommendations):

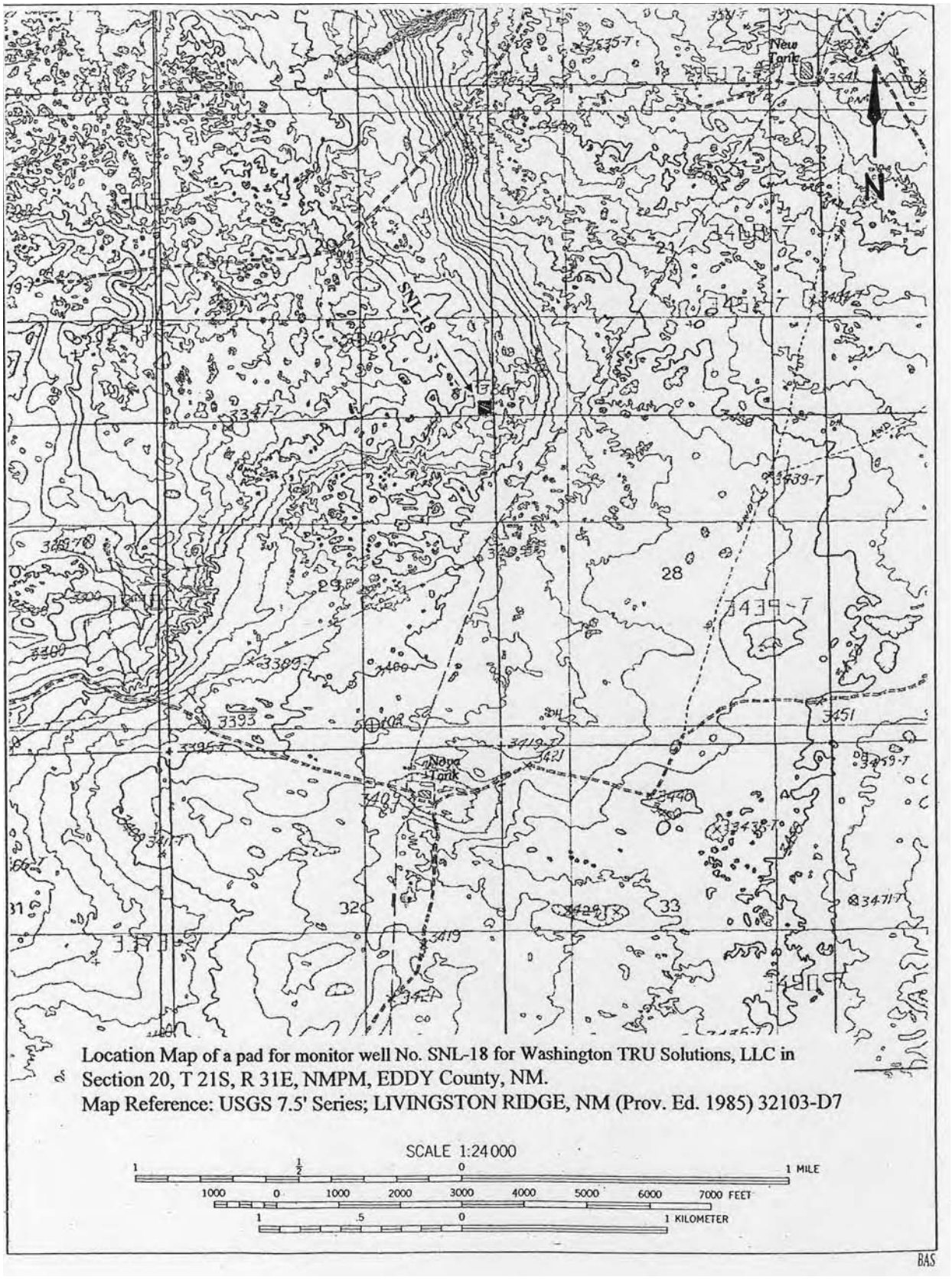
Archaeological clearance of a pad for monitor well No. SNL-18 for Washington TRU Solutions, LLC as presently staked is recommended. If cultural resources are encountered at any time all activity should cease and the BLM Archaeologist notified immediately.

19.

I certify that the information provided above is correct and accurate and meets all appreciable BLM standards.

Responsible Archaeologist Dany Boone 26 October, 2005

Signature Date




Location Map of a pad for monitor well No. SNL-18 for Washington TRU Solutions, LLC in Section 20, T 21S, R 31E, NMPM, EDDY County, NM.
Map Reference: USGS 7.5' Series; LIVINGSTON RIDGE, NM (Prov. Ed. 1985) 32103-D7

# Appendix F
## Photograph Logs

Digital photographs were taken of the cores from SNL-18. These photographs have been compiled into a listing of consecutive photos beginning with the uppermost core (Magenta Dolomite Member of the Rustler Formation) and ending with the lowermost (Culebra Dolomite Member of the Rustler Formation). The photographs were taken in the field shortly after recovery. A CD-ROM with these images (jpeg format) is being archived, and a copy with photographic log is maintained by Geotechnical Engineering (Washington TRU Solutions LLC) with records of the cores stored for WIPP.

| File | DATE | LOCATION | DESCRIPTION OF SUBJECT (includes individual/group names, direction, etc. as appropriate) | PHOTOGRAPHER (initials and dept.) |
|---|---|---|---|---|
| SNL-18_Core001.jpg | 6/21/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Magenta Dolomite Mbr core, 493.5 - 494.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core002.jpg | 6/21/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Magenta Dolomite Mbr core, 493.9 - 495.0 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core003.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 513.7 - 514.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core004.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 513.9 - 515.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core005.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 514.9 - 516.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core006.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 515.9 - 517.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core007.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 516.9 - 518.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core008.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 517.9 - 519.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core009.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 518.9 - 520.0 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core010.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 519.9 - 521.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core011.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 520.9 - 522.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core012.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 521.9 - 523.0 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core013.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 522.9 - 524.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core014.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 523.9 - 525.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core015.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 524.9 - 526.0 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core016.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 526.0 - 527.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |

**Camera**: Nikon CoolPix 5700 **Resolution**: 2560 x 1920 **Page** 1 of 2

| File | DATE | LOCATION | DESCRIPTION OF SUBJECT (includes individual/group names, direction, etc. as appropriate) | PHOTOGRAPHER (initials and dept.) |
|---|---|---|---|---|
| SNL-18_Core017.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 527.0 - 527.9 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core018.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 527.9 - 529.0 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core019.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 528.9 - 530.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core020.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 529.9 - 531.0 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core021.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk Mbr core, 530.9 - 532.1 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core022.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Tamarisk/ Culebra Dolomite Mbr core, 531.9 - 533.0 ft bgl, with markings, scale | DW Powers Consultant to WTS |
| SNL-18_Core023.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Culebra Dolomite Mbr core, 532.9 - 534.1 ft bgl, with scale | DW Powers Consultant to WTS |
| SNL-18_Core024.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Culebra Dolomite Mbr core, 534.0 - 534.7 ft bgl, with scale | DW Powers Consultant to WTS |
| SNL-18_Core025.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Culebra Dolomite Mbr core, 537.0 - 538.1 ft bgl, with scale | DW Powers Consultant to WTS |
| SNL-18_Core026.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Culebra Dolomite Mbr core, 538.0 - 539.0 ft bgl, with scale | DW Powers Consultant to WTS |
| SNL-18_Core027.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Culebra Dolomite Mbr core, 539.0 - 540.0 ft bgl, with scale | DW Powers Consultant to WTS |
| SNL-18_Core028.jpg | 6/24/06 | SNL-18 drillpad; T21S, R31E, section 20 | Close-up photo of Culebra Dolomite Mbr core, 539.9 - 540.6 ft bgl, with scale | DW Powers Consultant to WTS |

**Camera**: Nikon CoolPix 5700 **Resolution**: 2560 x 1920 **Page** 2 of 2


Ron Richardson (WRES), Larry Keith (WTWWS), Ronnie Keith (WTWWS), and John Wood (DOWDCO) from left to right conferring during coring at SNL-18 on June 24, 2006. Photo by Dennis W. Powers.

# Appendix G
## Geophysical Logs

Geophysical logging of SNL-18 was conducted by Jet West Geophysical Services, LLC, 2550 La Plata Highway, Farmington, NM, 87499-3522, on June 29, 2006. The operator was Al Henderson. Copies of the logs are maintained by Washington Regulatory and Environmental Services, Environmental Monitoring and Hydrology Section, for the WIPP Project. A CD-ROM is being retained that includes:

1) Electronic copies of the logs produced by Jet West Geophysical Logging Services using WellCAD vs 4.0,
2) WellCAD Reader to open the electronic logs, and
3) Electronic data files in both .txt and .las formats.

The following geophysical logs were obtained:

- Caliper
- Natural gamma
- Density-porosity
- Spontaneous potential
- Neutron
- Resistivity

SNL-18 had been cored and drilled to about 566 ft at the time of logging. Logging was done to a depth of 548 ft. A conductor casing had been placed to a depth of 35 ft bgl. SNL-18 was drilled with air, then air and foam, and finally with heavy mud because of water inflow and lost circulation. Fluid level was about 278 ft bgl at the time of logging.

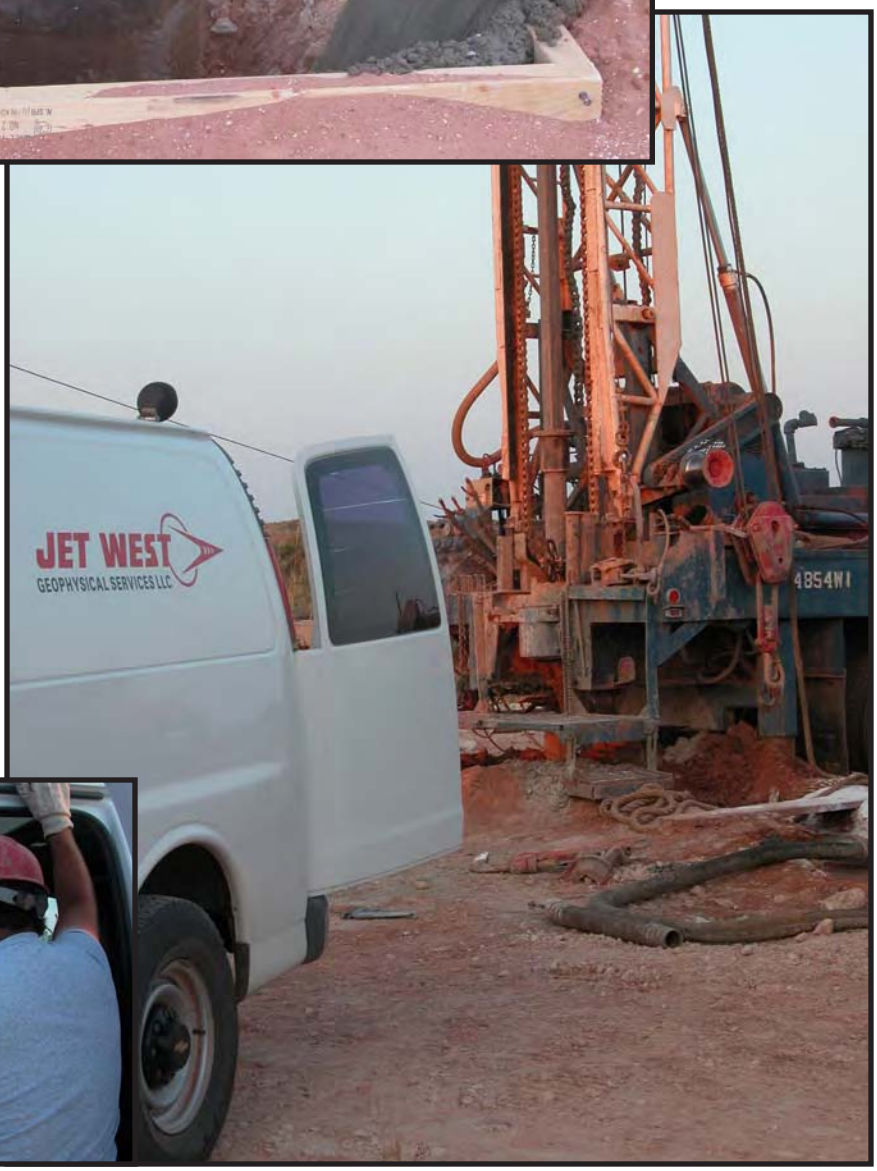
The caliper log was used for estimating material volume placed in the annulus between fiberglass reinforced plastic casing and the drillhole wall.

The reference point (0 ft depth) for geophysical logging was the level of the connector on top of the conductor casing (see photo, next page). This point was assigned an elevation of 3,371 ft amsl on the logs, based on the pre-drilling pad survey. A benchmark placed near the drillhole after completion has an elevation of 3,372.70 ft amsl (see Fig. 1-5 and Table 1-1 in the main text). The rounded elevation of 3,373 ft amsl for the reference point is appropriate for the measurements and elevations of units for later studies.

Above: Conductor casing being cemented in place at SNL-18 on June 19, 2006. The top of the green connector is the reference point for logging.

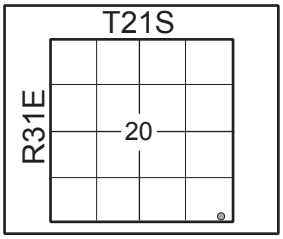
Right: Jet West set up and logging SNL-18 on June 29, 2006.

Below: Al Henderson (left), Jet West log engineer, and Ronnie Keith (right), WTWWS driller.




# Figure 2-1
# Well Record SNL-18 (C-3233)

Company: Washington TRU Solutions LLC
Well: SNL-18 (C-3233)
Section: 20 Twp: T21S Rge: R31E
Location: 39 ft from south line (fsl)
115 ft from east line (fel)




Reference point
Log measured from: top of connector on conductor casing (gl)
Drilling measured from: gl
Permanent Datum: benchmark

Elevation
KB:
DF:
GL: 3,373 ft amsl
(benchmark: 3,372.70)

Drilling contractor: West Texas Well Water Service
Coring contractor: Diamond Oil Well Drilling Co.
Geophysical logs: Al Henderson
Jet West Geophysical Services, LLC (NM)
Geologist: Dennis W. Powers
Spud date: June 19, 2006
Completion date: June 29, 2006
Total depth (TD): 566 ft bgl (driller log)

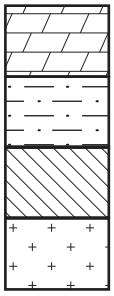
Casing Record
Conductor: 35 ft
12.75-inch o.d. steel
Casing: 5.45-inch o.d.
fiberglass reinforced
plastic to 559.0 ft bgl
Screened interval:
557.0-530.3 ft bgl

Geophysical Logs Date: June 29, 2006

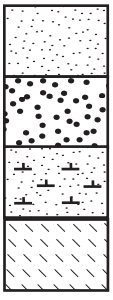
| | |
|---|---|
| Micro/Laterolog/SP: | 278-548 ft |
| Gamma | 0-544 ft |
| Caliper: | 0-542 ft |
| Density/Neutron: | 35-548 ft |

Type fluid in hole: top of drilling mud 278 ft bgl
Res mud: n/a
Res mud filtrate: n/a
Max. Rec. Temp.:
not recorded

## General Lithologic Symbols Used



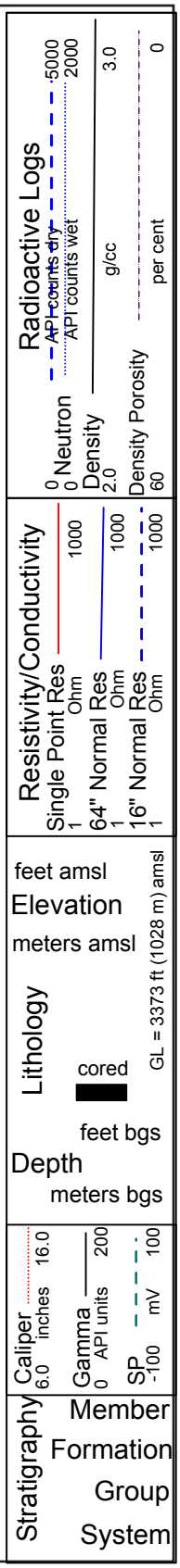
Dolomite
Mudstone/siltstone
Anhydrite
Halite



Fine sandstone & siltstone
Coarse sandstone
Sandstone w/caliche
Gypsum

Figure 2-1 Log Title & Header page.ai

SNL-18 Well Log Headers



Radioactive Logs
0 Neutron 0 — API counts dry — 5000
API counts wet — 2000
2.0 Density 3.0 — g/cc
60 Density Porosity 0 — per cent

Resistivity/Conductivity
Single Point Res 1 — Ohm — 1000
64" Normal Res 1 — Ohm — 1000
16" Normal Res 1 — Ohm — 1000

Top of mud in drillhole at time of logging
Note change in neutron scale

35 ft - Base of conductor casing

feet amsl
Elevation
meters amsl

GL = 3373 ft (1028 m) amsl

Lithology
cored

feet bgs
Depth
meters bgs

Caliper 6.0 inches 16.0
Gamma 0 API units 200
SP -100 mV 100

Stratigraphy
Member
Formation
Group
System

Sand
Mescalero
Gatuna
Dewey Lake
Rustler
Triassic
Permian (Ochoan)