DOE/WIPP 03-3294

Basic Data Report For Drillhole SNL-3 (C-2949) (Waste Isolation Pilot Plant)

May 2004

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Basic Data Report For Drillhole SNL-3 (C-2949) (Waste Isolation Pilot Plant)

Dennis W. Powers
Consulting Geologist
140 Hemley Road
Anthony, TX 79821

and

Ronald G. Richardson
Washington Regulatory and Environmental Services
P.O. Box 2078
Carlsbad, NM 88220

May 2004

West Texas Water Well Service Rig #15 (Gardner-Denver 1500) on-site at SNL-3, viewed toward the south. The drill rig is set up for drilling with brine, which discharges into the lined mud pit. The WIPP site waste handling building is on the horizon right of center, and the north access road to WIPP is on the left.

EXECUTIVE SUMMARY

SNL-3 (permitted by the New Mexico State Engineer as C-2949) was drilled to provide geological data and hydrological testing of the Culebra Dolomite Member of the Permian Rustler Formation within a dissolution reentrant north of the WIPP site and well east of Livingston Ridge. SNL-3 is located in the southeast quarter of Section 34, T21S, R31E, in eastern Eddy County, New Mexico. SNL-3 was drilled to a total depth of 970 ft below ground level (bgl). Below surface dune sand, SNL-3 encountered, in order, the Mescalero caliche, Gatuña, Dewey Lake, Rustler, and upper Salado Formations. Two intervals were cored: (1) from the lower Forty-niner Member through the Magenta Dolomite and into the upper Tamarisk Member; and (2) from the lower Tamarisk Member through the Culebra Dolomite and Los Medaños Members and into the uppermost Salado. Geophysical logs were acquired from the open hole at total depth.

Salado cores reveal a partial depositional cycle ending in a clastic-rich halite with corroded crystal margins. A poorly lithified sandstone with rounded grains overlies the halite. It is uncertain whether the sandstone is a dissolution residue or a depositional unit; this sand is not found in other cores from the interval. Siltstone and laminar gypsum may indicate halite dissolution, consistent with predrilling expectations. The Los Medaños has normal lithology, thickness, and stratigraphic sequence. There is no evidence of halite in the Los Medaños. Earlier investigations suggested that halite would be present in the lower Los Medaños here. The unit is somewhat fractured, but not brecciated. At about 20 ft, the Culebra Dolomite is a little less thick than average. Core recovery was poor, but recovered core shows bedding and porosity similar to other Culebra cores. Core was lost from most of the lower Culebra, which is usually the most porous and transmissive part of the unit. The Tamarisk has a normal stratigraphic sequence and thickness, and the mudstone unit shows typical reddish-brown sandy claystone overlain by gray and reddish-brown siltstone. Intraclasts of siltstone are preserved, as are angular clasts or fragments of gypsum. A thin interval of sulfate conglomerate in the basal upper anhydrite of the Tamarisk was encountered. The Magenta Dolomite is about 25 ft thick and shows typical laminar to wavy bedding, some ripples, and algal stromatolites. Cores and geophysical logs indicate some porosity in the upper part of the Magenta. Carbonate interbeds in sulfate above and below the boundaries of the Magenta indicate depositional environments changed over time. The Forty-niner is represented by a typical sulfate–mudstone–sulfate sequence. The Dewey Lake was partially eroded, and the Santa Rosa completely removed, prior to deposition of the Gatuña. Cuttings and geophysical logs indicate that the sulfate–carbonate cement transition in the Dewey Lake is about 225 ft bgl at SNL-3, below a sandstone that is found across the WIPP site area. The Gatuña is 65 ft thick at SNL-3 and likely represents fill of an old valley leading to Livingston Ridge to the west.

No water was encountered in the Gatuña or Dewey Lake, although geophysical logs suggest a possible slight influx above the sulfate-carbonate cement boundary. Water flowed into the drillhole after the Magenta was penetrated, reaching an overnight level about 600 ft bgl. After the Culebra was penetrated, water levels rose to 422 ft bgl. There was no indication of fluid inflow at the Rustler–Salado contact during drilling or from cores.

Most of the open drillhole below the Culebra was cemented, and the drillhole was reamed to a diameter of 12.25 inches through the Culebra. Fiberglass reinforced plastic casing (4.83 inches outside diameter) was placed in the hole, with a screen interval across the Culebra Dolomite. The annulus was filled with 8/16 Brady sand to just above the Culebra and topped with bentonite to separate the Culebra from the Tamarisk mudstone. The annulus above the bentonite was cemented to the surface. Water and sediment were bailed from the well, and ~2200 gallons of water were pumped at about 10 gallons per minute to develop SNL-3. Water level since development has reached about 3,058 ft above mean sea level (February 2004).

West Texas Water Well Service Rig #15 at SNL-3 and crew: Ronnie Keith, Josh Bowman, Donnie Basile, and Luis Armendariz, from left to right.

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List of Figures and Tables

In keeping with practice at the WIPP site, the basic data for SNL-3 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)

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1.0 INTRODUCTION

SNL-3 was drilled in the northwest quarter of Section 34, T21S, R31E, in eastern Eddy County, New Mexico (Fig. 1-1). It is located 2369 ft from the south line (fsl) and 2701 ft from the west line (fwl) of the section (Fig. 1-2). This location places the drillhole north of the Waste Isolation Pilot Plant (WIPP) site and east of the Livingston Ridge escarpment among oil wells of the Lost Tank field. SNL-3 will be used to test hydraulic properties and to monitor groundwater levels of the Culebra Dolomite Member of the Permian Rustler Formation for WIPP.

SNL-3 was permitted by the New Mexico State Engineer as C-2949. 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 New Mexico Environment Department. WIPP is located ~25 miles east of Carlsbad, New Mexico, in eastern Eddy County (Fig. 1-1). Disposal panels are being excavated in the Permian Salado Formation at a depth of ~2,150 ft below ground level (bgl).

1.2 Purpose of SNL-3

SNL-3 was designed and located to provide information for the integrated hydrology program for WIPP (Sandia National Laboratories, 2003). Among the objectives of the integrated hydrology program, SNL-3 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 …" (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 (Sandia National Laboratories, 2003) for the Compliance Certification Application (CCA; U.S. Department of Energy, 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, 2002; Powers and others, 2003). SNL-3 was located to test Culebra hydraulic properties within an area inferred to be a reentrant along the upper Salado dissolution margin as well as confirming the geological conditions used to estimate Culebra hydraulic properties (Sandia National Laboratories, 2003; Powers, 2002a, 2003a; Powers and others, 2003).

The drillhole is to (Sandia National Laboratories, 2003, p. 43; see also Appendix A):

1. Determine if dissolution of the upper Salado has in fact occurred at this location;
2. Determine if the inferred dissolution of the upper Salado has resulted in increased Culebra transmissivity;
3. Determine if the flow dimension inferred from a pumping test is consistent with a bounded, linear feature, or indicates connection with a larger volume of the Culebra;
4. Determine if shallow (e.g., Dewey Lake) water is present above the Magenta that could

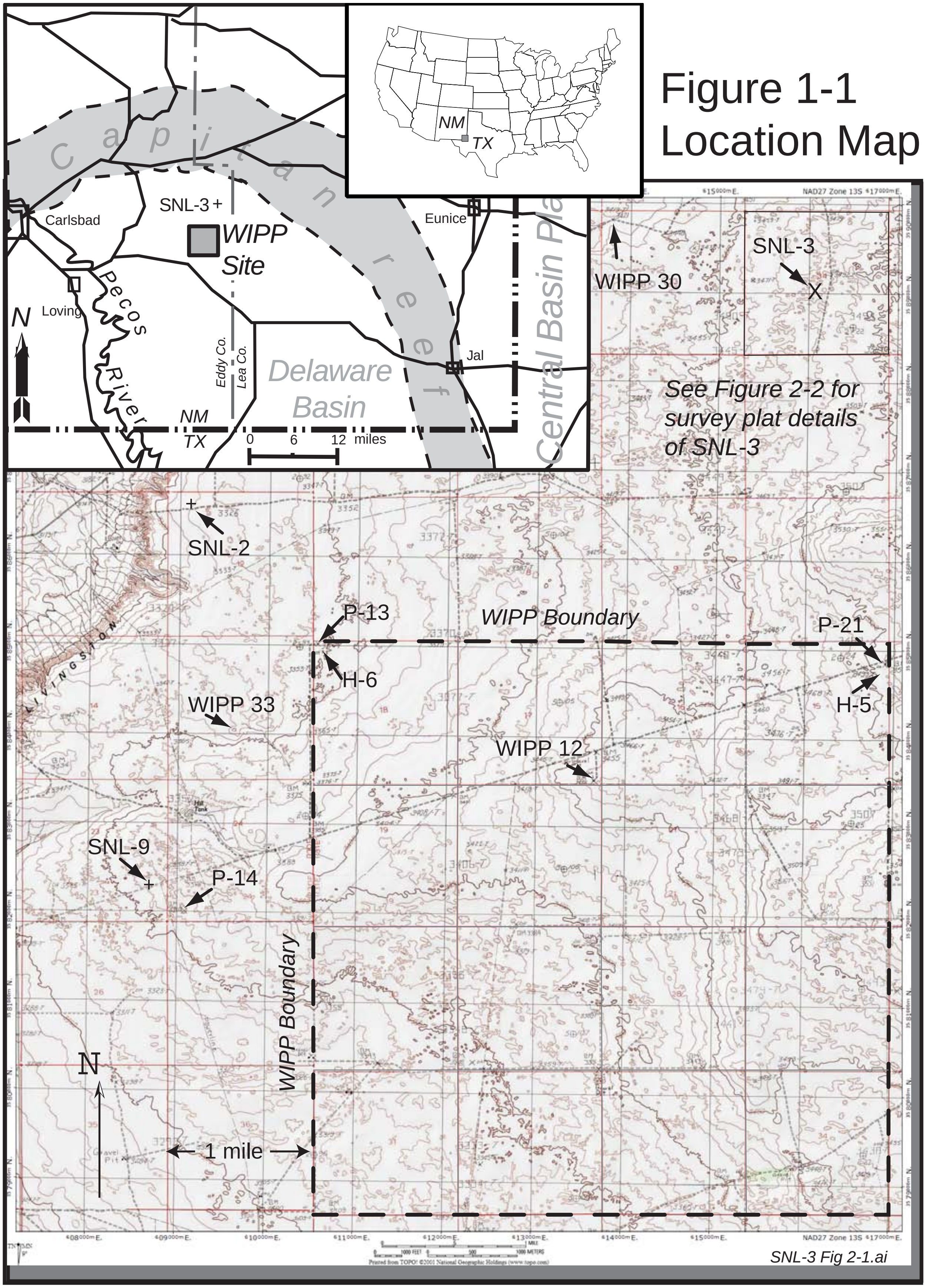


Figure 1-1
Location Map
NM
TX
Capitan reef
SNL-3
WIPP Site
Carlsbad
Eunice
Loving
Pecos River
Eddy Co.
Lea Co.
Delaware Basin
Central Basin Pla
Jal
N
NM
TX
0 6 12 miles
SNL-3
X
WIPP 30
See Figure 2-2 for survey plat details of SNL-3
SNL-2
P-13
WIPP Boundary
P-21
H-6
H-5
WIPP 33
WIPP 12
SNL-9
P-14
WIPP Boundary
N
1 mile
SNL-3 Fig 2-1.ai

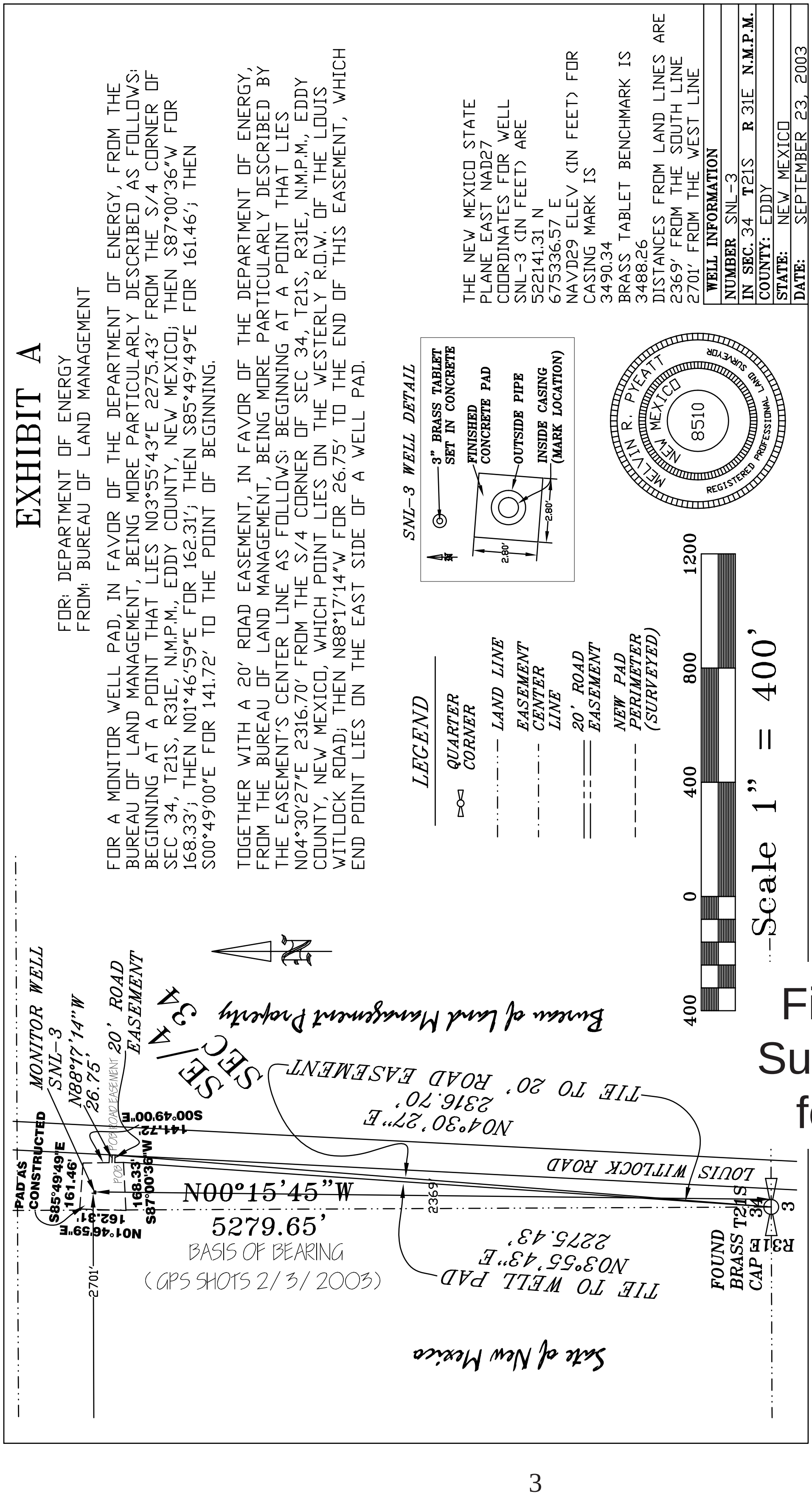


Figure 1-2
Survey Plat
for SNL-3

be leaking into the Culebra and Magenta through poorly plugged boreholes;

5. Determine the direction of flow at this location; and
6. Provide a monitoring location for a large-scale (multipad) pumping test (centered at SNL-5) to provide transient data for calibration of the Culebra model north of the WIPP site.

1.3 SNL-3 Drilling and Completion

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

SNL-3 was rotary drilled and cored to a total depth of 970 ft bgl (Fig. 1-3). As the drillhole progressed, circulating fluids were successively changed from air to fresh-water mist with foam to brine with surfactant. The changes reflect needs for determining geological and hydrological conditions in the drillhole as well as maintaining control of drillhole conditions.

Core recovery ranged from excellent to poor (Appendix C); this experience is common in these intervals (e.g., Powers, 2002b; Mercer and others, 1998).

In keeping with recent practice at WIPP, SNL-3 was cased with fiberglass reinforced plastic (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 similar to SNL-3 (Sandia National Laboratories, 2003).

SNL-3 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. If warranted, additional wells can be completed to other intervals, such as the Dewey Lake Formation, on the SNL-3 wellpad (Sandia National Laboratories, 2003).

Geophysical logs, especially the natural gamma and caliper logs, were used to make the final decisions regarding completion of SNL-3 (Fig. 1-4) (Appendices D and E). The drillhole was cemented back to a level below the Culebra to protect the lower Rustler from circulation of Culebra water (Fig. 1-4). The bottom of the Culebra screen interval was placed at 773 ft to remain above the claystone below the Culebra and avoid possible plugging of the lowermost slots (Fig. 1-4). The top of the screen, at 756 ft, is just below the top of the Culebra. The top of the sand pack (8/16 silica sand) (note: the material is referred to as a sand pack for simplicity, although the larger grain diameter slightly exceeds the standard upper limit for sand size) is below the level of the mudstone in the Tamarisk to prevent connection to the Culebra. The annulus above the sand pack was cemented to the surface. A final caliper log (Fig. 1-3) after the drillhole was reamed to 12.25 inches shows thin zones of drillhole enlargement in the Gatuña, the Forty-niner mudstone, and the Tamarisk mudstone. The annulus behind the casing was cemented through these intervals.

The surface configuration (Fig. 1-5) provides stability, security, and ready access to the casing for measurements, sampling, or other testing. The benchmark is an accessible reference point for future measurements if the well configuration is changed. Geophysical logs and depths for FRP casing, screen, and fill in the annulus are measured from the top of the connector on the steel surface conductor casing. The top of FRP casing was cut off 2 ft above this point before the outer protective steel casing was threaded to the connector on the steel surface conductor casing. The cement pad was poured around the surface conductor casing and connector.

1.4 Other Background

SNL-3 was drilled and completed by the West Texas Water Well Service, 3410 Mankins, Odessa, Texas, under contract from Washington TRU Solutions LLC (WTS). Coring was done by Billy Pon, Diamond Oil Well Drilling Co., Inc., P.O. Box 7843, Midland, Texas. Geophysical logging was conducted by Raymond Federwisch, Geophysical Logging Services, 6250 Michele Lane, Prescott, Arizona, under contract to West Texas Water Well Service. Geological support was provided by Dennis Powers under contract to WTS. Mike Stapleton of the New Mexico Office of the State Engineer witnessed hole completion activities (Appendix E). Well drilling wastes (brine and mud) were removed from SNL-3 and disposed of by Controlled Recovery, Inc., Hobbs, New Mexico, under New Mexico Discharge Permit DP-818 (Appendix E). Archeological clearances obtained from the U.S. Bureau of Land Management were based on field work and reports by Mesa Field Services, Carlsbad, New Mexico (Appendix F). Cores from SNL-3 were photographed with digital cameras; a photo log is included in Appendix G. Electronic images can be requested from WTS.

1.5 Acknowledgements

Drafts of this document were reviewed by Mark Crawley, Wayne Stensrud, Rick Salness, Joel Siegel, and Rick Beauheim, and their comments improved the final report. Mark Crawley (Washington Regulatory and Environmental Services - WRES) provided field support and information on well development. Doug Lynn (WRES) obtained permits and provided permitting and regulatory information included in appendix material. Ronnie Keith and Rodney Dutton (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. Ray Federwisch (Geophysical Logging Services) provided the printed and electronic files that were used to develop Figure 2-1. Chris Mahoney checked certain files and figures and provided data files for sections. Vivian Allen (L&M Technologies) provided useful editorial guidance.

Table 1-1. Summary of Drilling and Well Completion Records for Hydrologic Drillhole SNL-3 (C-2949)

LOCATION: Southeast ¼, Section 34, Township 21 South (T21S), Range 31 East (R31E)

SURFACE COORDINATES: The well is located 2,369 ft from the south line (fsl) and 2,701 ft from the west line (fwl) of Section 34. The New Mexico State Plane (NAD 27) horizontal coordinates in feet are 522141.31 North, 675336.57 East (Fig. 1-2 shows the survey plat). UTM horizontal coordinates (NAD27, Zone 13) in meters were calculated for SNL-3 using Corpscon for Windows (v. 5.11.08): 616102.67 East, 3589046.84 North. Figure 1-1 shows a 1,000-m UTM coordinate grid.

ELEVATION: All depths used in geological and geophysical data here are reported below ground level (bgl), which is taken as 3,488 ft above mean sea level (amsl), the rounded value for the brass tablet benchmark (3,488.26 ft amsl) adjacent to the cement well pad. The primary datum for the completed well is 3,490.34 ft amsl (NAVD 29) for a mark on the top of the casing inside the protective well pipe. Figures 1-3 and 1-4 show the as-built configuration of SNL-3.

DRILLING RECORD:

Dates: Began drilling August 14, 2003; drillhole reamed to completion depth (970 ft) on August 25, 2003. Final geophysical logging was conducted on September 10, 2003. Drillhole was prepared for casing, and was cased and cemented September 11, 2003. Rig was moved off the drillpad September 12, 2003. SNL-3 well development began September 17, 2003; the pump was removed on September 18, 2003. On April 1, 2004, SNL-3 was further developed by jetting across the screen interval, and 2,366 gallons were pumped from the well after jetting (Appendix B).

Circulation Fluid: SNL-3 was drilled to 212 ft bgl with circulating air. The hole was drilled and cored from 212 ft bgl to 782 ft bgl (below Culebra) using Baroid Quik-Foam® and fresh water mist driven by compressed air. From 782 ft bgl to total depth (970 ft bgl), the drillhole was cored and drilled using circulating brine with Flowzan® biopolymer (MSDS# 463650) in a portable mud pit. After coring was completed at 881 ft bgl, the upper 30 ft was reamed and a permanent surface conductor casing was cemented. After geophysical logging and plugging the lower part of the drillhole, SNL-3 was reamed to a final diameter (12.25 inches) to 785 ft using circulating brine with Flowzan® in a portable mud pit.

Cored Intervals: 4.0-inch core was taken through these intervals (depths from drilling data):
631.0-672.9 ft bgl: lower Forty-niner, Magenta Dolomite, and upper Tamarisk Members
719.6-881.0 ft bgl: lower Tamarisk, Culebra Dolomite, and Los Medaños Members; and upper Salado Formation

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-3 (C-2949), continued.

Drillhole Record:

Size (inches)	From (ft bgl)	To (ft bgl)
18	0	30
12.25	30	785
7.875	785	970

Casing Record:

Outside diameter (inches)	Inside diameter (inches)	Weight/ft (pounds)	From (ft bgl)*	To (ft bgl)
13.38	12.72	48 steel	0	30
4.83	4.33	3.20 FRP** blank	-2.0	756.0
4.83	4.33	3.20 FRP screen	756.0	773.0
4.83	4.33	3.20 FRP blank	773.0	783.5

*Top of the casing connector is the reference for depth denoted below ground level (bgl). The FRP extends 2 ft (-2) above the connector casing.
**FRP: fiberglass reinforced plastic

Coring Record:

Core Run No.	Depth Interval (ft) From	To	Interval (ft) Cored	Recovered	Recovered %
1	631	657	26	26.4	101.54%
2	657	672	15	15.5	103.33%
3	719.6	750	30.4	30.4	100.00%
4	750	762.5	12.5	8	64.00%
5	762.5	782	19.5	7.5	38.46%
6	782	812	30	27.2	90.67%
7	812	839	27	15.2	56.30%
8	839	856	17	10	58.82%
9	856	881	25	22.4	89.60%
		Totals	202.4	162.6	80.34%

Note: Marked core depths (e.g., Appendix C) vary slightly within core interval depths partly due to differing recoveries and estimates of lost core intervals.

Figure 1-3
SNL-3 As-Built Diagram

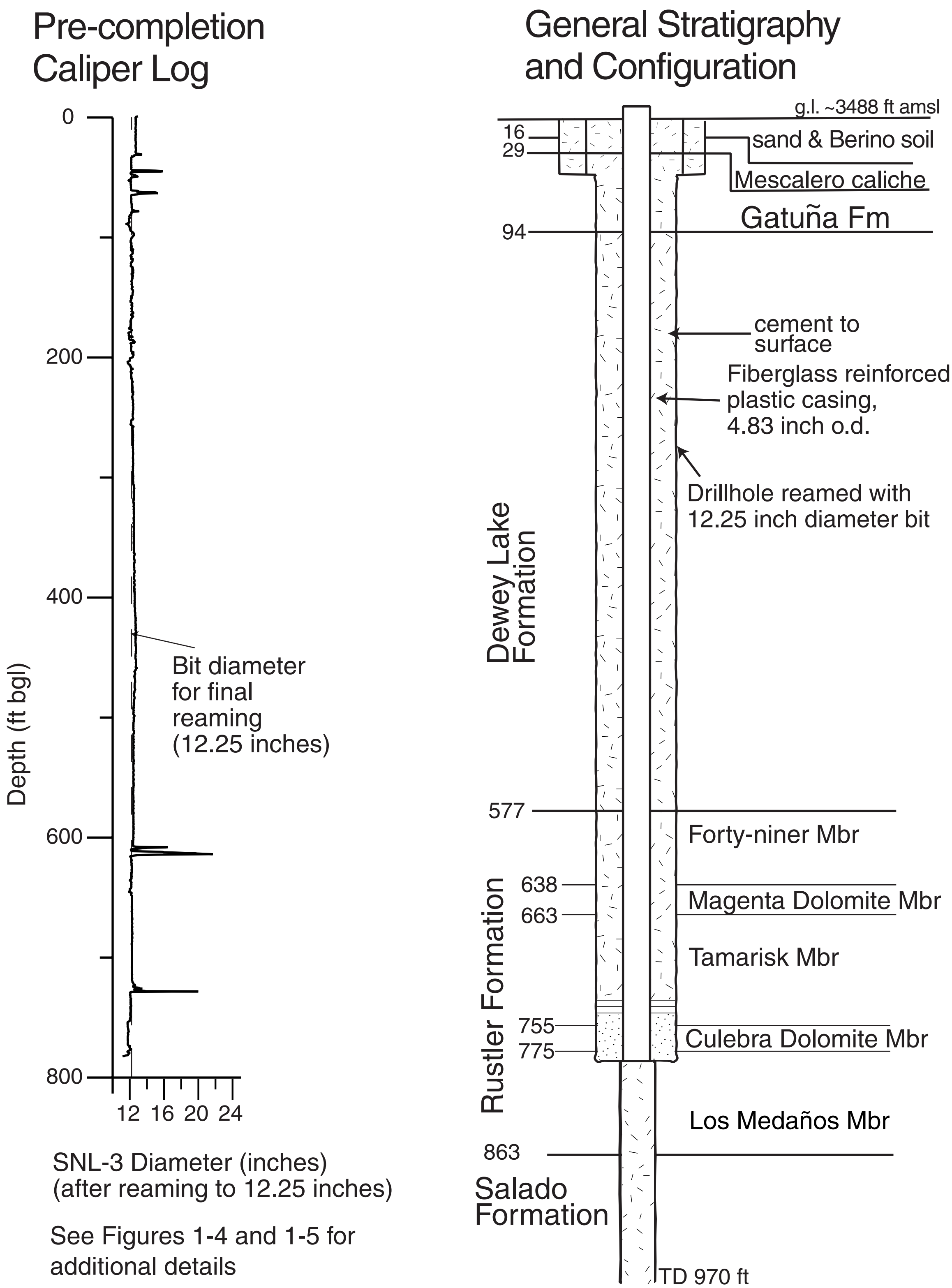


Figure 1-4
SNL-3 Completion and Monitoring Configuration (9/11/03)

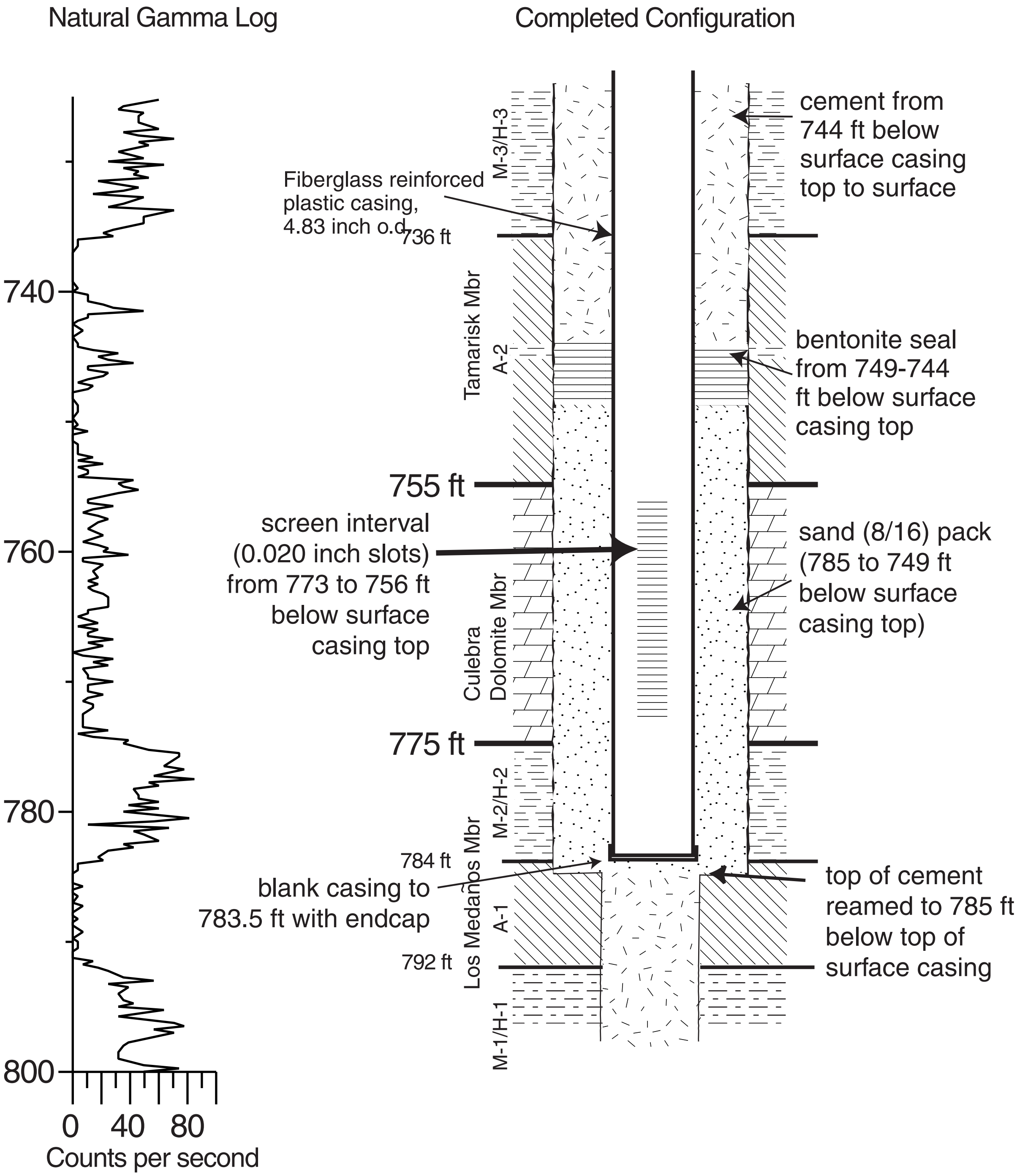
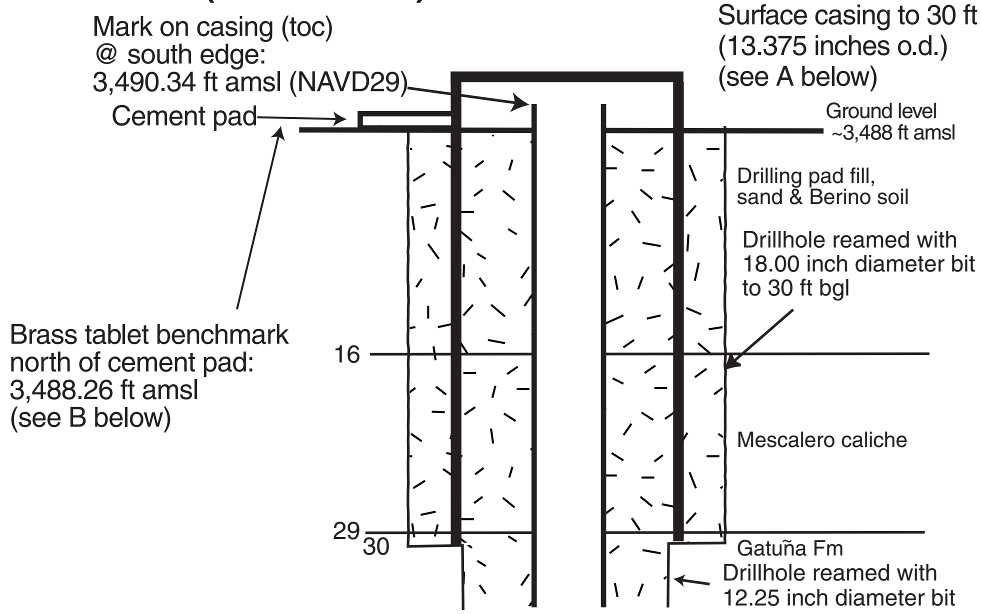
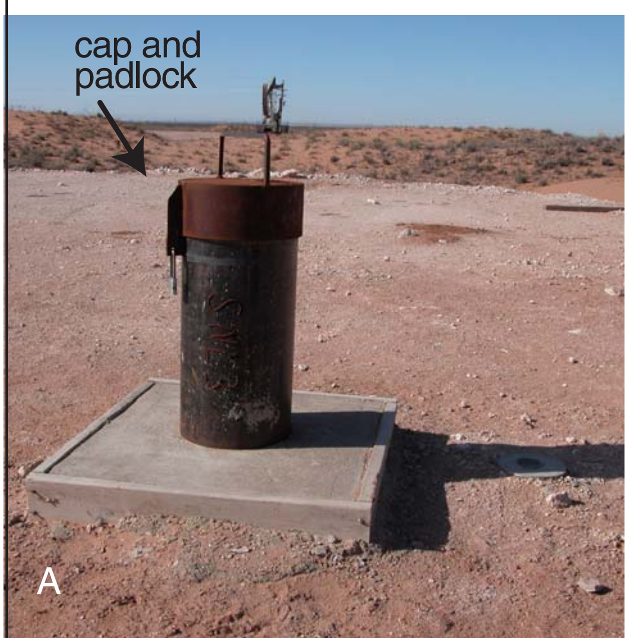


Figure 1-5
SNL-3 Surface Configuration and Elevations (9/23/03)



A - Surface casing for SNL-3 with cap and padlock.

B - Detail of brass tablet benchmark on north side of SNL-3 cement pad. Enlarged inset of brass marker, with elevation 3,488.26 ft amsl.



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 the CCA submitted in 1996 by the DOE to the EPA (U.S. Department of Energy, 1996). Some salient features of the broader geological history, as well as more recent work on the geohydrology of the Rustler (e.g., Holt, 2002; Powers, 2002a, 2003a; Powers and others, 2003), are relevant to understanding the geology and hydrology at SNL-3.

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. The basin filled with sediments, and it no longer significantly limited the area of sedimentation. 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, continental environments prevailed, and significant redbeds were deposited. Although surrounding areas accumulated variable thicknesses of later Mesozoic and Cenozoic age sediments, the WIPP area appears to have mainly been subject to erosion during an extended period. Some basin tilting from mid-to-late Cenozoic 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-3

SNL-3 encountered a normal stratigraphic sequence for this area north of the WIPP site area, from ground level to total depth (Table 2-1; Fig. 2-1). Units encountered ranged from unconsolidated surficial sands to the upper part of the Permian Salado Formation. Structural, sedimentological, and diagenetic features were examined during investigation using cuttings, cores, and geophysical logs. A poorly consolidated sand in the upper Salado at SNL-3 has not been observed in other drillholes of this series. Details of the sedimentology of the Rustler will extend understanding of that unit. Units above the Rustler did not yield noticeable water during drilling.

The geologic units encountered in SNL-3 are described from total depth 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 logs and drilling depths is generally slight. The largest differences commonly resulted from depths and core markings through intervals of partial core recovery when compared to later geophysical logs. Decisions about placing screen intervals and annulus fillings were based on depths indicated by geophysical logs (Appendix D).

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 Salado Formation

Only the uppermost Salado (~ 18 ft) was cored in SNL-3. The core provides a record of the transition from the Salado to the Rustler and any dissolution that may have affected the upper Salado or basal Rustler.

Table 2-1
Geology at Drillhole SNL-3

	System/ **Period/**Epoch	**Formation or unit**	**Member** *Informal units*	**Depth below surface (ft)[1]**
Cenozoic	Holocene	surface dune sand and Berino soil		0 - 16 ft
Cenozoic	Pleistocene	Mescalero caliche		16 - 29 ft
Cenozoic	Miocene-Pleistocene	Gatuña		29 ft - 94 ft
Mesozoic	**Triassic**	Santa Rosa[2]		eroded
Mesozoic	**Triassic**	Dewey Lake[3]		94 ft - 577 ft
Paleozoic	**Permian**	Rustler	Forty-niner *A-5* *M-4/H-4* *A-4*	577 ft - 638 ft *577 ft - 608 ft* *608 ft - 621 ft* *621 ft - 638 ft*
Paleozoic	**Permian**	Rustler	Magenta Dolomite	638 ft - 663 ft
Paleozoic	**Permian**	Rustler	Tamarisk *A-3* *M-3/H-3* *A-2*	663 ft - 755 ft *663 ft - 721 ft* *721 ft - 736 ft* *736 ft - 755 ft*
Paleozoic	**Permian**	Rustler	Culebra Dolomite	755 ft - 775 ft
Paleozoic	**Permian**	Rustler	Los Medaños[4] *M-2/H-2* *A-1* *M-1/H-1*	775 ft - 863 ft *775 ft - 784 ft* *784 ft - 792 ft* *792 ft - 863 ft*
Paleozoic	**Permian**	Salado	 *?Marker Bed 100* *Marker Bed 101* *Marker Bed 102* *Marker Bed 103*	863 - total depth (970 ft) *?* *?* *?* *931 ft - 948 ft*

[1]Depths are based on measurements by geophysical logging; drilling and coring provided supplemental data to total depth (TD) of 970 ft bgl. Geological logs based on field descriptions (Appendix C) and markings on cores (Appendix G) vary modestly because of incomplete recovery and lesser precision using cuttings.

[2]The Santa Rosa Formation, part of the Dockum Group or undifferentiated Triassic, is apparently completely eroded at SNL-3.

[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.

The program plan (Sandia National Laboratories, 2003) outlined a potential drilling target of a marker bed (possibly MB103) in the upper Salado. Powers (2002a, 2003a) estimated before drilling that this location had been affected by dissolution of upper Salado halite, based on the thickness of the interval between the Culebra Dolomite Member of the Rustler Formation and the Vaca Triste Sandstone Member of the Salado Formation in surrounding industry drillholes. The core provides direct stratigraphic and textural evidence to investigate any dissolution at the top of the Salado. Drilling beyond the uppermost Salado to an identifiable marker bed (possibly MB103) was expected to help in relating thickness changes of the larger stratigraphic interval to dissolution, if any, of upper Salado halite.

The upper Salado is dominated by coarse halite ranging in color from white to orangish or reddish-brown from included accessory minerals. From 970 to 881 ft, cuttings and drilling rates indicated halite with a sulfate from 948–931 ft. Relatively high natural gamma through this interval indicate that the sulfate is at least partially polyhalite [$Ca_2K_2Mg(SO_4)_4 \cdot 2H_2O$]. Depositional cycles (either Type 1 or Type 2) defined by Lowenstein (1988) are only partially represented in the core from SNL-3 (Fig. 2-2). The halite sequence is similar to part of the idealized sequence described by Holt and Powers (1990a,b). From the base of the core at 881 ft upward to 877 ft, the halite beds of the basal part of the depositional cycle display coarse halite with few disseminated impurities, some thin bedding (1–4 inches), and some discontinuous thin sulfate laminae along bedding (stratified mud-poor halite; Fig. 2-2). Above this basal part of the cycle, from 877–872 ft, the halite crystals tend to become smaller vertically, and clastic content increases upward (silty, argillaceous halite; Fig. 2-2). At the top of this apparent cycle (from 872–870 ft), a soft, pinkish-colored sandstone that is silty and argillaceous accumulated (Fig. 2-3). This sandstone is not evident in other cores obtained recently (i.e., SNL-2, SNL-9, SNL-12). Other cores and logs from this area are expected to be carefully reexamined as the cores from this program are studied regarding the Salado–Rustler transition and dissolution of upper Salado halite.

From 870–863.4 ft, there are two sequences of siliciclastics with overlying thin gypsum beds. There is no visible halite in these two sequences. The lower sequence, from 870–867 ft, is dominantly sandy, argillaceous siltstone. It displays both mottling and some bedding on a scale of ~0.5 inch. This sequence may be a continuation of the deposition of the underlying sandstone, as the sand grains appear generally similar. The upper siliciclastic sequence is a silty, sandy claystone that is gray and mottled. It includes clasts or smeared intraclast textures (Powers and Holt, 2000). The gypsum or gypsiferous beds at 867.7 ft, 866.5–867 ft, and 863.4–863.8 ft include thin laminae, with limited deformation. The top of the Salado has been assigned to the top of the gypsum in cores at 863.4 ft, following Holt and Powers (1990a,b) and Powers and Holt (1999). This gypsum marks the beginning of the fresher water in the basin that was followed by basal clastics of the Rustler Formation.

As discussed in Section 4.0, SNL-3 was drilled in an area where a reentrant of upper Salado dissolution has been inferred (Powers, 2002a, 2003a). The core from SNL-3 has not revealed macroscopic features of large strain or fractures that might accompany such dissolution. Detailed examination of cores and comparison with nearby drillholes will help differentiate between depositional and dissolution processes leading to thinner intervals across the Salado–Rustler contact.

2.2.2 Permian Rustler Formation

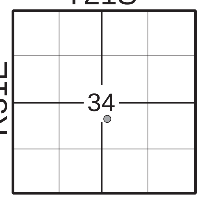
The Rustler was completely drilled. The contact with the underlying Salado Formation is marked at 863.4 ft on the core and 863 ft on geophysical logs. The contact between the Rustler and the overlying Dewey Lake Formation is at 577 ft bgl, and the total Rustler thickness at SNL-3 is 286 ft.

Figure 2-1
Well Record SNL-3 (C-2949)

Company: Washington TRU Solutions LLC
Well: SNL-3 (C-2949)
Section: 34 Twp: T21S Rge: R31E
Location: 2,369 ft from south line (fsl)
2,701 ft from west line (fwl)

T21S

R31E



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

Elevation
KB:
DF:
GL: 3488 ft amsl
(benchmark: 3488.26)

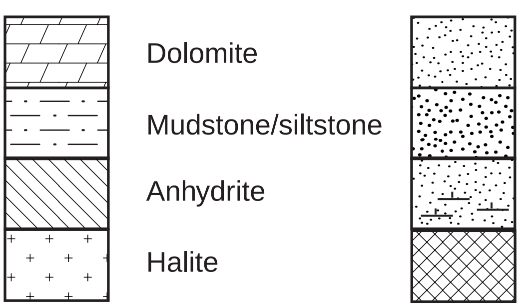
Drilling contractor: West Texas Well Water Service
Coring contractor: Diamond Oil Well Drilling Co.
Geophysical logs: Raymond Federwisch
Geophysical Logging Services (AZ)
Geologist: Dennis W. Powers
Spud date: August 14, 2003
Completion date: September 11, 2003
Total depth (TD): 970 ft bgl (driller log)

Casing Record
Conductor: 30 ft
13.375 inch steel
Casing: 4.83 inch o.d.
fiberglass reinforced
plastic to TD
Screened interval:
773-756 ft

Geophysical Logs Date: August 26, 2003	
Micro/Laterolog/Induction/SP:	0-970 ft
Gamma/Fluid:	0-970 ft
Caliper:	0-970 ft
Density/Neutron:	0-970 ft

Type fluid in hole: Brine
Res mud: 0.42 ohm-m.
Res mud filtrate:
9.2 ohm-m.
Max. Rec. Temp.:
26.27^{o}C

General Lithologic Symbols Used



Symbol		Symbol	
	Dolomite		Fine sandstone & siltstone
	Mudstone/siltstone		Coarse sandstone
	Anhydrite		Sandstone w/caliche
	Halite		Polyhalite

SNL-3 Well Log Headers

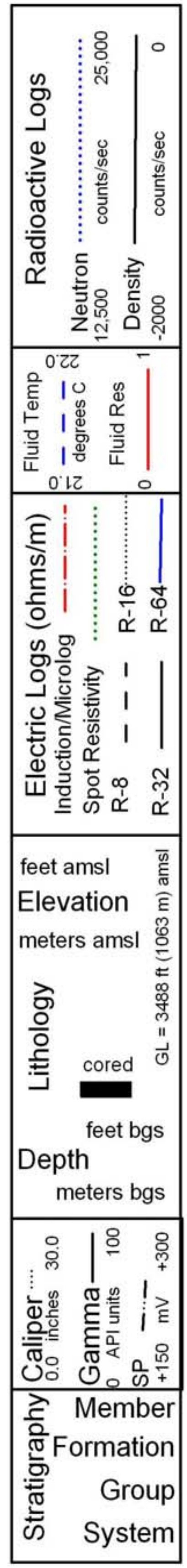
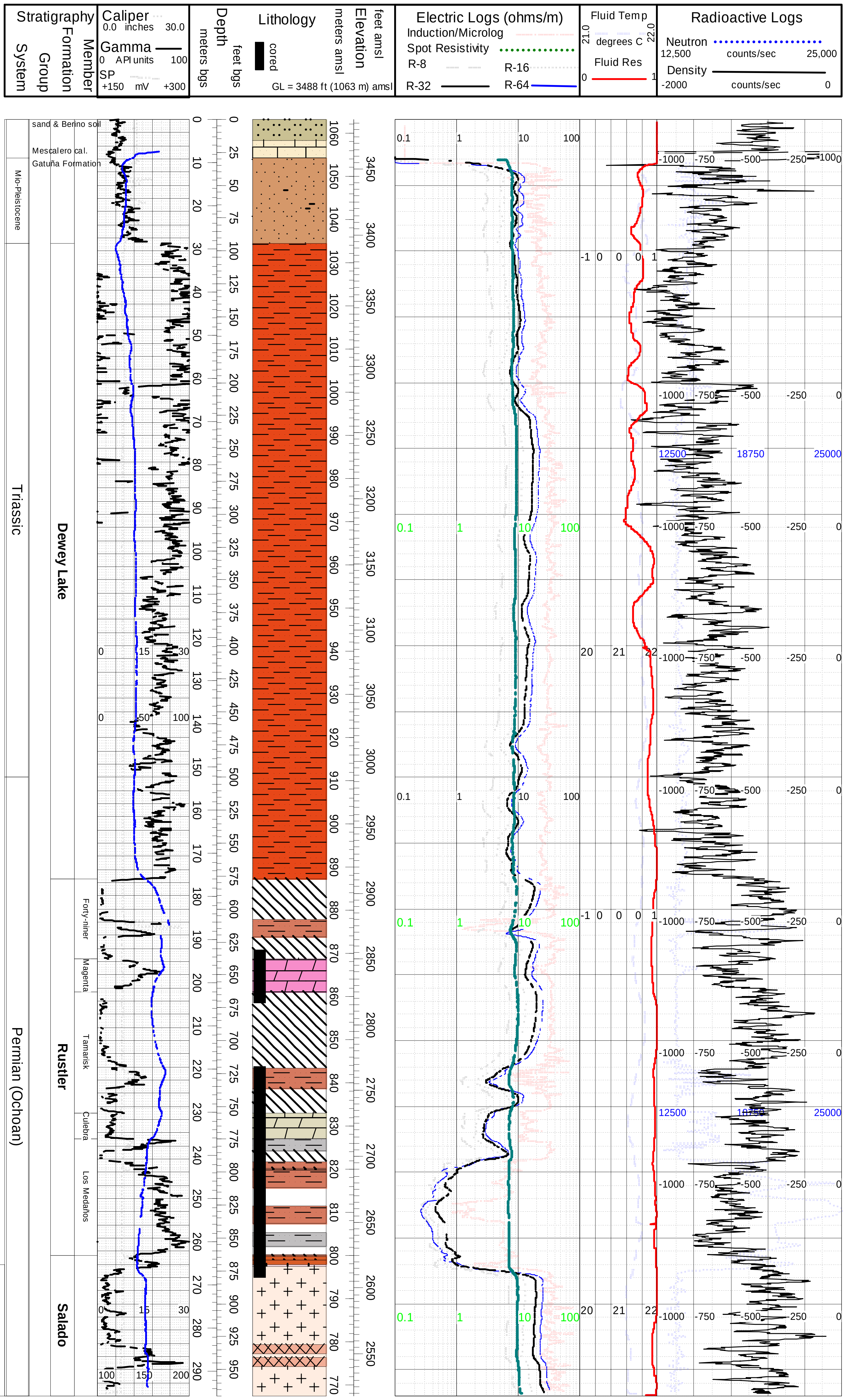


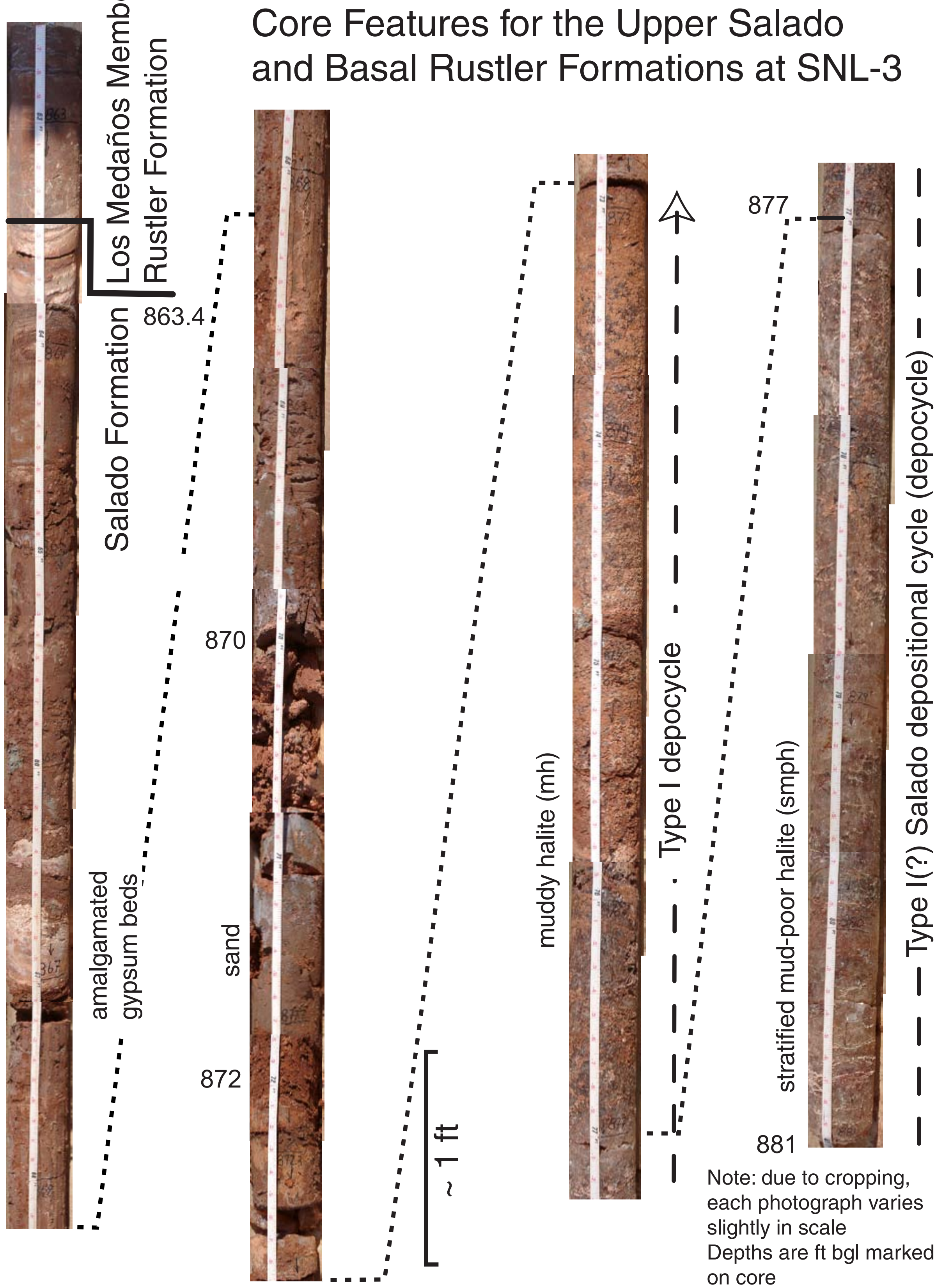
Figure 2-1 Log Title & Header page.ai



Stratigraphy
System
Group
Formation
Member
Caliper
0.0 inches 30.0
Gamma
0 API units 100
SP
+150 mV +300
Depth
meters bgs
feet bgs
Lithology
cored
Elevation
meters amsl
feet amsl
GL = 3488 ft (1063 m) amsl
Electric Logs (ohms/m)
Induction/Micrlog
Spot Resistivity
R-8
R-16
R-32
R-64
Fluid Temp
21.0 degrees C 22.0
Fluid Res
0 1
Radioactive Logs
Neutron
12,500 counts/sec 25,000
Density
-2000 counts/sec 0
sand & Berino soil
Mescalero cal.
Gatuña Formation
Mio-Pleistocene
Triassic
Permian (Ochoan)
Dewey Lake
Rustler
Salado
Forty-niner
Magenta
Tamarisk
Culebra
Los Medaños

page 15-16

Figure 2-2
Core Features for the Upper Salado and Basal Rustler Formations at SNL-3



Note: due to cropping, each photograph varies slightly in scale
Depths are ft bgl marked on core

Figure 2-3
Sand in Upper Salado
Between 870-872 ft bgl

2.2.2.1 Los Medaños Member

The Los Medaños Member of the Rustler Formation 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 (Fig. 2-4), because halite below A-1 is not restricted to the thinner zone designated M-1/H-1 in these earlier publications.

The entire thickness (88 ft) of the Los Medaños was cored in SNL-3, although significant portions of the unit were only partially recovered (Table 1-1).

The informal unit *mudstone-halite 1* unit (M-1/H-1; Fig. 2-4) (Holt and Powers, 1988) is considered here to extend from the top of the Salado at 863 ft to 792 ft (based on geophysical logs) or from 863.4 ft to 791.6 ft (based on core markings). M-1/H-1 includes the bioturbated clastic interval and sandy transition without separation.

At the base of M-1/H-1 at SNL-3, ~0.6 ft of reddish brown (~2.5YR4/4; Munsell Soil Color Chart, 1971 edition; dry sample colors unless noted as wet) sandstone overlies the gypsum considered the top of Salado (Figs. 2-2, 2-5). The sandstone is thin bedded to laminar, with an erosional contact above the base. A sulfate clast is included, and the base appears conglomeratic. The erosional contact is stratigraphically equivalent to more substantial erosion and channeling observed elsewhere in WIPP shafts and cores (Holt and Powers, 1990a,b; Powers and Holt, 1999).

From ~862.8 to 846 ft bgl, M-1/H-1 is dominated by gray (10YR5/1) silty, argillaceous sandstone that is generally uniform in grain size through the interval. Thin laminae to thin beds are common, with bed thickness ~0.25 inch. Some small cross-bedding occurs near the base of this interval. Some of the bedding appears modestly disturbed by bioturbation in the form of mottling and circular to oval discoloration on the core surface. Holt and Powers (1988) also informally described this portion of the Los Medaños as the bioturbated clastic interval.

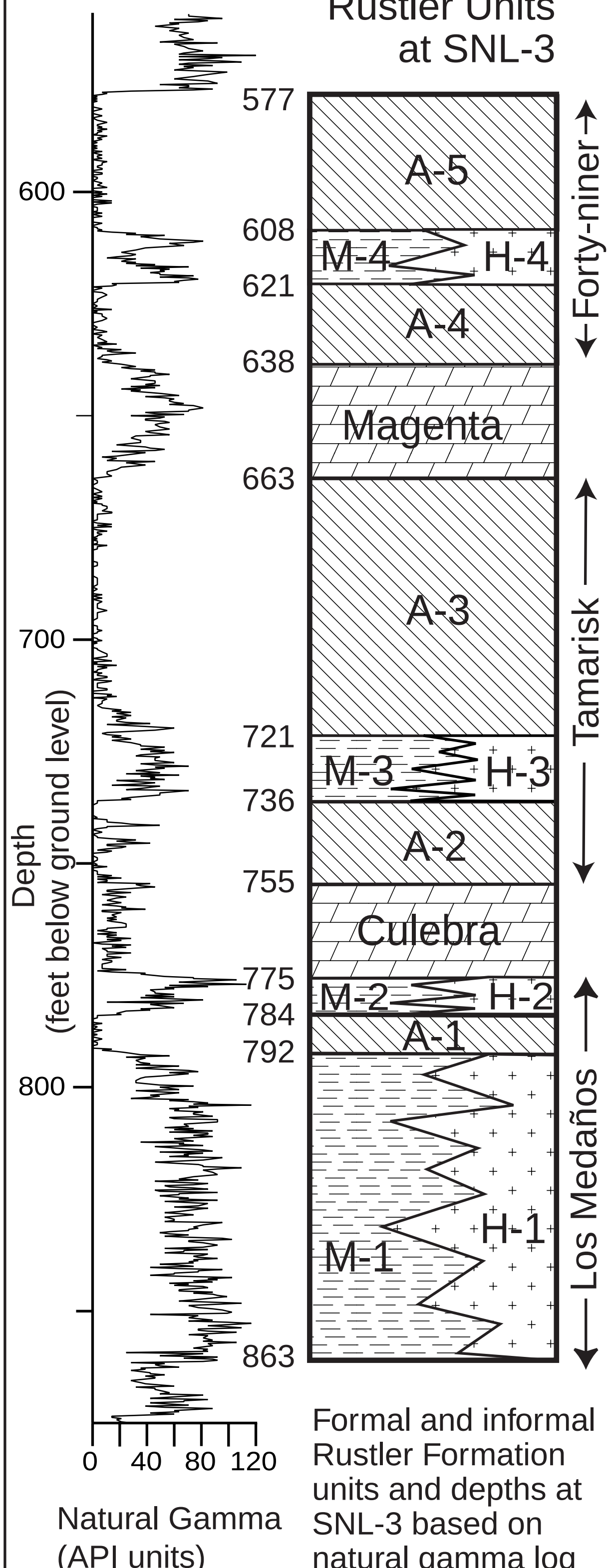
The cores within this same interval revealed blocks or fragments near the base. The core surface from the upper portion of this interval displays vertical to diagonal washouts that are indicating probable fracturing (Fig. 2-6). There is little macroscopic evidence of open apertures. The interval is slightly calcareous, but it does not include halite or gypsum cements.

The core interval marked from 839–823.8 ft is dominated by reddish brown (~2.5YR4/4) sandstone that is very fine grained and silty. Local zones of greenish gray (10YR6/3; light brownish gray) sandstone are also present. Grain size is generally uniform through the interval. The cores generally show thin bedding, although the zone from ~ 832–835 ft is apparently featureless.

In this interval, neither halite nor sulfate were observed, but some cores are slightly calcareous. The cores are not well indurated. Possible high-angle fractures, with silt fill, occur from 836–837 ft. A vertical fracture occurs from 831.4–831 ft. Short segments show diagonal washouts on core surfaces that also probably indicate fracturing.

The cores from the interval from ~809.2–791.6 ft are dominated by dark reddish brown (2.5YR3/4) to reddish brown (2.5YR4/4) silty sandstone and sandy siltstone with some grayish zones. Two thin interbeds of gray, laminated anhydrite were recovered from 798.5–798.3 ft and 797.5–797 ft. Thin interbeds of gypsum, ~ 0.25 inch thick, are widely spaced in the sandstone below the lower anhydrite interbed. Reddish brown siltstone fills the interval between the sulfate beds and overlies the upper anhydrite. Bedding is thin and nearly horizontal throughout much of the interval; some

Figure 2-4
Rustler Units
at SNL-3



Formal and informal Rustler Formation units and depths at SNL-3 based on natural gamma log

Figure 2-5
Amalgamated(?) Sulfate Beds at Top of Salado at SNL-3

Figure 2-6
Diagonal Slight Washouts Indicating Fractures in the Lower Los Medaños at SNL-3

bedding appears slightly wavy or irregular. Possible smeared intraclast textures were observed from 800–804 ft. Siltstone clasts overlie erosion surfaces on each of the thin anhydrites.

The informal unit *anhydrite 1* (A-1; Fig. 2-4) (Holt and Powers, 1988) was encountered from 792–784 ft bgl, based on the natural gamma log from SNL-3 (Figs. 2-1, 2-4). Based on the drilling records and apparent loss of core from the unit above A-1, the core of A-1 was attributed to the interval from 791.6–783.1 ft bgl and was marked accordingly. The sedimentology of A-1 is discussed according to core depth markings.

A-1 at SNL-3 is a single bed. At SNL-2 and SNL-9 (Powers and Richardson, in review), thin anhydrites occur below A-. At SNL-2, the intervening clastic unit was thin and the underlying sulfate beds were included in A-1. More detailed log and core studies should determine the detailed correlations of these units.

A-1 is composed of anhydrite and gypsum that are gray. Thin beds and laminae are near horizontal. Stylolites, or crinkly bedding, were noted at 789.8 ft, 787.6 ft, 786.1 ft, and 784.4 ft; the upper stylolite is most developed. Upper and lower contacts are sharp, and the upper contact is likely to be erosional.

The informal unit *mudstone-halite 2* (M-2/H-2; Fig. 2-4) (Holt and Powers, 1988) was encountered from 784–775 ft bgl, based on the natural gamma and caliper logs from SNL-3 (Figs. 2-1, 2-4). Only 1.1 ft of core was recovered from this interval, and it is believed to directly overlie A-1. The core reveals a conglomerate of gypsum and anhydrite clasts to 1-inch diameter. They are subangular to subrounded, with clay and sulfate matrix. The core from SNL-2 from this interval also revealed conglomerate at the base of M-2/H-2 (Powers and Richardson, in review).

The upper contact with the overlying Culebra Dolomite Member was not recovered in cores.

2.2.2.2 Culebra Dolomite Member

Based on the natural gamma log from SNL-3, the Culebra extends from 775.0–755.0 ft bgl, a thickness of 20 ft (Fig. 2-1). Based on drilling depths available at the time, the recovered Culebra core was marked from ~770 to 754.2 ft bgl (as used in information in Appendices C and F). Recovered Culebra core (Fig. 2-7) totals ~11 ft thick, indicating a core loss of ~9 ft from this unit. Based on the drilling activity and recovery of adjacent units, the core loss was attributed to two zones, both in the upper middle and base of the Culebra (see Appendix C, sheets 5 and 6).

Holt and Powers (1988) found a range of 20–30 ft thickness in Culebra cores 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 because of the porosity of that zone.

The dolomite recovered in core from SNL-3 is commonly pinkish gray (7.5YR7/2). The core from run 5 was very fragmented, with larger sections indicating high-angle fractures with very fine apertures. Gypsum is rare, and most blocks show few vugs or pores. The upper Culebra recovered in core run 4 is better preserved, although it is fractured in elongate blocks with fresh surfaces. Vugs (~0.125–1.0 inch) are present in the interval above 758 ft, but they are not abundant. Sparse larger vugs are elongate along bedding planes. A thin (0.1 ft) light reddish brown (5YR6/3) organic-rich zone is present at the top of the Culebra.

The basal hydrostratigraphic unit (CU-4) proposed for the Culebra by Holt (1997) does not appear to have been recovered in cores. The partial core recovered from ~770–762.5 ft probably represents some combination of CU-3 and CU-2, but the vuggy porosity that generally marks these hydrostratigraphic units is poorly sampled. The core from the upper Culebra is characteristic of hydrostratigraphic unit CU-1.

The geophysical logs of the Culebra provide a few additional details of the unit. The natural gamma increases from a relatively low value of ~10–15 API (American Petroleum Institute) units

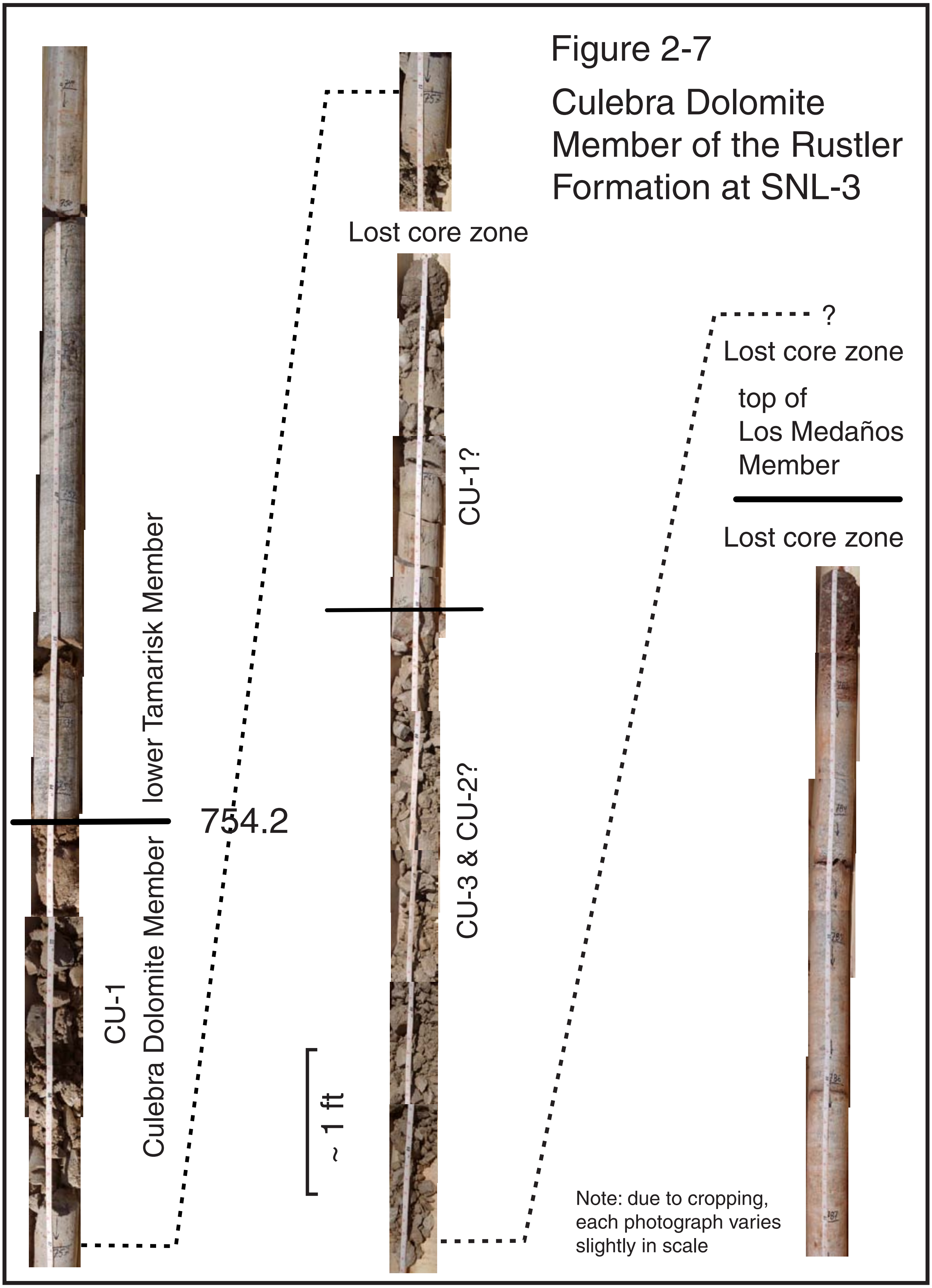


Figure 2-7
Culebra Dolomite
Member of the Rustler
Formation at SNL-3
Lost core zone
?
Lost core zone
top of
Los Medaños
Member
Lost core zone
lower Tamarisk Member
754.2
Culebra Dolomite Member
CU-1
CU-1?
CU-3 & CU-2?
~ 1 ft
Note: due to cropping,
each photograph varies
slightly in scale

(Fig. 2-4) near the base of the unit and then increases toward the top, with small spikes. This most likely represents a modest, general increase upward in clay minerals and possibly organic content. The resistivity log shows a distinctive, lower resistivity zone through the Culebra with two thin zones of higher microresistivity. The fluid resistivity log through the Culebra does not appear to be significantly affected by influx of less saline water, though the fluid temperature log does show a broad, slight decrease centered on the Culebra.

2.2.2.3 Tamarisk Member

The natural gamma log of SNL-3 shows that the Tamarisk Member occurs from 755–663 ft bgl (Fig. 2-1). The Tamarisk comprises three basic subunits: a lower anhydrite, a middle mudstone to halite, and an upper anhydrite; all three are clearly shown by geophysical logs and were recorded by cuttings during drilling. Powers and Holt (2000) labeled these A-2, M-3/H-3, and A-3, respectively, and showed that the lateral gradation from mudstone M-3 to halite H-3 reflects lateral changes in deposition. SNL-3 is located in the mudflat or M-3 facies of these beds. The basal 34.6 ft and upper 10.8 ft of the Tamarisk were cored; the remainder of the unit is described on the basis of cuttings and geophysical logs.

The informal unit *anhydrite 2* (A-2; Fig. 2-4) (Holt and Powers, 1988) at the base of the Tamarisk is 19 ft thick (755–736 ft bgl) on the geophysical logs. Core retained from the interval was marked from 754.2–735.2 ft, an interval thickness of 19 ft. A-2 is predominantly gray anhydrite, with some gypsum as well as thin claystone interbeds.

Above the contact with the Culebra (Fig. 2-7), A-2 has subhorizontal bedding and laminae from 754.2–745.2 ft, with dips to ~15 degrees from horizontal. The lower contact displays fine, crinkly laminae that probably result from algal growth. Silty claystone occurs at 753 ft. There are some possible nodular textures below 747 ft.

A silty claystone in the core from ~745.2–744 ft is reddish brown (2.5YR4/4) and has thin laminae at the top. This zone has numerous thin gypsum-filled fractures ranging from subhorizontal to subvertical. There are slickensides on many fractures.

Gray anhydrite from 744–741 ft includes fractures, dipping ~45 degrees from vertical, filled with reddish-brown clay.

The claystone from 741–740.5 ft is reddish-brown (2.5YR4/4) and thinly laminated. A fracture, dipping ~45 degrees from vertical, has slickensides parallel to the dip.

From 740.5–735.2 ft, gray anhydrite and gypsum appears to be nodular and bedded. The interval also includes disseminated gray clay or organic material. The upper contact is sharp.

The informal Tamarisk unit *mudstone-halite 3* (M-3/H-3; Fig. 2-4) (Holt and Powers, 1988) is 15 ft thick (736–721 ft bgl) at SNL-3, based on the geophysical logs. The cored interval marked from 735.2–721.5 ft corresponds to the logged interval, and the thicknesses are consistent within the limits of interpreting the logs.

The basal contact with A-2 is sharp and is erosional. M-3 is dominantly claystone and siltstone that can be subdivided by color and by vertical grain size changes. The unit is reddish brown (2.5YR4/4-5/4) from 735.2–723 ft and is gray (2.5YRN5/-N3/) from 722.4–721.5 ft. A gray gypsum bed from 723–722.4 ft includes some dark gray clay, some possible thin clay laminae, and is inclined at a very high angle from horizontal. From 735.2–728 ft, the claystone is conglomeratic with pebbles decreasing upward.The upper contact may be erosional, and there is some loading deformation. A second fining-upward sequence of argillaceous siltstone to silty claystone occurs from 728–725 ft, and a third sequence occurs from 725–723 ft. Some bedding is apparent in these fining-upward sequences. Slickensides occur on fractures in claystone dipping ~45 degrees from vertical, and there is some fibrous gypsum filling some fractures. The gray claystone from 722.4–721.5 ft is bedded, and the bedding is inclined.

The informal unit *anhydrite 3* (A-3; Fig. 2-4) (Holt and Powers, 1988) occurs from

721–663 ft bgl on geophysical logs, a thickness of 58 ft. Core markings for the base and top, respectively, for this unit are 721.5 ft and 662.1 ft, for a thickness of approximately 59.4 ft. The upper and lower contacts were cored, and the main part of the unit was drilled.

Approximately 1.9 ft of the basal A-3 were cored, and this part of the unit is mainly gray gypsum and anhydrite overlain by anhydrite conglomerate. From 721.5–719.8 ft, the gypsum and anhydrite is laminar, with a high-angle basal contact. From 719.8–719.6 ft, the core reveals a conglomerate of anhydrite clasts to 0.5-inch diameter in a clay and sulfate matrix.

Most of A-3 was not cored, and the drilling returned few cuttings for examination. The geophysical log for natural gamma (Fig. 2-1) indicates increased natural gamma for the conglomerate near the base of A-3 associated with the clay matrix. The natural gamma decreases upward to 715 ft on the log; this may indicate the upper limit of the conglomeratic zone. From 720–707 ft, the microresistivity log shows four zones of relatively high resistivity, indicating zones of lower porosity. The bulk of A-3 displays low natural gamma and other log properties consistent with relatively uniform anhydrite.

Core from the upper 10.8 ft of A-3 is a brownish-gray bedded anhydrite with some coarse gypsum and thin (1–2 inch) carbonate bands. Scattered nodules are poorly displayed. Carbonate and organic-rich zones occur at 671.4, 670.45–670.5, 668, 666.6–666.2, 665.6–665, and 663.3–663 ft. There are some horizontal fractures with filling in carbonate zones.

The contact between the Tamarisk and the overlying Magenta Dolomite Member has been placed at a relatively sharp boundary between anhydrite and dolomite. Nevertheless, the depositional change is more gradational, as the carbonate and sulfate alternate through the cored zone.

The Tamarisk stratigraphy and thickness are consistent with other drillholes and shafts in the area (Holt and Powers, 1988) and do not suggest unusual conditions. Conglomerates at the base of A-3 indicating erosion are also consistent with depositional environments proposed for the unit (Holt and Powers, 1988).

2.2.2.4 Magenta Dolomite Member

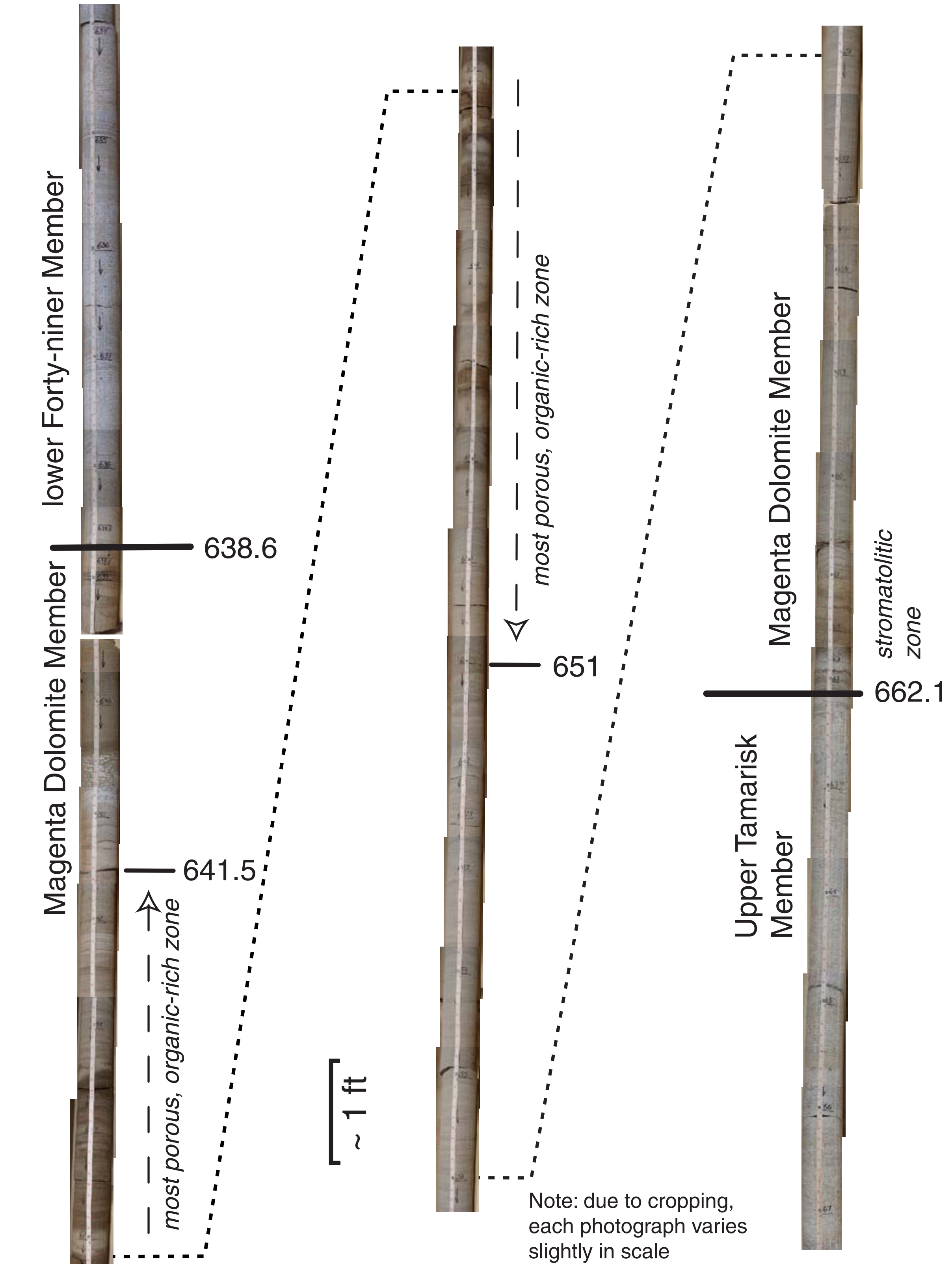
The Magenta Dolomite Member at SNL-3 is 25 ft thick (663–638 ft bgl) based on geophysical logs. Core from the Magenta is marked from 662.1–638.6 ft, a thickness of ~23.5 ft (Fig. 2-8). The entire unit was cored; recovery was excellent, with little fragmentation.

The Magenta consists of dolomite and gypsum, and it is commonly light gray (2.5YR7/2) to grayish brown (2.5YR5/2) in core. The reddish-purple color for which the Magenta is named occurs in outcrop and apparently is a consequence of weathering. The dominant characteristic of the Magenta in cores from SNL-3, like outcrops and shaft exposures of the Magenta, is strong wavy to laminar bedding. A few laminae are thicker than 0.5 inch.There are zones of small ripples on minor erosional surfaces and some isolated ripples indicating a sediment starved depositional system, along with zones of algal stromatolites. Erosional surfaces are present at 643.5 ft and 640.4 ft, and there is slight soft-sediment deformation on the erosional surface at 640.6 ft. Dolomite and gypsum grains are generally medium sand size, with some fine to very coarse grains.

The base of the Magenta includes dark layers of organic matter from low-amplitude algal stromatolites. Organic-rich laminae also occur from 646–643.5 ft and at 638.9 ft. These probable stromatolites are consistent with well-exposed algal features in the air intake shaft (Holt and Powers, 1990a; Powers and Holt, 1990). Nodular gypsum in dolomite is preserved from 640.9–640.4 ft and is overlain by one of the erosional surfaces.

The core of the Magenta appears to be most porous through the interval from 651–641.5 ft, and this coincides in part with the most organic-rich zone from 646.3–643.4 ft. The microresistivity log also decreases from ~652–641 ft. From 662.1–656 ft, gypsum increases in fractures at an angle to

Figure 2-8 Magenta Dolomite Member of the Rustler Formation at SNL-3



Note: due to cropping, each photograph varies slightly in scale bedding. A high-angle fracture was observed at 648 ft, but the unit is not greatly fractured.

Like the basal contact of the Magenta, the top contact is placed at a relatively sharp boundary in the core, but the carbonate bands in the overlying sulfate show that the depositional environment changed over some time.

The Magenta is typical in thickness, composition, and sedimentary features. The more porous zone in the upper Magenta is consistent in thickness and stratigraphic position with porous zones in many other Magenta cores, although the porosity may not be great. The Magenta is little fractured, especially compared, for example, to SNL-2, near Livingston Ridge (Powers and Richardson, in review).

2.2.2.5 Forty-niner Member

The Forty-niner Member at SNL-3 is 61 ft thick (638–577 ft bgl), based on geophysical logs. A change in drilling rates was noted at a depth of ~577 ft, consistent with the logging depths. The Forty-niner is described on the basis of cuttings and geophysical logs through the upper part of the member to the coring depth beginning at 631 ft bgl. All Forty-niner coring took place in the lower sulfate bed of the member. Like the Tamarisk, the Forty-niner consists of upper and lower anhydrites with a middle unit that ranges from siltstone and claystone at SNL-3 to halite east of the WIPP site area. Powers and Holt (2000) informally designated these units as A-4, M-4/H-4, and A-5, and 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. 2-4) (Holt and Powers, 1988), is gray to white very coarse gypsum to finer anhydrite. A-4 is 17 ft thick (638–621 ft), based on geophysical logs. The interval from drilling and coring is from 638.6–622 ft. The recovered core of A-4 from 638.6–631 ft is laminar to thin bedded, and thin dolomite beds similar to the Magenta occur at 638.6–638, 637–636.8, 635.2–634.9, 633.9, and 633.4 ft. Some nodular textures are arranged in thin beds. Thin (<0.25 inch) subhorizontal zones of fibrous white gypsum are most prominent in carbonate zones. Vertical fractures occur with fibrous gypsum fill at 637 ft. This section was placed stratigraphically in A-4 instead of the Magenta because of the dominance of gypsum and because of the continuous dolomite below 638.6 ft (as marked on the core).

Mudstone-halite 4 (M-4/H-4; Fig. 2-4) (Holt and Powers, 1988) is ~13 ft thick (621–608 ft bgl), based on the natural gamma log. Cuttings returns and drilling rates indicating clastics from ~610–622 ft are consistent with the geophysical log. Cuttings from M-4 showed a lower dark gray (7.5YRN5/) siltstone and an upper reddish-brown claystone. Neither zone was calcareous; the siltstone was better indurated than the claystone.

The natural gamma log of M-4 shows a marked decrease in the middle of the unit. This part of the unit is likely more sandy and less argillaceous, but cuttings were not sufficient to differentiate a sandy bed.

The upper sulfate unit, *anhydrite-5* (A-5), is white to gray gypsum and anhydrite ranging from coarse translucent gypsum to fine anhydrite. It is ~31 ft thick (608–577 ft bgl) at SNL-3.

2.2.3 Permo-Triassic Dewey Lake Formation

The Dewey Lake Formation has most commonly been assigned to the Permian System (e.g., Hills and Kottlowski, 1983), although there is no direct evidence, either paleontological or radiometric, of age in the vicinity of WIPP. More recently, Renne and others (1996, 2001) obtained radiometric (Ar-Ar) ages from ash beds near the base of lithologically equivalent red beds (Quartermaster Formation) in the Texas panhandle. These ages show that the basal Quartermaster is Permian, but most of the formation is early Triassic in age. Although lithologic contacts are not inherently isochronous, the particular relationships of evaporites to red beds suggest that the Dewey Lake is mainly Triassic in age (e.g., Schiel, 1988, 1994; Powers and Holt, 1999). Lucas and Anderson (1993) have asserted that the Quartermaster, and Dewey Lake, are Permian in age, but more recent direct evidence supersedes their discussion.

At SNL-3, the Dewey Lake is 483 ft thick (577–94 ft bgl) and is composed mainly of reddish brown (2.5YR5/4) interbedded sandy claystone, siltstone, sandy siltstone, and fine–grained sandstone. Small (< 0.04 inch) light olive brown (2.5YR5/4) reduction spots are a common characteristic of the Dewey Lake but are poorly recorded by the fine cuttings at SNL-3. The Dewey Lake is described on the basis of cuttings, drilling rates, and geophysical log characteristics.

Geophysical logs from SNL-3 can be interpreted to indicate different basic sedimentary regimes as well as porosity conditions (e.g., Doveton, 1986). The following information follows the basic template developed for a study of the Dewey Lake hydrogeology (Powers, 2003) and applied to other drillholes such as C-2737 (Powers, 2002b) and SNL-2 (Powers and Richardson, in review).

Only the lower two of three general depositional regimes for the Dewey Lake Formation can be clearly distinguished on natural gamma logs of SNL-3 (Fig. 2-1). The base of the third may be preserved.

The interval from 577–466 ft bgl in SNL-3 displays the natural gamma and resistivity features of the lower Dewey Lake informally called the *basal bedded zone* (Powers, 2003). The natural gamma fluctuates around a similar value (~70 cps in this case) over this vertical interval. There are zones of lower gamma, but there are no apparent trends over the entire interval. The resistivity tends to fluctuate as well, on a vertical scale of ~4–40 ft. The fluctuations are too coarse to correlate with other boreholes as is possible in some logs. The patterns are consistent with broad-scale bedding, and the interval corresponds to a bedded section clearly exposed in the air intake shaft (Holt and Powers, 1988).

The interval from 466–140 ft bgl (326 ft thick) is marked by generally upward increasing gamma above thinner low gamma units. These are interpreted as an interval of *fining upward cycles* because increasing natural gamma is frequently an indicator of finer clastic grain sizes (Doveton, 1986; Powers, 2003). The base of this interval is defined by a sandstone unit from ~466–446 ft bgl. Near the center of the site, this interval is more than 300 ft thick; at C-2737 it was 260 ft thick (Powers, 2002b). West of SNL-3, at SNL-2, sandstones of the upper fining upward cycles are removed by erosion (Powers and Richardson, in review).

The natural gamma log through the *fining upward cycles* shows a marked decrease over the interval from 214–200 ft, corresponding to very fine to medium grained reddish brown sand and sandstone cuttings. The sand grains are subangular to well rounded and include few opaque grains. This unit corresponds to sandstone 1 (*ss1*), a persistent sandstone in this stratigraphic interval (Powers, 2003).

The natural gamma appears to decrease somewhat above 140 ft to the top of the preserved Dewey Lake at 94 ft. This interval is tentatively attributed to the third sequence, a slight coarsening upward cycle at the top of the Dewey Lake in drillholes to the east of this area.

The broad sedimentological units definable by natural gamma logs for the Dewey Lake are present and are generally representative below the erosional surface at 94 ft.

Cuttings from the upper Dewey Lake were slightly calcareous to a depth of ~225 ft bgl. Below ~225 ft bgl, cuttings included gypsum and were non-calcareous. Resistivity logs show an increase at ~230–200 ft bgl, across the interval including *ss1*. Across the same interval, fluid temperature decreases ~0.5 degree C. These changes suggest there may be may be slight inflow from *ss1* to the drillhole, although none was observed during drilling (see Section 3.0). The neutron flux and density logs are not helpful in defining this change in minerals cementing the Dewey Lake.

The boundary between natural carbonate (above) and sulfate (below) cements in the Dewey Lake at ~225 ft bgl is similar to some other drillholes in the southern part of the WIPP site. This cement change is observable in other cores from the area (Powers, 2002b, 2003) and was reported in the air intake shaft (Holt and Powers, 1988).

On the basis of the resistivity log (Fig. 2-1) and by comparison with other similar situations, the Dewey Lake is likely to be more transmissive above ~225 ft bgl, at or near the carbonate–sulfate boundary. This is further discussed in Section 4.0.

2.2.4 Miocene-Pleistocene Gatuña Formation

Based on the cuttings from drilling and geophysical logs, the Gatuña occurs from 94–29 ft bgl. The Gatuña at SNL-3 is primarily reddish-brown (5YR4/4) to yellowish-red (5YR5/8) calcareous sandstone with pebble and gravel zones. A zone of pebbles was encountered from 57–44 ft bgl. Some of the upper Gatuña shows MnO_2 stains and extensive engulfing of grains by carbonate from the overlying Mescalero caliche. The formation is porous and mottled due to pedogenic processes.

The Gatuña generally increases in thickness from SNL-3 to the west toward SNL-2. The depositional edge of the formation at the WIPP site is in the same general area where the Santa Rosa pinches out because of erosion that preceded Gatuña deposition (Powers and Holt, 1993). The Gatuña is relatively thick at SNL-3, as it is along the Livingston Ridge escarpment west of the drillhole location. Bachman (1985) also found thicker Gatuña in this area and suggested it was filling an erosional valley. The SNL-3 data are consistent with this interpretation.

The Gatuña ranges in age from at least 13.5 to ~ 0.5 million years old (Powers and Holt, 1993). SNL-3 is located east of an outcrop of Lava Creek B ash found at the top of the Gatuña by Bachman (Bachman, 1980; Izett and Wilcox, 1982). From general relationships along Livingston Ridge, the Gatuña at SNL-3 includes younger portions of the unit range, but it may also represent a significant portion of the age.

2.2.5 Pleistocene Mescalero caliche

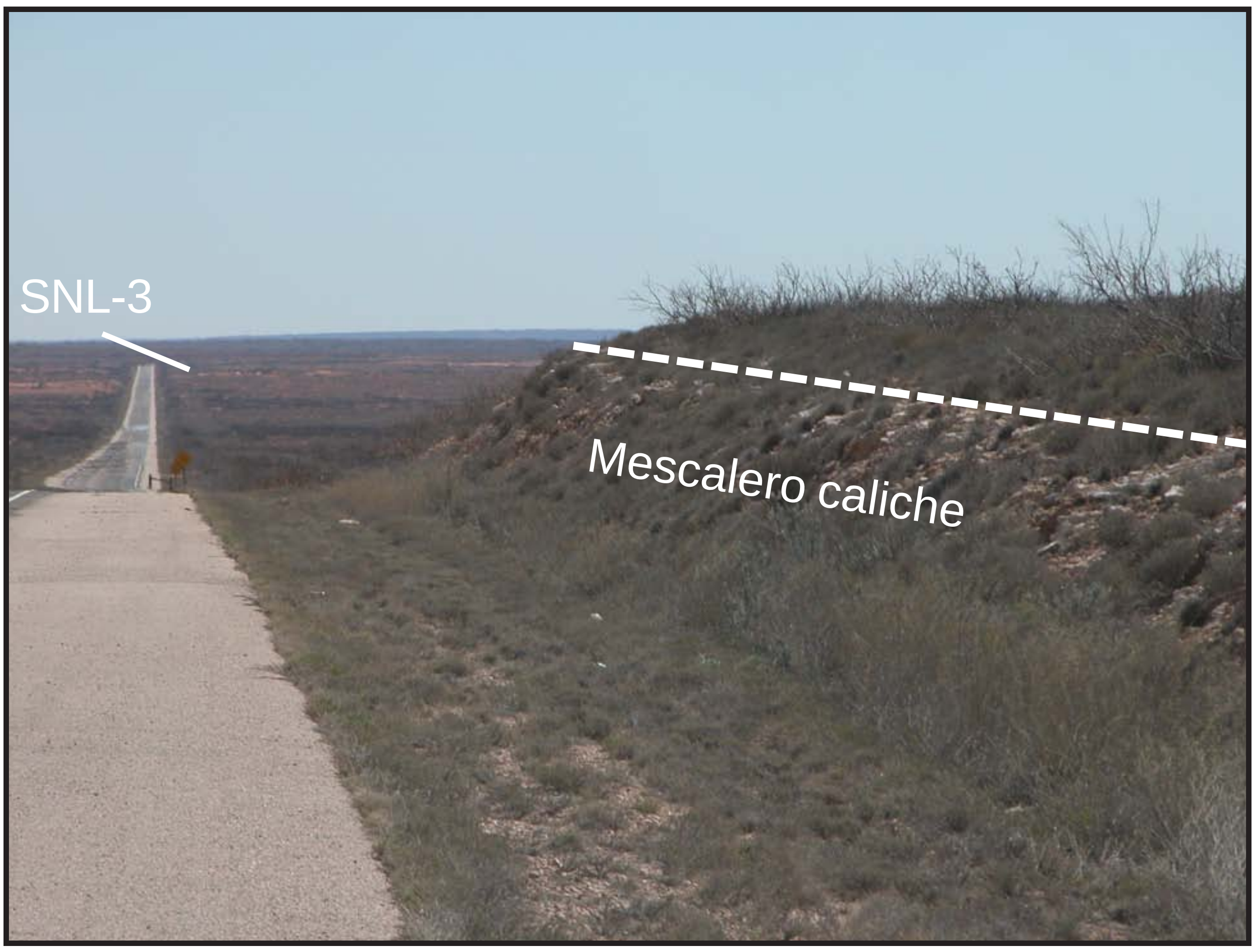
The Mescalero is an informal soil stratigraphic unit defined by Bachman (1973). It is widespread in southeastern New Mexico, and it is a continuous stratigraphic unit at the WIPP site. Uranium-disequilibrium ages indicate the Mescalero formed as a pedogenic unit between ~570,000 (± 100,000) and ~420,000 (± 60,000) years ago (Rosholt and McKinney, 1980). The age is further bounded by the Lava Creek B ash, ~600,000 years old, which underlies the Mescalero west of SNL-3 along Livingston Ridge (Izett and Wilcox, 1982).

At SNL-3, the Mescalero is ~13 ft thick (29–16 ft bgl). From cuttings, the Mescalero is a white to reddish brown, variegated calcareous sandstone to sandy limestone. Chert pebbles are included. Textures show evidence of pedogenic processes such as nodule, ped, and laminae development. Cuttings were too limited to determine if the upper portion of the unit is locally plugged or if subhorizontal laminae are partially developed at the upper surface. 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 at least at stage IV at SNL-3. The Mescalero crops out along the WIPP access road north of SNL-3 (Fig. 2-9) and is stage V to stage VI at that location. The Triassic Santa Rosa Formation, not present at SNL-3, underlies the Mescalero at that location. The Mescalero overlies Dewey Lake in the low valley south of this outcrop, as illustrated in Figure 2-10.

2.2.6 Pleistocene Berino Soil and Surficial Sands

The Berino is a yellowish-red (2.5YR5/6) sandstone that is friable and argillaceous. Sand grains are very fine to medium. The Berino soil is not a geologic unit; it is a pedogenic unit defined by the soil scientists in the area (Chugg and others, 1971). At SNL-3, the Berino was not identified in cuttings, although it occurs in the vicinity of SNL-3 (Fig. 2-10). Yellowish red (5YR5/6) sand, similar to that in dunes surrounding the drill pad, was recovered below the pad construction fill to the top of the Mescalero at 16 ft. Imported Mescalero caliche was used to construct the drilling pad, forming ~1.5-ft fill over the dune sands.

Figure 2-9. Mescalero Caliche Overlying Triassic Santa Rosa Formation North of SNL-3. (View to south, from section 15, T21S, R31E.)



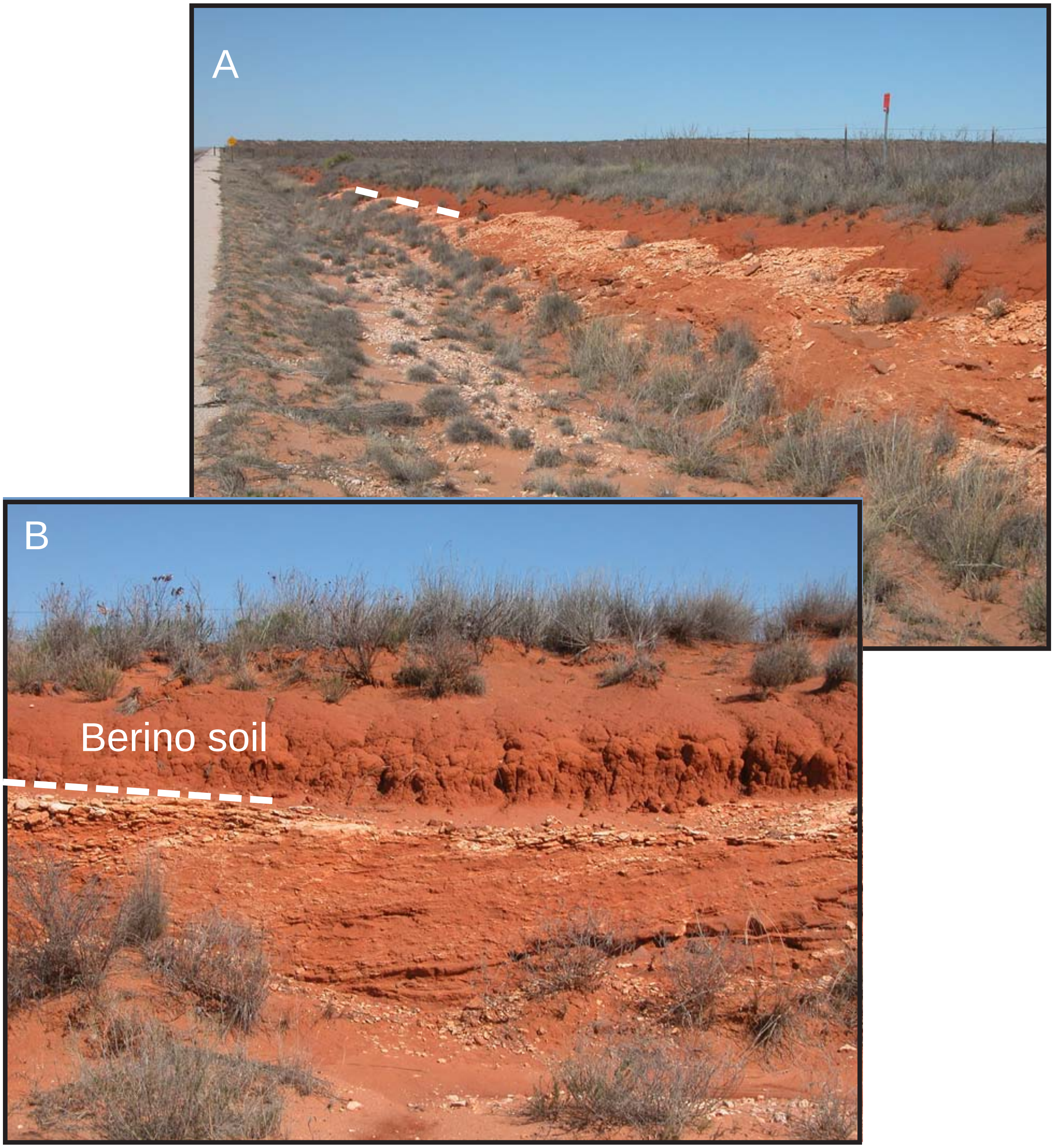


Figure 2-10. Berino Soil Overlying Weak Mescalero Caliche North of SNL-3. (A: view to north, showing irregular eroded surface on the Mescalero. B: east side of road cut, showing weak Mescalero developed on Dewey Lake Formation.)

3.0 PRELIMINARY HYDROLOGICAL DATA FOR SNL-3

SNL-3 was drilled specifically to monitor water levels and water quality from the Culebra Dolomite Member of the Rustler Formation and to serve as a location for observations during pumping tests.

3.1 Checks for Shallow Groundwater Above the Rustler Formation

Groundwater was not encountered in the Dewey Lake or Gatuña Formations. After normal overnight shutdown on August 14, the drillhole was checked for fluids using an electric probe. No moisture was detected at the bottom of the open drillhole, which was at 150 ft.

At a depth of 212 ft bgl, in the Dewey Lake, the drillhole was observed for 59 minutes to determine if groundwater was coming into the drillhole. The return air flow did not include moisture, indicating no significant inflow.

This depth was chosen for several reasons. Cuttings had appeared slightly moist from ~184 ft depth. The drillhole had reached the informal *ss1* associated by Powers (2003) with saturated zones in the upper Dewey Lake in the southern part of the WIPP site. In addition, the drillhole stability was a concern, given the poor induration of the sand at the interval and the difficulty of lifting cuttings just using circulating air. Following the period of observation, drilling continued, using mist and Quik-Foam® for hole stability and return of cuttings.

On the morning of August 18, after normal weekend shutdown, an electric probe was run to the bottom of the drillhole, then in A-5 of the Rustler at 590 ft bgl. Possible moisture was detected at 587.40 ft bgl. Nevertheless, after the drillpipe was run to the bottom of the hole, air circulated to the surface did not include observable water. We infer little or no water production from the open drillhole above the Rustler from these observations. Nevertheless, changes in fluid resistivity and temperature from 230–200 ft in the geophysical logs (Fig. 2-1) are possible indicators of limited inflow.

3.2 Initial Results From the Magenta Dolomite

The lower Forty-niner, Magenta, and upper Tamarisk were cored to 672.9 ft on August 18, 2003, and drilling was shut down overnight. On August 19, 2003, the water level was determined to be 600.9 ft bgl, using an electric probe in the open drillhole. This water level is above the Magenta and would stand in the upper anhydrite (A-5) of the Forty-niner.

Previous checks indicate that the drillhole was not yielding significant fluid above 590 ft. The most likely source of the inflow is the Magenta. It is possible that the M-4 unit of the Forty-niner was yielding water, as that was not eliminated by the check at a depth of 590 ft. The drillhole diameter was ~6 inches through this zone. With a 69-ft column of water, the total volume of inflow was ~14.1 cubic ft, or ~106 gallons, over a period of ~13.5 hours. It is undetermined if the fluid level had reached equilibrium.

3.3 Initial Results From the Culebra Dolomite

After coring through the Culebra to a depth of 782 ft on August 20, 2003, drilling was shut down for the evening. At 07:11 MDT on August 21, 2003, the water level was 422.50 ft below the top of the connector on the surface casing. Both Culebra and Magenta likely contributed to this water level.

After the well was completed, the Culebra was developed to prepare it for future testing and monitoring. On September 17, 2003, seven bailers of water and sediment were removed from SNL-3. A pump was then placed in the hole. On September 18, pumping began at 6:55 MDT, but the meter was not working. Pumping continued steady to 08:05; measurement with a bucket indicated a pumping rate of 10.5 gallons per minute (gpm). The water was clear and steady. The pump was surged four times over 25 minutes, and the water quickly cleared. From 08:30 to 09:30, the pump was run at ~10 gpm. The pump was turned off, and then was surged again between 09:30 and 10:00. From

10:00 to 11:30, the well was pumped at 10 gpm with very clear water. Development was ended at 11:30; ~2,200 gallons were produced by pumping. The water density was measured at 1.042 grams/cubic centimeter (g/cc).

On April 1, 2004, SNL-3 was jetted and pumped to develop the well. The screen interval was jetted in three passes, using 150 barrels of water from the Jal Municipal system. A pump was installed, and the well was initially pumped for ~2 hours at rates between ~12–14 gpm. The well was surged four times and then was pumped again for ~1 hour at 13–13.5 gpm. The water was clear, and the final density was 1.028 g/cc.

Beginning October 2003, static water levels for the Culebra were regularly measured (Table 3-1) (Siegel, 2004). Water levels measured through May, 2004, as well as calculated fresh-water-equivalent (FWE) levels, are shown in Figure 3-1.

3.4 Observations About the Rustler–Salado Contact

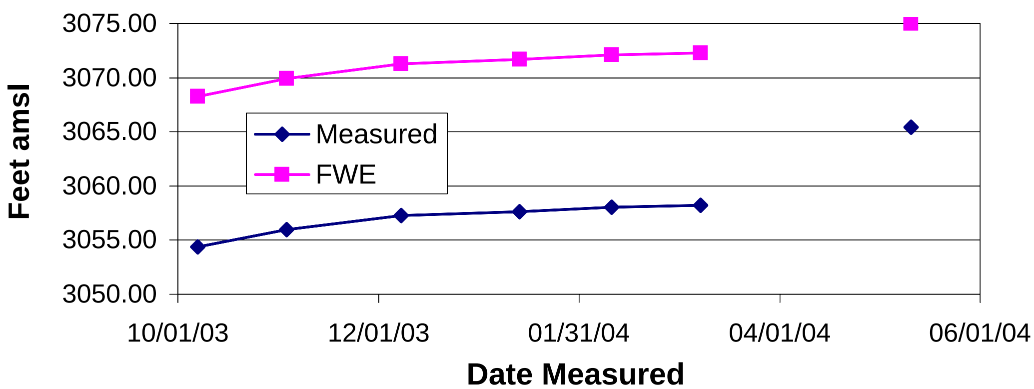
The Rustler-Salado contact was cored with good recovery. There was no indication during drilling of changes in drilling fluid or of flow into the drillhole from this zone affecting the drilling fluid returns. Cores across the Rustler–Salado contact indicate likely postdepositional dissolution of the upper Salado.

Table 3-1
Culebra Water Levels and Elevations in SNL-3

Date	Time (MST)	Depth (ft) to water level	Water Elevation (ft amsl)	FWE Water Elevation (ft amsl)
10/07/03	08:04	435.98	3054.36	3068.27
11/03/03	11:03	434.39	3055.95	3069.92
12/08/03	11:24	433.09	3057.25	3071.28
01/13/04	8:15	432.69	3057.65	3071.69
02/10/04	13:40	432.32	3058.02	3072.08
03/08/04	11:37	432.15	3058.19	3072.26
	no April data because of pumping test			
05/11/04	14:25	424.93	3065.41	3074.99

Source: Siegel, 2004. Measuring point reference for depth is 3,490.34 ft amsl.
Fluid density measured 4/1/04 is 1.028 g/cc.

Figure 3-1
Culebra Water Elevation at SNL-3



4.0 SIGNIFICANCE/DISCUSSION

The materials used in completing SNL-3 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.

The lower Rustler and uppermost Salado were cored to obtain direct evidence bearing on the status of dissolution of halite in the uppermost Salado in this vicinity. Powers (2002a, 2003a), Holt and Powers (2002), and Powers and others (2003) showed an area (Fig. 4-1) where the interval between the Vaca Triste Sandstone Member of the Salado Formation and the top of the Culebra is thinner than in the surrounding areas. This zone is interpreted as a reentrant of the dissolution margin from its broader association with Livingston Ridge and the eastern margin of Nash Draw. Geophysical logs from oil and gas wells and potash drillhole data generally indicate the change in thickness occurs because of dissolution of halite at the top of the Salado. The relationship between upper Salado dissolution and Culebra hydraulic properties (Holt and Yarbrough, 2002; Powers and others, 2003) indicates that the Culebra at SNL-3 should be affected by this process.

The cores across the boundary between the Rustler and Salado preserved ~9 ft of siliciclastics, with some gypsum, below the base of the Rustler. The gypsum immediately below the boundary includes thin siltstones and may be amalgamated by dissolution of halite. Approximately 2 ft of pinkish sandstone, with rounded grains, overlying the top of halite is unusual. The rounded grains suggest considerable transport; grain rounding and the amount of sand are not what is expected for a dissolution residue. This zone needs careful examination to determine if it is a post-depositional dissolution residue or a function of original depositional environments and exposure. The halite underlying this sand shows corroded boundaries, indicating fresher water circulated, but neither timing nor process of circulation. There are some fractures within the lower Rustler, and gypsum and halite cements were not found. The lower Rustler is not brecciated. Erosional features in the basal Rustler, similar to those found in large-diameter WIPP shafts, also show that this is a sedimentary accumulation with a modest amount of fracturing that is consistent with, but probably not diagnostic of, some postdepositional dissolution of the upper Salado.

The uppermost Los Medaños (M-2/H-2) is not believed to include halite at SNL-3, although core was not recovered from this interval. Geophysical logs do not indicate any halite in this zone, and deeper cores do not include halite. This is consistent with previously defined halite margins for this unit and a depositional origin for mudstone-halite facies.

Culebra core recovery was poor overall, with most of the recovered core attributed to the upper Culebra. This is a common problem, and not one that is specific to SNL-3. Resistivity logs indicate rather uniform conditions through the Culebra; there is a slightly increased resistivity in the upper 4 ft, which may indicate reduced porosity. In testing at other locations, the lower Culebra is generally more transmissive than the upper Culebra. The Culebra at SNL-3 is only ~20 ft thick, less than in most other drillholes in the area; and some of the hydraulic zones identified for the Culebra in numerous other drillholes cannot be verified at SNL-3.

The Magenta core showed some surface porosity and wetting in the upper part that is at the same zone where microresistivity decreased noticeably, suggesting a zone with relatively higher hydraulic conductivity compared to the rest of the Magenta. The water level in the drillhole after the Magenta was cored rose above this level, and this zone of the Magenta is the most likely source.

Cuttings and resistivity changes suggest that the change in natural mineral cements of the Dewey Lake is ~225 ft bgl. This position is just below a persistent sandstone that produces water in the southern part of the WIPP site when the cement boundary is below the sandstone (Powers, 2003b). Powers (2003b) hypothesized that this cement boundary provides a perching horizon for natural groundwater. The broad trend for this boundary is to be stratigraphically low west and south of the WIPP site center and stratigraphically higher in the center and eastern part of the site (Powers, 2003b). The boundary tends to drop stratigraphically to the north of the WIPP site center, but SNL-3 provides additional data. There does not appear to be a saturated zone at this boundary in SNL-3, or in any other part of the Dewey Lake, in view of the observation periods during drilling. Only the changes in fluid temperature and resistivity suggest there might have been some fluid inflow from this zone.

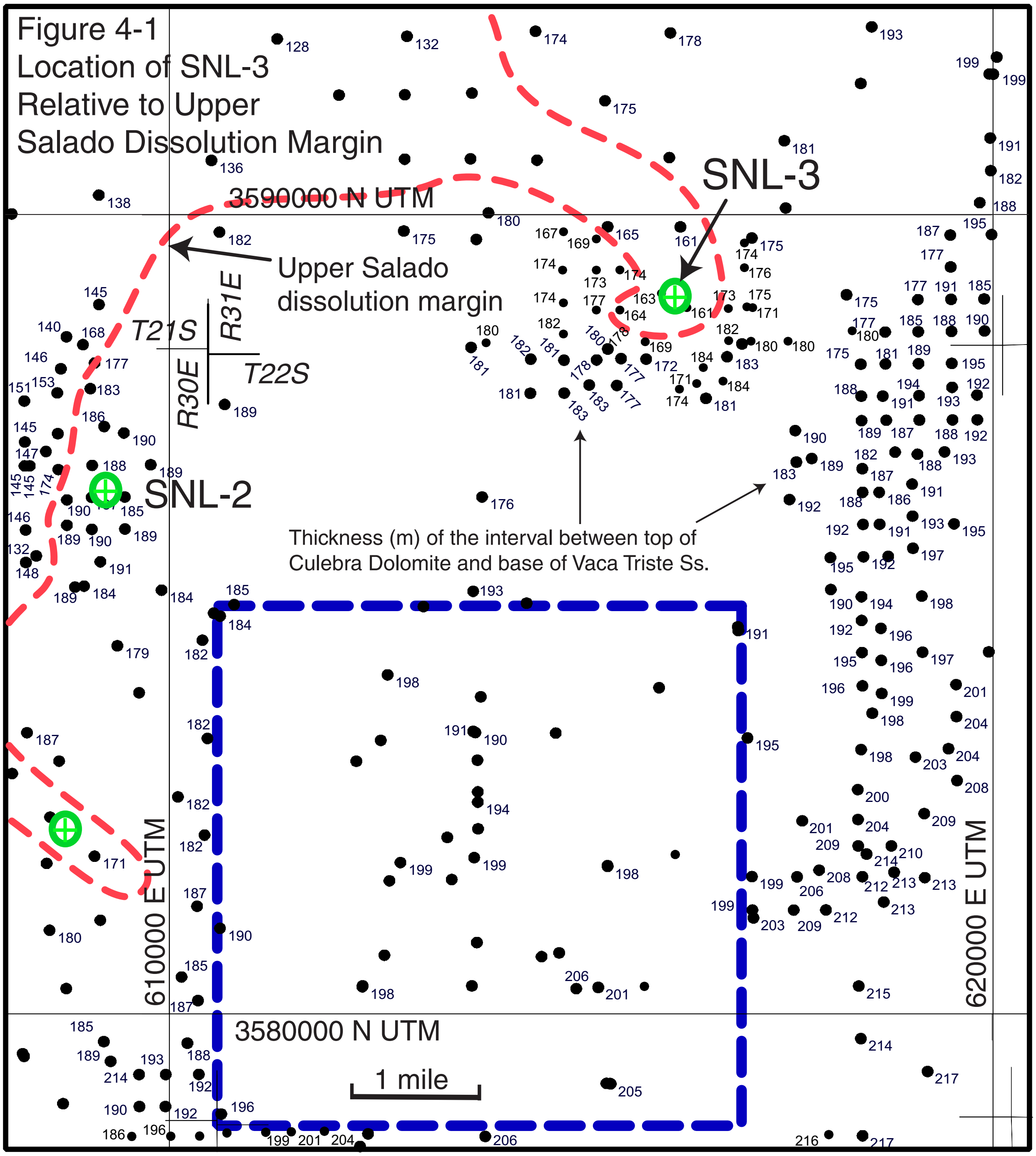


Figure 4-1 Location of SNL-3 Relative to Upper Salado Dissolution Margin

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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 in the extracted text.

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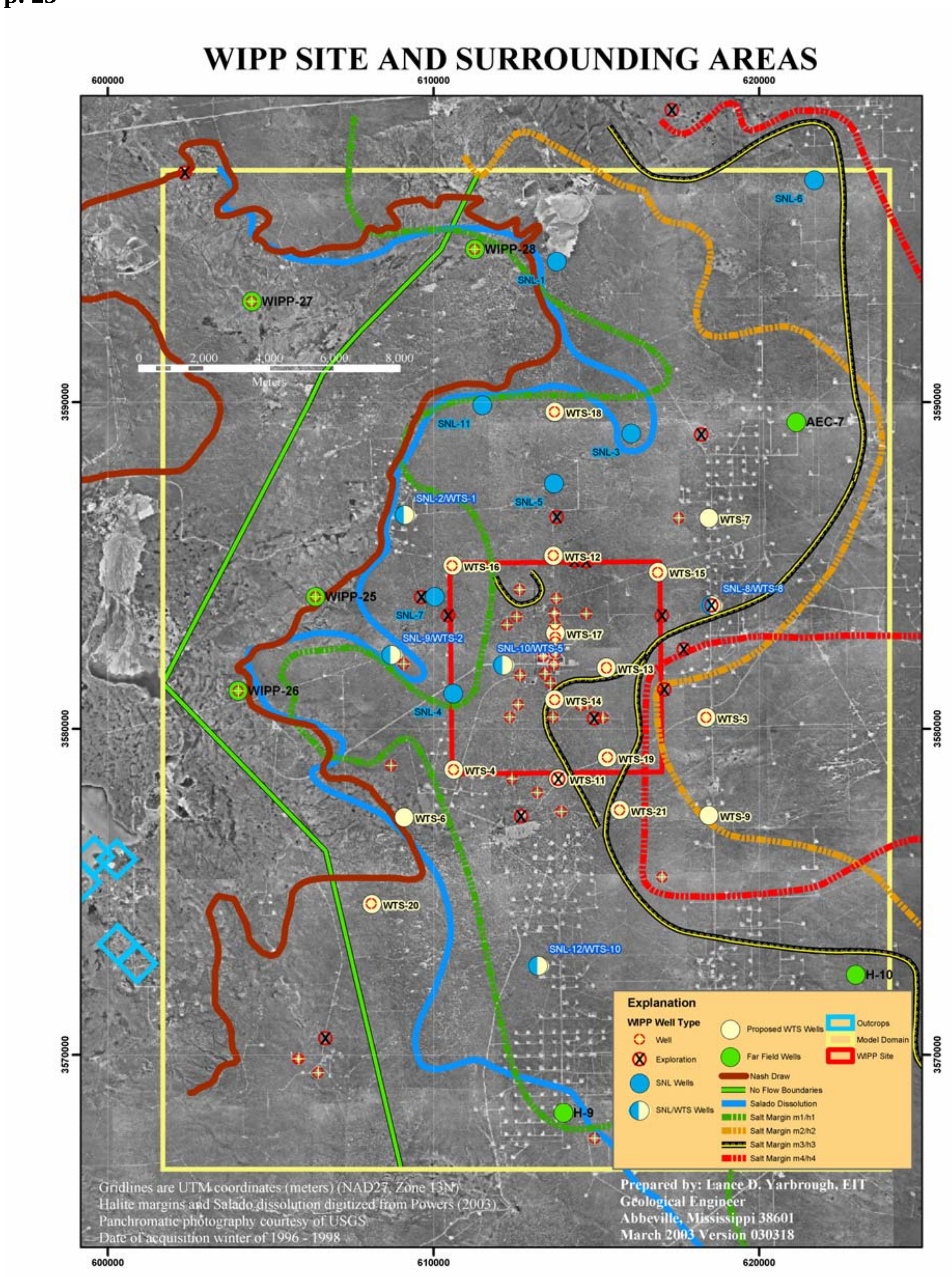
WIPP SITE AND SURROUNDING AREAS
600000
610000
620000
3590000
3580000
3570000
0 2,000 4,000 6,000 8,000
Meters
WIPP-28
WIPP-27
WIPP-25
WIPP-26
SNL-1
SNL-6
SNL-11
SNL-3
SNL-5
SNL-2/WTS-1
SNL-7
SNL-9/WTS-2
SNL-10/WTS-5
SNL-4
SNL-8/WTS-8
SNL-12/WTS-10
AEC-7
H-10
H-9
WTS-18
WTS-7
WTS-12
WTS-16
WTS-15
WTS-17
WTS-13
WTS-14
WTS-3
WTS-19
WTS-4
WTS-11
WTS-21
WTS-6
WTS-9
WTS-20
Explanation
WIPP Well Type
Well
Exploration
SNL Wells
SNL/WTS Wells
Proposed WTS Wells
Far Field Wells
Outcrops
Model Domain
WIPP Site
Nash Draw
No Flow Boundaries
Salado Dissolution
Salt Margin m1/h1
Salt Margin m2/h2
Salt Margin m3/h3
Salt Margin m4/h4
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.

5.1.1 SNL Well Justifications…

SNL-3: This Culebra well is to be located in the northern re-entrant of inferred dissolution extending to the southeast from Nash Draw (see Figure 8). If present, this dissolution re-entrant may short-circuit the long recharge path assumed for the Culebra in the CCA, and allow anthropogenically induced changes in the flow regime in Nash Draw to affect the Culebra (and Magenta) at the WIPP site. Alternatively, it could act as a drain on the unfractured, low-transmissivity Culebra lying to the east. This area has also been recently targeted for oil exploration. Logs were obtained from as many of these wells as possible to help optimize the location of SNL-3. Specifically, the logs were used to identify the boundaries of the dissolution re-entrant so that SNL-3 could be located as centrally within the re-entrant as possible. Six primary purposes will be served by SNL-3:

1. determine if dissolution of the upper Salado has in fact occurred at this location;
2. determine if the inferred dissolution of the upper Salado has resulted in increased Culebra transmissivity;
3. determine if the flow dimension inferred from a pumping test is consistent with a bounded, linear feature, or indicates connection with a larger volume of the Culebra;
4. determine if shallow (e.g., Dewey Lake) water is present above the Magenta that could be leaking into the Culebra and Magenta through poorly plugged boreholes;
5. determine the direction of flow at this location; and
6. provide a monitoring location for a large-scale (multipad) pumping test (centered at SNL-5) to provide transient data for calibration of the Culebra model north of the WIPP site.

If water is found in the Dewey Lake, a Dewey Lake well may also be installed at the SNL-3 location.

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Table 1. Roles Served by Planned Wells.

Well	Addresses leakage from tailings pile	Addresses high-T conduits	Addresses leaking boreholes	Addresses Salado dissolution	Provides model boundary condition information	Provides other information needed for modeling	Provides information supporting conceptual model	Provides information on flow across WIPP site
SNL-3		X	X	X				

…

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Table 2. Testing to Be Performed in New/Replacement Wells.

Well	4-day Pumping Test	Slug Tests	Multipad Pumping Test	Scanning Colloidal Borescope Logging	Testing Not Needed—Replacement Well
SNL-3	C, DL?			C	

C=Culebra well
M=Magenta well
DL=Dewey Lake well

…

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5.3.2 Multipad Pumping Tests …

Well SNL-9/WTS-2 will be the pumping well for the western multipad test, with observation wells as shown in Figure 18[not included]. Provided that it is able to produce at least approximately 5 gpm, SNL-5 will be the pumping well for the northern multipad test, with observation wells as shown in Figure 19. If SNL-5 does not have the needed pumping capacity, SNL-11, SNL-3, and WTS-12 (in that order) will be considered as potential fallback pumping wells for the test. The pumping well for the southern multipad test will prospectively be SNL-12/WTS-10, with observation wells as shown in Figure 20. Should SNL-12/WTS-10 not have the required pumping capacity, WTS-11 and WTS-6 (in that order) will be considered as fallback pumping locations.
…

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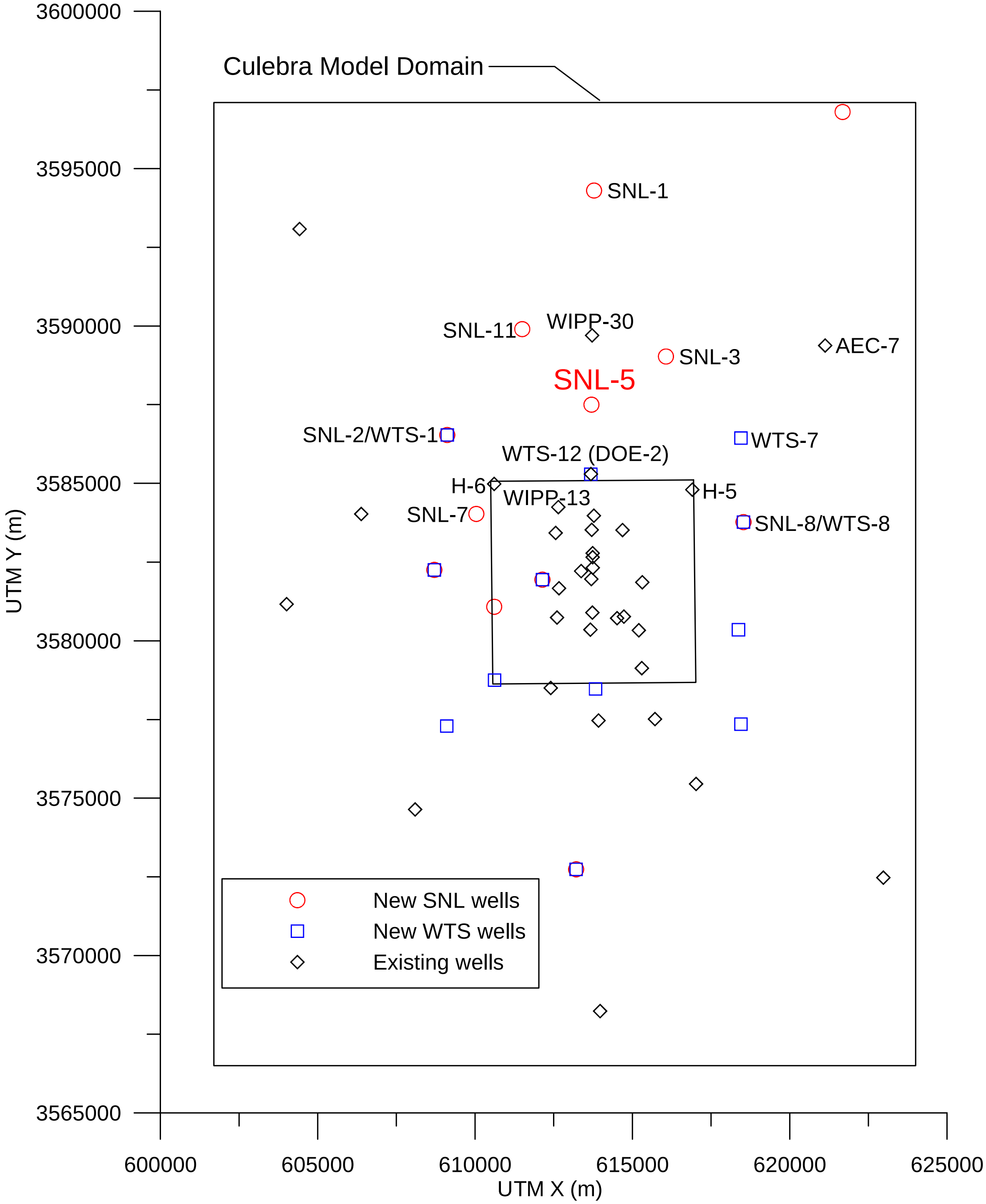

Figure 19. Pumping well and principal observation wells for northern multipad pumping test.

…

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5.3.3 Scanning Colloidal Borescope Logging

Direct measurement of the direction of groundwater flow is needed in the inferred Salado dissolution re-entrants, near the Mississippi East tailings pile, and on the edge of Nash Draw. Therefore, after SNL-1, 2, 3, 7, 9, and 11 have recovered from well development or pumping tests, the screened intervals of both the Culebra and Magenta (if present) wells will be logged using the scanning colloidal borescope. The scanning colloidal borescope images colloidal-size particles moving with the water through the wellbore, and tracks their motion to determine the direction and velocity of groundwater flow. In SNL-3 and 9, this will provide direct indications of whether the dissolution re-entrants serve as sources of fluid to the WIPP site, or as sinks for fluids coming from the east and north. In all cases, the information will be useful in flow model calibration.

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Table 4. Expectations and Contingent Actions for New Wells.

Well	Expectations	Possible Actions if Expectations Not Met
SNL-3	• dissolution of upper Salado • high Culebra T • subradial flow dimension • flow direction parallel to dissolution re-entrant	• increases importance of SNL-5 and SNL-11 in understanding flow north of the site • shifts more focus on cause of water-level rise to Nash Draw

…

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Table 5. Anticipated Total Depths of Proposed Wells.

Location	Culebra Well Depth (ft)	Magenta Well Depth (ft)	Dewey Lake Well Depth (ft)
SNL-3	940*		??

*depth to MB103

…

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Dissolution of the upper Salado Formation will be studied in up to eight drilling locations: SNL-2, 3, 4, 7, 9, and 12 and WTS-4 and 6. At these selected locations, the boreholes that will become the Culebra wells will be cored from the lower part of the upper Tamarisk anhydrite to the halite beds of the upper Salado (approximately 175 ft), and then will be rotary drilled through Marker Bed (MB) 103. If MB100, 101, or 102 are well defined, the on-site geologist together with the Lead Hydrologist and Field Operations Lead may terminate drilling at any one of these marker beds. If MB103 is disturbed by deeper dissolution, the borehole may need to be deepened by an estimated additional 100 ft by rotary drilling through MB109 or other suitable stratigraphic marker bed as determined by the on-site geologist in consultation with the Lead Hydrologist and Field Operations Lead. This decision is most likely for four holes (SNL-2, SNL-3, SNL-11, and SNL-12) where the uppermost Salado may have been dissolved to greater depths, obscuring the upper Salado stratigraphic record. After all desired core and geophysical logs have been collected from the upper Salado, the holes will be plugged with cement back to a depth approximately 20 ft below the base of the Culebra before the upper part of the hole is reamed to its final diameter.

Available information is adequate to justify coring the upper Salado in holes SNL-2, SNL-3, and SNL-9. …

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7.3 Logging

Open-hole geophysical logging will be performed after each Culebra hole is drilled to total depth and reamed, but before the casing and well screen are installed. Wells drilled into the upper Salado will be logged prior to reaming, and caliper logging will be repeated after reaming. The suite of logs to be run in all wells includes: natural gamma, resistivity (induction if the well is not fluid-filled), neutron, density, and caliper. These logs will be used to confirm stratigraphic contact depths determined from core, and will aid in selecting final casing and screening depths. In addition, a high-resolution microresistivity log (e.g., FMI, FMS, EMI) will be run in the SNL-2 Culebra well to determine its effectiveness at identifying fractures and their orientations. If successful, a microresistivity log may be run in other holes. In the Magenta and Dewey Lake wells, only natural gamma and caliper logs are planned, although resistivity (or induction) and neutron logs could be required in Dewey Lake wells to resolve uncertainty about the zone of saturation. After well completion, an acoustic cement-bond log may be run to provide a baseline of cement conditions behind the well casing. The logger must provide all logs in both paper and digital form.

Appendix B
Abridged Borehole History

The abridged borehole history has been prepared by compiling information from driller's reports by West Texas Water Well Services (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.

8-14-03 Arrived on SNL-3 site at 07:00 CDT (*see note above*). Drilled through drillpad, sand and caliche to 18 ft. Set temporary casing. Drilled with air to 150 ft.

8-15-03 Arrived on site at 07:00. Held safety meeting. *Measured fluid level, dry hole.* Started tripping in at 07:15. Began drilling 7 7/8" hole at 07:30. Drilled from 150' *to 160' by 07:45. Paused for rig maintenance. Continued drilling from 160' at 07:58. Moist cuttings at 190'. Blew hole dry. Continued drilling from 190' at 08:42.* Drilled to 212' by 09:00. *Cuttings are moist and poorly lithified.* Paused to verify whether hole was producing water. *Concluded that well does not appear to be producing water. Due to poorly consolidated sand zones, decided to continue drilling with mist.* Continued drilling at 10:00. Drilled to 338' by 13:00. *Drilling rate increased noticeably.* Stopped for lunch. Continued drilling at 13:40. Drilled to 592' by 18:10. Tripped out. Left site at 19:00.

8-18-03 Arrived on site at 08:00. Held safety meeting. Repaired entrance gate at 08:15. Measured static water at 587.4'. Started tripping into hole at 08:30. *No fluid blown from hole.* Began drilling at 09:15. Drilled from 590' to 631' by 10:05. Tripped out of hole. Set up coring tool at 10:30. Started tripping back into hole at 11:15. Began core run #1 at 12:10. Cored 26' from 631' to 657' by 12:45. Tripped out of hole. Stopped for lunch at 13:20. Collected core at 14:00. Prepared coring tool for next run. Started tripping into hole at 14:17. Began core run #2 at 15:10. Cored approximately 15' from 657' to 672.9'. Started tripping out of hole at 15:40. Collected core at 16:47. Secured site and left for evening.

8-19-03 Arrived on site at 07:00. Held safety meeting. *Measured fluid level at 600.9'.* Started tripping into hole at 07:36. Reamed hole until 09:00. Compressor down. A. Rivas and D. Ripley arrived on site for safety inspection at 10.30. *Instructed WTWW to reroute water line and block wheels on water-pipe truck. No other safety concerns were noted.* Returned from Hobbs and replaced fuel filter to repair compressor. Continued reaming at 11:45. Drilled to 720' by 13:12. Tripped out of hole. Prepared coring tool at 13:50. Started tripping back into hole at 14:10. Began core run #3 at 15:05. Cored 30' from 720' to 750' by 16:07. Tripped out of hole. Collected core at 16:45. Reassembled coring tool at 17:05. Shut down for evening and left site at 17:30.

8-20-03 Arrived on site at 07:00. Held safety meeting. *Measured fluid level in hole – dry.* Started tripping in at 07:15. *Blew hole out without adding foam and the hole (as expected) made water. Most probable explanation is that a part of the hole squeezed in enough to obstruct the water level probe.* Cleaned out 15' fill at 08:30. Began core run #4 at 08:45. Cored approximately 12.5' before core barrel jammed. Started tripping out at 09:16. Tore down core barrel at 09:57.

Retrieved 8' core. Started tripping back into hole at 10:11. Began core run #5 at 11:12. Cored 19.5' (762.5' to 782') by 12:20. Recovered 7.5'. Tripped out of hole. Stopped for lunch at 13:05. Laid out core at 13:35; rig diverter down. Began rigging up portable pit at 15:00. Secured site and left for evening.

8-21-03 Arrived on site at 07:00. Held safety meeting. Measured static water level at 422.5' *below temporary collar*. Prepared to switch to mud drilling. Started tripping into hole at 09:05; 20' of fill. Began circulating bottom with brine at 10:45. Began core run #6 at 11:40. Cored 30' from 782' to 812' by 13:15. Circulated. Started tripping out of hole at 13:40. Retrived core at 14:35. Recovered 27.2'. Started tripping back into hole at 14:45. Circulated bottom of hole at 15:35. Began core run #7 at 15:40. Cored 27' from 812' to 839' by 16:40. Circulated hole. Started tripping out at 16:55. Left core hanging in hole. Secured site and left for evening.

8-22-03 Arrived on site 07:00. Measured fluid level at 65' below surface casing. Laid down core from day before. Recovered 15.2'. Tripped into hole; about 4' of fill. Began cuting core #8 from 839' at 09:06. Cut 17' of core, and tripped out from 11:40 to 12:00. Laid down core. Tripped into hole and began coring run #9 at 13:12. Cut 25' of core to 881' at 14:39. Tripped out of hole, laid down core. Recovered 22.4'. Left site at 17:50.

8-23-03 Arrived on site at 07:00. Held safety meeting. Rigged up 18" bit for surface casing. Measured static water level at 85.4'. Began drilling 30' of 18" hole at 07:45. Set 30' of 13 3/8" casing. Mixed 27 bags of Portland cement at 11:00. Tremie cement into annulus. Secured site and left for weekend.

8-25-03 Arrived on site at 08:00. On stand-by. Held safety meeting at 08:15. Measured static water level at 47.8'. Started tripping in at 08:30. Circulated hole. Began reaming 6¾" core hole to 7 7/8" from 720' at 10:25. Wash out at 735' to 748'. Worked on lift pump at 11:30. Wash out at 765' to 770'. Finished reaming to 881' at 13:30. Circulated hole. Began drilling 7 7/8" hole from 881' at 14:51. Drilled to 970' by 17:25. Circulated hole. Began tripping out at 18:00. Secured site and left for evening.

8-26-03 Arrived on site at 07:45. Held safety meeting. On stand-by for logger. Measured static water level at 20'. Began logging well at 09:00. Finished logging at 13:50. Began running tremmie pipe at 13:55. Mixed cement; pumped 2.3 yards (470 gallons of water and a total of 49 bags of Portland cement) at 15:30. Cleaned out mud pump. Started tripping out at 16:25. Secured site and left for evening.

8-27-03 Arrived on site at 08:00. Held safety meeting. Started tripping into hole at 08:55. Tagged cement at 776'. Started tripping out at 10:37. Rigged up to ream 12¼". Shut down rig to let cement set for 24 hours. Secured site and left for evening at 11:45.

8-28-03 Arrived on site at 07:00. Held safety meeting. Measured static water level at 65.3'. Began reaming to 12¼" from 30' to 180' at 07:15. Stopped reaming and shut down rig at 12:30. Attended meeting at WIPP site regarding the broken water line at SNL-3. Returned to site and resumed reaming from 180' at 14:00. Reamed to 225' by 15:30. Circulated hole at 15:30. Began tripping out at 15:40. Secured site and left for evening.

9-02-03 Held safety meeting in Odessa. Arrived on site at 10:00. Performed rig maintenance. Measured static water level at 68.5'. Started tripping in at 10:20. Began drilled 12¼" from 225' at 10:40. Drilled to 307' by 17:50. Circulated hole. Began tripping out at 18:00. Secured site and left for evening.

9-03-03 Arrived on site at 07:00. Held safety meeting. Measured static water level at 16'. Serviced rig at 07:15. Replaced 12¼" bit. Tripped in. Began drilling 12¼" from 307' at 08:45. *Drilled to 339' by 11:50. Drilled to 403' by 15:47. Drilling rate has increased in the last 40'. Drilling rate slowed again by 16:00.* Drilled to 424' by 17:00. Circulated hole and tripped out. Secured site and left for evening at 17:50.

9-04-03 Arrived on site at 07:00. Held safety meeting. Measured static water level at 42.4'. Serviced rig at 07:15. Tripped in. Began drilling 12¼" from 424' at 07:50. *Drilled to 498' by 12:45.* Drilled to 557' by 17:15. Circulated hole. Began tripping out at 17:30. Secured site and left for evening.

9-05-03 Arrived on site at 07:00. Held safety meeting. *Measured fluid level at 76'.* Serviced rig at 07:15. Tripped in. Reamed back to bottom of hole. Began drilling 12¼" from 557' at 09:00. Drilled to 600' by 17:00. Circulated hole. Started tripping out at 17:50. Bit broken. Secured site and left for evening.

9-06-03 Arrived on site at 07:00. Held safety meeting. *Measured fluid in hole at 54'.* On standby for 12¼" bit from Odessa. Rigged up replacement bit at 09:00. Started tripping into hole at 09:10. Drilled 2' – hard drilling. Planned to trip in with 9 5/8" bit on 6-08-03. Tripped out and shut down site for weekend.

9-08-03 Arrived on site at 08:00. Held safety meeting. Serviced rig at 08:15. *Measured fluid level in hole at 94'.* Changed 12¼" bit for 9 5/8" bit. Tripped in. Began drilling from 602' at 09:40. *Drilled to 625' by 10:30. Drilled to 656' by 12:20. Drilled to 720' by 16:30. Drilled to 751 by 17:32.* Drilled to 782' by 18:30. Circulated hole and tripped out. Secured site and left for evening.

9-09-03 Arrived on site at 07:00. Held safety meeting. Serviced rig at 07:15. Changed 9 5/8" bit for 12¼" bit. Measured static water level at 28'. Started tripping into hole at 07:30. Reamed through the Dewey Lake. Began drilling 12¼" from 602' at 09:00. *Drilled to 625' by 10:25.* Drilled to 688' by 18:05. Circulated hole and tripped out. Secured site and left for evening.

9-10-03 Arrived on site at 07:00. Held safety meeting. Serviced rig at 07:15. Started tripping into hole at 07:30. Reamed to the Dewey Lake. Began drilling 12¼" from 688' at 09:00. *Drilled to 720' by 12:50. Drilled to 751' by 15:35. Drilled to 782' by 17:15.* Drilled to 785' by 18:15. Circulated hole and tripped out. Ran caliper log from 19:30 to 20:15. Secured site and left for evening.

9-11-03 Arrived on site at 07:00. Held safety meeting. Serviced rig. Measured static water level at 30'. Tripped into hole. Reamed each joint down as hole was swelling. Total of 35' of fill. Circulated hole at 09:45. Started tripping out of hole at 11:00. Prepared tremmie pipe at 11:35. Began running 5" diameter fiberglass casing. Bottom 10.50' was blank; 19.65' screen, and blank to surface. of which the. Landed casing at 783.50' below top of conductor pipe. Ran 27 joints, 794.75', and left 2' stickup for locking cap. Pumped 27 sacks of 8/16 Colorado silica sand. Pumped 5 sacks of baroid hole plug. Grout pump down at 18:00. Cement trucks on stand-by, waiting for part from Odessa. Started pumping 19 yards of cement (513 bags) at 21:45. Pulled tremmie pipe. Shut down rig and secured site for night at 12:35 (am, 9-12-03).

9-12-03 Arrived on site at 11:00. Held safety meeting. Ran tremmie pipe in casing at 11:15. Flushed with clean water. Tripped out at 13:00. Shut down rig and secured site.

9-17-03 *Arrived on site at 09:20. Started bailing well; water was very red and muddy with chunks of red clay in bailer. Observed screen slot impressions on clay. Removed about 7 bailers, with red clay chunks in water. Collected 5 more bailers of water, with water still very muddy and including small amounts of clay chunks. Stopped bailing at 10:35 and set up to install pump. Will set pump about 2' from base of screen. Pump set at about 771 ft at 13:00. Tested electric cable at surface; found short, removed from hole. Checked pump and all cable without finding short. Used 500' of new cable, started back in hole with tubing at 16:40. Leave site at 17:40.*

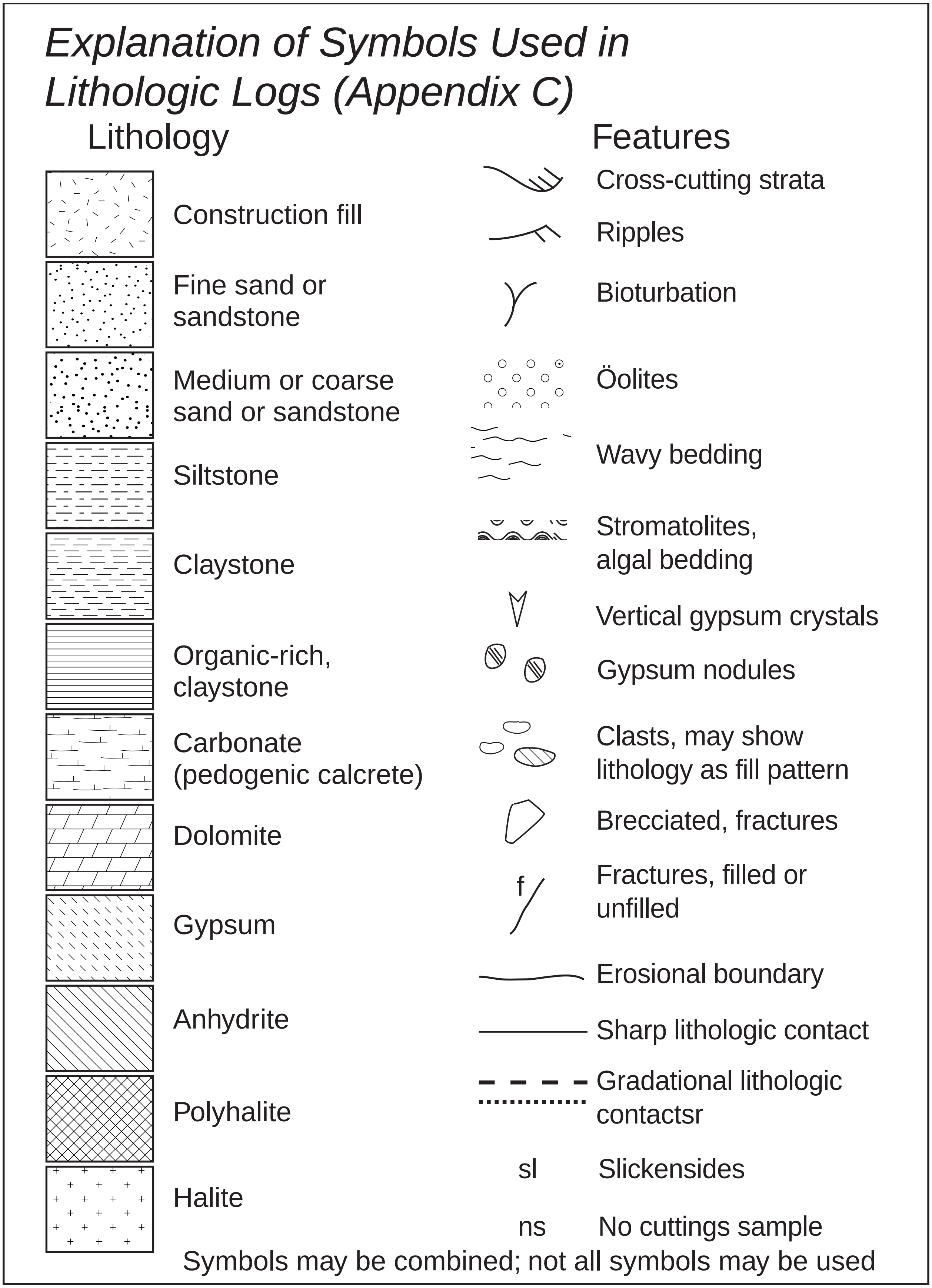
9-18-03 *Arrived on site at 07:20. Started generator for pump and turned pump on at 07:45. Flow started at about 12 gpm at 7:55; meter is not working. Water started to get muddy at 08:12. Flow steady at 10-12 gpm at 08:20; water cleared up. Measured flow with 5 gallon bucket at 08:30. Five gallons/28 seconds is 10.5 gpm. Flow is steady and slightly silty. Pumping clear and steady at 10 gpm at 08:45. Turned pump off at 09:05. Pumped 10 gpm for 70 minutes for a total of 700 gallons. Surged well 4 times by 09:30. Water cleared up quickly, pumping steady at 10-11 gpm. Pumped 60 minutes (to 10:30) at 10 gpm for 600 more gallons, and turned pump off. Surged 3 times between 10:30 and 11:00. Began pumping again at 11:00 until 12:30. Stopped pumping after 90 minutes at 10 gpm for additional 900 gallons. Ended development. Fluid density measured at 1.042 g/cc. Total of 2200 gallons pumped.*

4-1-04 *Arrived on site at 08:00. Set up to jet at 200 psi across 20 ft screen interval. Source is 150 barrels of Jal Municipal water. Repaired transfer pump. Completed first full pass at 09:10. Water is silty, tan with black flakes, but is not really muddy. Completed second full pass by 09:21; water is cleaning up well. Pumped 110 barrels for jetting by 09:30. Completed third full pass by 08:42; water is very clear, with no flakes. Pumped full 150 barrels by 09:50; water clear. Stopped jetting. Pulled pipe to get ready to set pump. Back in hole with pump and pipe. Set pump at same point as jet tool at 775.38 ft, 2' below screen. Completed rigging discharge pipe. Started intial pumping at 12:05. First flow rate was 13 gpm at 12:13. Flow rate at 12:20 was 13 gpm. Flow rate at 12:25 was 13 gpm. Flow rate at 12:30 was 12.5 gpm; water was slightly milky, tan in color. Flow rate at 12:40 was 12.7 gpm. Flow rate at 12:50 was 12.8 gpm. Flow rate at 13:00 was 13 gpm. Flow rate at 13:15 was 13.5 gpm and rising; water is clear with air bubbles. Flow rate at 13:30 was 13.7 gpm; fluid density = 1.025 g/cc, temperature = 24.6 degrees C. Flow rate at 14:00 was 13.7 gpm; water was crytal clear. Surged well 4 times on and off. Pump back on at 14:35; water is very clear. Flow rate at 14:45 was 13 gpm. Flow rate at 15:00 was 13.5 gpm; fluid density was 1.029 g/cc, and temperature was 23.9 degrees C. Water was crystal clear. Flow* *rate at 15:15 was 13.5 gpm; fluid density = 1.029 g/cc, and temperature was 24.0 degrees C. Flow rate at 15:25 was 13.4 gpm; fluid density was 1.028 g/cc, and temperature was 23.9 degrees C. Pump was turned off at 15:30. Water was crystal clear, with no flakes. Surging did not cause water to become turbid. Total discharge during pumping was 2366 gallons. Started pulling pump from well at 15:40. Pump out of hole by 16:30; loaded up equipment. Departed SNL-3 at 17:15 for portacamp.*

Appendix C
Geologic Logs

Note: The original field descriptions and graphic logs were prepared at somewhat variable 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.

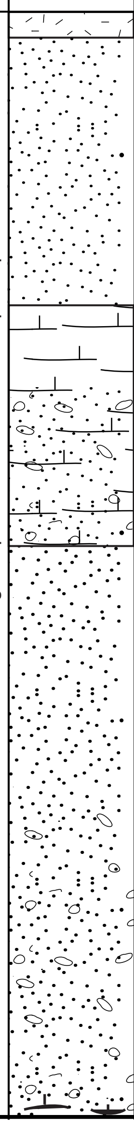

Explanation of Symbols Used in
Lithologic Logs (Appendix C)
Lithology
Construction fill
Fine sand or sandstone
Medium or coarse sand or sandstone
Siltstone
Claystone
Organic-rich, claystone
Carbonate (pedogenic calcrete)
Dolomite
Gypsum
Anhydrite
Polyhalite
Halite
Features
Cross-cutting strata
Ripples
Bioturbation
Öolites
Wavy bedding
Stromatolites, algal bedding
Vertical gypsum crystals
Gypsum nodules
Clasts, may show lithology as fill pattern
Brecciated, fractures
f
Fractures, filled or unfilled
Erosional boundary
Sharp lithologic contact
Gradational lithologic contactsr
sl
Slickensides
ns
No cuttings sample
Symbols may be combined; not all symbols may be used

CORE LOG — Sheet 1 of 10

Hole ID: SNL-3	Location: about 2369 ft fsl, about 2701 ft fwl, sec. 34, T21S, R31E	
Drill Date: 8/14/03-8/25/03 Drill Crew: West Texas Water Well Service (Ronnie Keith, driller)	Drill Method: rotary Hole Diameter: initial 7.875 inches Hole Depth: TD 970 ft Hole Orient: vertical downward	Drill Make/Model: Gardner-Denver 1500 Barrel Specs: 6 in o.d., 4 in core Drill Fluid: air; foam, brine Core Preserv: box as is
Logged by: Dennis W. Powers, Ph.D., Consulting Geologist	Date: 8/14/03	Scale: variable

	Northing	Easting	Elevation
Survey Coordinate (Zone 13): (m)	3589046.84 N (UTM NAD27)	616102.67 E (UTM NAD27)	3488.26 ft (brass marker at surface)

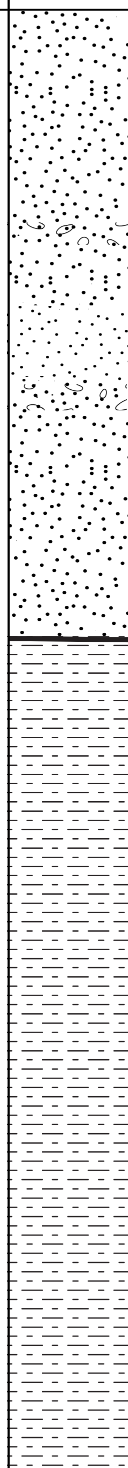
Comments: The State Engineer assigned the number C-2949 for this well, and official records reflect this number. The reference elevation for coring and drilling is ground level. Differences in stratigraphic intervals compared to geophysical logs derive mainly from uncertainties during drilling and from core recovery. Core depth marks were based on best estimate of recovered depths.

Run Number	Depth (feet)	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
N/A	0	N/A	N/A		Construction fill (caliche) to ~ 1.5 ft	
					1.5-16.0 ft Sand, yellowish red (5YR5/6), non-calcareous, very fine to fine grained, subround to round (dune sand).	Begin 1150 MDT; 12.25 inch hole to 18 ft, place temporary 8.625 inch o.d. casing to 18 ft.
	10					
			C-1			16 ft @ 1235 MDT
					16-29 ft Caliche (limestone), sandy, gravelly; white to reddish brown, variegated; chert pebbles scattered through lower half. Sand increasing downward, carbonate decreases.	Begin drilling @ 18 ft @ 1430 MDT
	20					
			C-2			25 ft @ 1432 MDT
	30		C-3		Sandstone, yellowish red (5YR5/8) to reddish brown (5YR4/4) downward, very calcareous, with small pebbles of chert from about 44 ft to 57 ft, some MnO_2 stains	30 ft @ 1433 MDT add jt
	40		C-4			
			C-5			
			C-6			45 ft @ 1449 MDT
	50		C-7			50 ft @ 1456 MDT
					58 ft Sandstone, light brown, fine to coarse, subangular grains may be separated by carbonate cement.	
	60		C-8			60 ft @ 1500 MDT add jt

cutting sample number noted at sample depths

Hole ID: SNL-3 | CORE LOG (cont. sheet) | Sheet 2 of 10

Logged by: Dennis W. Powers, Ph.D., consulting geologist | Date: 8/14/03

Run Number	Depth (feet)	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
N/A	60	N/A	N/A		60-95 ft: sandstone, similar to section from ~30-40 ft, with some zones of pebbles	
	70	C9				70 ft @ 1511 MDT
					zone of fine-grained dark reddish sand	
	80	C10				80 ft @ 1515 MDT
	90	C11				90 ft @ 1520 MDT add jt
					Base of Gatuña Formation 94 ft Top of Dewey Lake Formation	
		C12				
	100	C13			95-577 ft: Siltstone and claystone, with some fine to very fine grained sandstone; red (2.5YR4/6) with small greenish gray reduction spots. Very calcareous to calcareous from 95-225 ft, gypsiferous and mainly non-calcareous from 225-577 ft.	100 ft @ 1532 MDT
	110	C14				110 ft @ 1539 MDT
	120	C15				118 ft @ 1544 MDT add jt, begin drilling 1607 MDT
	130	C16				130 ft @ 1617 MDT
	140	C17				140 ft @ 1630 MDT

cutting sample number noted at sample depths

Hole ID: SNL-3

CORE LOG
(cont. sheet)

Sheet 3 of 10

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

Date: 8/14/03; 8/15/03

Run Number	Depth (feet)	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
N/A	140	N/A	N/A		Note scale change	

% Recovered column: cutting sample number noted at sample depths

Depth (feet)	Sample
140	
	C18
160	C19
	C20
180	C21
	C22
200	C23
	C24
	C25
220	C26
	C27
	C28
240	C29
	C30
260	C31
	C32
280	C33
	C34
300	C35

Description

Dewey Lake Formation, cont.

95-577 ft: Siltstone and claystone, with some fine to very fine grained sandstone; red (2.5YR4/6) with small greenish gray reduction spots. Very calcareous to calcareous from 95-225 ft, gypsiferous and mainly non-calcareous from 225-577 ft.

159-163 ft, 166-167 ft: Sandstone, reddish-brown (2.5YR5/4), fine to very fine grained, moderately calcareous.

172 ft: Small chip of gypsum; moderately calcareous zone.

172-200 ft: Claystone and siltstone, interbedded; moderately calcareous.

200-211 ft: Sandstone, reddish brown, very fine to medium, subangular to well rounded, with few opaque grains; very poorly indurated (informal SS1 of Dewey Lake)

Interbedded claystone, siltstone, and very fine grained sandstone; gypsiferous from 225 ft, non-calcareous.

Remarks

150 ft @ 1644 MDT; end drilling 8/14 begin 8/15 @0630 MDT; no water in hole

160 ft @ 0649 MDT

165 ft @ 0706 MDT

170 ft @ 0710 MDT

175 ft @ 0715 MDT

180 ft @ 0720 MDT add jt @ 181 ft cuttings slightly moist @ 184 ft

190 ft @ 0738 MDT; circulate air

195 ft @ 0747 MDT

200 ft @ 0752 MDT

205 ft @ 0757 MDT

210 ft @ 0759 MDT stop 212 ft @0801 MDT to observe, add jt; circulate @ 0900, no moisture; started drilling with mist and Quick Foam to control hole conditions

220 ft @ 0916 MDT

225 ft @ 0922 MDT

230 ft @ 0927 MDT

235 ft @ 0932 MDT

240 ft @ 0937 MDT add jt

250 ft @ 0956 MDT

260 ft @ 1012 MDT

270 ft @ 1027 MDT add jt

280 ft @ 1048 MDT

285 ft @ 1053 MDT

290 ft @ 1056 MDT

295 ft @ 1101 MDT

300 ft @ 1109 MDT

Hole ID: SNL-3	CORE LOG (cont. sheet)	Sheet 4 of 10
Logged by: Dennis W. Powers, Ph.D., consulting geologist		Date: 8/15/03

Run Number	Depth (feet)	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
					Note scale change	
N/A	300	N/A	N/A		**Dewey Lake Formation, cont.** 95-577 ft: Siltstone and claystone, with some fine to very fine grained sandstone; red (2.5YR4/6) with small greenish gray reduction spots. Very calcareous to calcareous from 95-225 ft, gypsiferous and mainly non-calcareous from 225-577 ft.	308 ft add jt
		C36				310 ft @ 1133 MDT
	320	C37				320 ft @ 1140 MDT
						325 ft @ 1146 MDT
		C38				330 ft @ 1150 MDT
						338 ft @ 1200 MDT add jt, stop for lunch
	340	C39				340 ft @ 1245 MDT
		C40				350 ft @ 1255 MDT
	360	C41				360 ft @ 1303 MDT
					365-385 ft: easier drilling; abundant gypsum @ 385 ft	
		C42				370 ft @ 1315 MDT add jt
						375 ft @ 1325 MDT
	380	C43				380 ft @ 1328 MDT
						385 ft @ 1331 MDT
		C44				390 ft @ 1335 MDT
	400	C45				400 ft @ 1346 MDT add jt
		C46				410 ft @ 1400 MDT
	420	C47				420 ft @ 1407MDT
		C48				430 ft @ 1415 MDT add jt
	440	C49				440 ft @ 1431 MDT
		C50				450 ft @ 1439 MDT
	460	C51				460 ft @ 1449 MDT add jt

cutting sample number noted at sample depths

Hole ID: SNL-3

CORE LOG
(cont. sheet)

Sheet 5 of 10

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

Date: 8/15/03; 8/18/03

Run Number	Depth (feet)	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
					Note scale change	
N/A	460	N/A	N/A		Dewey Lake Formation, cont. 95-577 ft: Siltstone and claystone, with some fine to very fine grained sandstone; red (2.5YR4/6) with small greenish gray reduction spots. Very calcareous to calcareous from 95-225 ft, gypsiferous and mainly non-calcareous from 225-577 ft.	
		C52				470 ft @ 1510 MDT
	480	C53				480 ft @ 1516MDT
		C54				490 ft @ 1524 MDT add jt; get water
	500	C55				500 ft @ 1606 MDT
		C56				510 ft @ 1612 MDT
	520	C57			365-385 ft: easier drilling; abundant gypsum @ 385 ft	520 ft @ 1616 MDT add jt @ 528
		C58				530 ft @ 1630 MDT
	540	C59				540 ft @ 1635 MDT
		C60				550 ft @ 1639 MDT
	560	C61				560 ft @ 1644 MDT add jt
		C62			Base of Dewey Lake Formation 577 ft	570 ft @ 1654 MDT
	580	C63			Top of Rustler Formation	580 ft @ 1700MDT
		C64			A-5 577-610 ft: Gypsum and anhydrite, white to gray; fine sugary to coarse translucent crystals	590 ft @ 1709 MDT end drilling 8/15/03 @ 592 ft, 1711 MDT
	600	C65				8/18/03, 0730 MDT, moisture indicated 587.40 ft below temporary casing; on bottom @ 0815 MDT, hole clean, no fluid blown from hole
		ns			M-4/(H-4) 610-616 ft: Claystone, reddish brown (2.5YR4/4), very soft, non-calcareous.	
		C66			616-622 ft: Siltstone, dark gray (7.5YRN5/), indurated, non-calcareous	
	620	C67				620 ft @ 0848 MDT

cutting sample number noted at sample depths

Hole ID: SNL-3

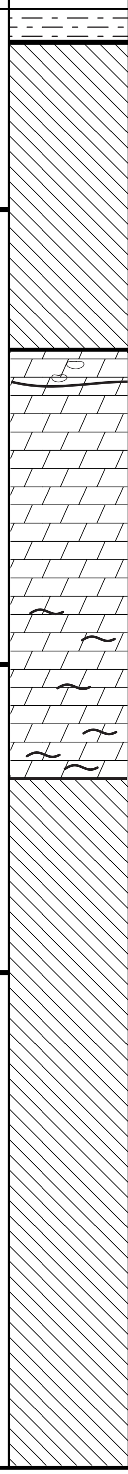
CORE LOG
(cont. sheet)

Sheet 6 of 10

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

Date: 8/18/03

Note scale change

Run Number	Depth (feet)	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
N/A	620–631 (630)	N/A; C68	N/A; 622		M-4/(H-4): 616-622 ft: Siltstone, dark gray (7.5YRN5/), indurated, non-calcareous 622-631 ft: Gypsum and anhydrite, dark gray	
1	631–657.4 (640, 650)	Cut 26 ft; recovered 26.4 ft	631; ~0.5' in segments < 4 inches; RQD = 98.1		A-4: 631-638.6 ft: Gypsum and anhydrite, dark gray, fine to coarse crystalline; laminar to bedded, probable thin beds of bedded nodular textures. Carbonate and organic-rich zones @ 633.4, 633.9, 634.9-635.2, 636.8-637, 638-638.6 ft. Thin (0.0625-0.25 inch) subhorizontal zones of fibrous white gypsum, most prominent in carbonate zones. Vertical fractures with fibrous gypsum @ 637 ft. Larger nodule @ ~637.5 ft. 638.6 ft: base Forty-niner Member, top Magenta Dolomite Member 638.6-662.1 ft: Dolomite and gypsum, light gray (2.5YR7/2) to grayish brown (2.5YR5/2); laminar to thin bedded throughout; zones of small ripples on minor erosional surfaces, some isolated ripples (starved system). Dolomite and gypsum are granular, generally ~ medium sand, some fine to very coarse; a few laminae are > 0.5 inch thick. Nodular gypsum in dolomite 640.9-640.4 ft; erosional surface overlying nodular zone, fine laminae and slight soft sediment deformation on erosional surface. Very little gypsum from 640.4-638.9 ft, organic-rich laminae at top, possible stromatolite. Organic-rich, fine laminae from 646-643.5 ft (erosional surfaces), very little gypsum. Very little gypsum 643.5-656 ft. Darker/lighter laminae may imply different clay or organic content. 650-662.1 - increasing gypsum in fractures (and laminae?) parallel to bedding. High-angle fracture at 648 ft. Basal dark layers of organic matter are probable stromatolites, low amplitude.	
2	657.4–672.9 (660, 670)	Cut 15 ft; recovered 15.5 ft	657.4; all segments > 4 inches; RQD = 100		662.1 ft: base Magenta Dolomite Member, top of Tamarisk Member	672.9 ft, end coring 8/18/03; begin 8/19/03, ream to 673 ft, drill with mist to 720 ft fluid level 600.9 ft below casing @ 0636 MDT, 8/19/03
N/A	672.9–700 (680, 690, 700)	N/A; C69 (680); C70 (690); ns (700); cutting sample number noted at sample depths	N/A; 672.9		A-3: 662.1-719.6 ft: Anhydrite, brownish-gray, with coarse gypsum and thin (1-2 inch) carbonate-rich bands. Poor to moderate nodule development in upper cored section. Laminar to bedded. Carbonate-organic zones @ 663-663.3, 665-665.6, 666.2-666.6, 668, 670.45-670.50, 671.4. Horizontal separations filled with fibrous gypsum are observable in the carbonate zones.	680 ft @ 1106MDT 690 ft @ 1120 MDT; add jt; lunch break 700 ft @ 1158 MDT

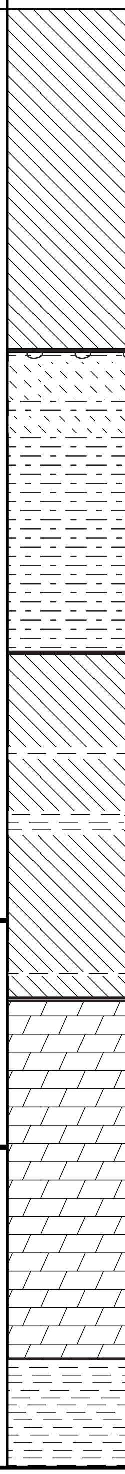
Hole ID: SNL-3

CORE LOG
(cont. sheet)

Sheet 7 of 10

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

Date: 8/19/03; 8/20/03

Run Number	Depth (feet)	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
N/A	700–719.6	ns; N/A; C70 (710); C71 (720); cutting sample number noted at sample depths	N/A	 A-3	672.9-719.6 ft: Anhydrite and gypsum, gray; limited cuttings.	705 ft @ 1200 MDT 710 ft @ 1203MDT 715 ft @ 1206MDT 720 ft @ 1211 MDT
3	719.6–750	Cut 30 ft; recovered 30.4 ft	all recovered core in segments > 4 inches; RQD = 100	A-3; M-3/(H-3); A-2	719.6-719.8 ft: Conglomerate; rounded anhydrite clasts to 0.5"; clay, sulfate matrix. 719.8-721.5 ft: Gypsum and anhydrite, gray, laminar, high-angle lower contact 721.5-722.4 ft: Claystone, gray (2.5YRN5/ to N3/); bedding deformed to overlying gypsum 722.4-723 ft: Gypsum, gray, with dark gray clay; thin clay laminae at high-angle (~70^{o}) from horizontal, parallel to lower contact. 723-735.2 ft: Claystone, silty, reddish brown (2.5YR4/4) and argillaceous siltstone, reddish brown (2.5YR5/4); conglomeratic from base to 728.5 ft, pebbles decrease in size upward, basal contact erosional, upper contact erosional and loaded; some slickensides normal to dip. Fining upwards cycles 728-725, 725-723. Most of unit is bedded 735.2-740.5 ft: Anhydrite, gray, and gypsum; dispersed clay or organics; possible bedded nodular texture 740.5-741 ft: Claystone, silty, reddish brown (2.5YR4/1); thin laminae of anhydrite; slickensided. 741-744 ft: Anhydrite, gray; fractures filled with reddish brown claystone. 744-745.2 ft: like 740.5-741; numerous thin gypsum-filled subhorizontal fractures, slickensides.	
4	750–762.5	Cut 12.5 ft; recovered 8 ft	5' core > 4"; RQD = 62.5		745.2-747 ft: Anhydrite, gray to brown upward, carbonate laminae; silty and gypsiferous upward. 747-754.2 ft: anhydrite and gypsum, gray; laminar to bedded, inclined about 15^{o}; silty claystone at 753; fine, crinkly laminae from algal growth at base. 754.2 ft: base Tamarisk Member, top of Culebra Dolomite Member	750 ft, end coring 8/19/03 begin coring 8/20/03; no water measured in hole @ 0620 MDT with probe; bridged, blew water from hole with compressed air
5	762.5–780	Cut 19.5 ft; recovered 7.5 ft	1.5' core in segments > 4"; RQD = 20.0	M-2/(H-2)	754.2-774 ft (based on geophysical log): Dolomite, pinkish gray (7.5YR7/2), with light reddish brown (5YR6/3) organic-rich zone at top. Fractured in elongate blocks with fresh surfaces. Vugs common, from very small (0.125") to large (>1"). Larger vugs elongate in horizontal plane. 774 ft: base Culebra Dolomite Member, top of Los Medaños Member (based on log) 774-784 ft: M-2/(H-2) not recovered in coring; interval determined by geophysical logs.	vertical fractures appear fresh; horizontal fractures have dark staining Much of Culebra core was lost and middle and lower part are poorly represented.

Hole ID: SNL-3

CORE LOG
(cont. sheet)

Sheet 8 of 10

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

Date: 8/20-22/03

Run Number	Depth (feet)	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
	780		782	no core	A-1 782-783.1 ft: Conglomerate, gypsum and anhydrite clasts to 1" diameter; subangular to subround; clay and sulfate matrix. 783.1-791.6 ft: Anhydrite and gypsum, gray, laminar to thin bedded, ~ horizontal; stylolites or crinkly bedding @ 784.4, 785.1, 787.6, 789.8, 790.2; best developed at 784.4.	Coring ended 782' on 8/20/03. Water level 422.5 ft below casing collar (~ ground level) at 0711 MDT 8/21/03 Begin drilling with brine
6	790 800 810	Cut 30 ft; recovered 27.2 ft	~2 ft in segments < 4 inches; RQD = 92.6		M-1/(H-1) 791.6-~810.0 ft: Sandstone, silty, and siltstone, sandy, dark reddish brown (2.5YR3/4) to reddish brown (2.5YR4/4). Sand is very fine; thin beds, wavy to irregular, not well exposed; unit is not well indurated. Local grayish mottling or thin zones of gray. Possible smeared intraclast textures from 800-804. Small anhydrite clasts in siltstone on erosional surface over anhydrite at 797.0 and 798.3. 797.0-797.5 and 798.3-798.5: Anhydrite, gray, laminated. Some thin beds of gypsum, about 0.25 inch thick, from 800-802.	Note re core box markings. Recovered 0.3 ft of material at top of core run 6 of undetermined origin. It is not consistent with the sequence and is likely infill between coring runs. Total marked interval is from 782-808.9 ft = 26.9 ft. Core loss from core run 6 is believed mainly from lower 10 ft interval.
			812	no core		
7	820 830	Cut 27 ft; recovered 15.2 ft	11.5' core > 4"; RQD = 75.7		A-2 825.7-839 ft: Sandstone, very fine grained, silty, argillaceous, reddish brown (2.5YR4/4) with local zones of greenish gray (10YR6/2; light brownish gray). Grain size appears uniform from base to top of section cored. Zone is poorly indurated, soft. No halite, no sulfate observed; slightly calcareous in gray zones. Thin bedded, with zone ~832-835 with no visible bedding. Vertical fracture 831-831.4; possible high-angle fracture 836-837, with silt fill? Short segments @ ~45^{o} from horizontal show washouts on core surface and may indicate fractures.	Core loss from core run 7 is attributed mainly to upper part; core was marked from base of core run.
	840		839	no core		End of coring 8/21/03 Fluid level 65 ft below casing top before drilling began 8/22/03.
8	850	Cut 17.0 ft; recovered 10.0 ft	~6' core in segments > 4"; RQD = 60.0		846-856 ft: Sandstone, very fine grained, silty, argillaceous, gray (10YR5/1). Grain size appears uniform and similar to core from run 7. Zone cored is poorly to moderately well indurated. No halite or sulfate, slightly calcareous. Zones shows extensive lamination and very thin bedding, with some laminae ~ 0.25 inch. Scattered circular to oval discoloration on core surface is probably bioturbation. Core surface shows vertical to diagonal narrow washouts indicating fractures. Few fractures show open apertures.	
	860		856	no core		

Hole ID: SNL-3

CORE LOG
(cont. sheet)

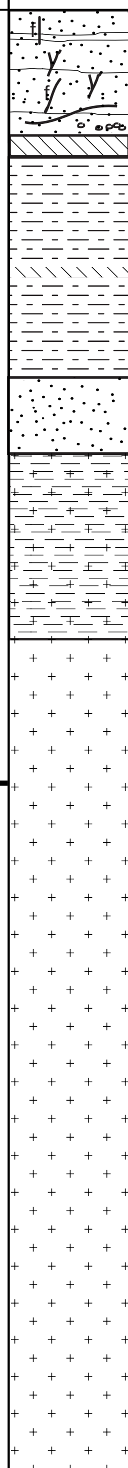
Sheet 9 of 10

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

Date: 8/22/03; 8/25/03

Run Number	Depth (feet)	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
9	860–881	Cut 25 ft; recovered 22.4 ft	~3 ft in segments < 4 inches; RQD = 86.6		Note Scale Change	
N/A	881–900	N/A; ns; C72; cutting sample number noted at sample depths	N/A			

Depth scale: 860, 865, 870, 875, 880, 881, 885, 890, 895, 900



Note Scale Change

858.6-862.8 ft: Sandstone, argillaceous, gray; bedded to cross-bedded; fragmented into blocks with fractures vertical to diagonal; gypsum in fractures at base. Mottled by possible bioturbation.

862.8-863.4 ft: Sandstone, argillaceous, reddish brown, thin beds, with erosional contact above base. Anhydrite pebble, some conglomerate at base below erosional surface.

863.4 Base of Rustler Formation
Top of Salado Formation

863.4-863.8 ft: Gypsum, white to gray, fine laminae to thin beds, somewhat wavy, with thin claystone interbedded. Probably amalgamated unit.

863.8-864.6 ft: Siltstone, reddish brown, tiny white mottles along horizontal plane. Gray laminae at base.

864.6-866.5 ft: Claystone, silty, sandy, mottled gray; probable smeared intraclast textures, some clasts (?) near base. Sulfatic at top.

866.5-867 ft: Gypsum, white to brown, laminar, with claystone between. Upper gypsum is deformed.

867-870 ft: Siltstone, sandy, argillaceous; sand is similar to unit below, more silt and clay. Bedded @ 0.5 inch scale to 868; sulfate @ 867.7. Slight gray mottling in upper 6 inches.

870-872 ft: Sandstone, silty, argillaceous, pinkish red; very soft; mottled. No obvious bedding. Mottling is gray, some discontinuous horizontal mottling. Sand grains are round to well-rounded, well sorted, mainly quartz with 1-2% opaques.

872-877 ft: Halite, argillaceous, silty, with clastic content increasing upward to 872.9. Halite with less clastics from 872.9-872. Halite is medium coarse, general < 1 inch, with corroded boundaries rather than displacive boundaries. Some mudstone laminae ~ 0.25-0.5 inch thick.

877-881 ft: Halite, clear to brownish, generally very coarse, with crystals 0.5-1.0 inch; some cloudy crystals from small fluid inclusions; some (~1%) gypsum or polyhalite in discontinuous laminae (< 0.0625 inch) near bottom of cored section. Bedded at 0.1-03 ft. Vug at 881 possibly due to KCl dissolution.

Remarks:

Coring and drilling ended 881' on 8/22/03.
Begin drilling at 881' at 1351 MDT 8/25/03 after reaming cored zone.

890' @ 1403 MDT

Hole ID: SNL-3	CORE LOG (cont. sheet)	Sheet 10 of 10
Logged by: Dennis W. Powers, Ph.D., consulting geologist		Date: 8/25/03

Run Number	Depth (feet)	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
					Note Scale Change	
N/A	900	N/A	N/A		881-970 ft: Halite, similar to halite in core; some probable polyhalite/gypsum cuttings associated with harder drilling zones from 931-938 and 941-948.	900' @ 1413 MDT
	910	C73				910' @ 1427 MDT; add jt
	920	C74				920' @ 1455 MDT
						925' @ 1500 MDT
	930	C75				930' @ 1506 MDT
		C76				935' @ 1523 MDT
	940	C77				940' @ 1533 MDT
		C78				947' @ 1545 MDT; add jt drilling @ 1554 MDT
	950	C79				950' @ 1558 MDT
						955' @ 1604 MDT
	960	C80				960' @ 1611 MDT
						965' @ 1617 MDT
	970	C81				Total depth 970 @ 1623 MDT
	980					

cutting sample number noted at sample depths

Appendix D
Geophysical Logs

Geophysical logging of SNL-3 was conducted by Geophysical Logging Services, 6250 Michele Lane, Prescott, Arizona 86305, on August 26, 2003, and on September 10, 2003. The operator was Raymond Federwisch. 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 by the Hydrology Section that includes:

1) Electronic copies of the logs produced by Geophysical Logging Services using WellCAD vs 3.2,
2) WellCAD Reader to open the electronic logs, and
3) Electronic data files in both .txt and .las formats.

On August 26, 2003, the following geophysical logs were obtained:

- Caliper
- Natural gamma
- Neutron
- Density
- Formation resistivity (including induction log)
- Fluid resistivity
- Fluid (or drillhole air) temperature

The drillhole was open to about 970 ft bgl at the time of logging. A conductor casing had been emplaced to a depth of 30 ft bgl. The fluid level at the time of logging was above the bottom of casing.

On September 10, 2003, the following geophysical log was obtained after the drillhole was reamed using a 12.25-inch-diameter bit to a depth of about 785 ft bgl:

- Caliper (0-784 ft)

The caliper log was used to determine drillhole size for estimating material volume placed in the annulus between fiberglass reinforced plastic casing and the drillhole wall. The top of the connector on the surface conductor casing (see photograph next page) was used as the reference point for depths measured during drilling and logging.

Geophysical Logging Services logging vehicle (above) set up and logging SNL-3 on August 26, 2003. A logging tool is at the top of connector on the surface casing (left, arrow) prior to making a logging run of SNL-3 on August 26, 2003. The connector is the reference point for depths measured during drilling and logging.

Appendix E
Permitting and Completion Information

A case file for SNL-3 (C-2949) containing official documents is maintained by the land management 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-2949.

Information on management of well-drilling fluids for SNL-3 is included at the end of this appendix. Original files are maintained by Washington Regulatory and Environmental Services.

Dennis W. Powers, Ph. D.

Consulting Geologist

September 1, 2003

Ron Richardson
Field Lead
WRES

Rick Beauheim
Hydrology Lead
Sandia National Laboratories

Re: Screen Interval for Culebra Dolomite Member in SNL-3

Our discussions regarding the Culebra Dolomite Member in SNL-3 indicate that the best interval to screen is from 773-756 ft below the top of the permanent conductor casing. This decision is based on geophysical logs completed on August 26, 2003 (see attached figure).

These are the factors we considered in this decision for SNL-3:

- The Culebra interval, as indicated by the natural gamma geophysical log, is from 775–755 ft below the top of the permanent conductor casing. This interval is 20 ft thick, which is less than the average around the WIPP site.
- The screened or slotted section of a single casing joint is ~ 27 ft long, too long for this shorter Culebra interval. Two shorter slotted casings, each about 10 ft long, provide a total screened interval of ~ 14 ft. This will provide a screened interval that will incorporate nearly all of the Culebra.
- No core was recovered from the basal Culebra or from most of the laminated claystone and mudstone (M-2/H-2) below the Culebra. Geophysical logs indicate a typical signature for the interval, with M-2/H-2 having a thickness of about 9 ft. The laminated claystone immediately underlying the Culebra commonly behaves somewhat plastically.
- Core and geophysical logs above the Culebra indicate the anhydrite/gypsum unit (A-2) is intact and separates the Culebra from the Tamarisk Member mudstone (M-3/H-3) by ~ 17 ft. Two thin claystone/siltstone beds within A-2 are at least 10 ft above the Culebra, and the top of the sand/gravel pack should be below these two thin beds.
- There is no indication of halite in the Los Medaños Member in either cores or logs.

By placing the bottom of the screened interval 773 ft below the top of the conductor, the mudstone below the Culebra should be isolated from squeezing into the screens. The top of the screened interval at 756 ft should be isolated from M-3/H-3. The top of the sand/gravel pack around the screen should not be higher than about 746 ft below the top of the casing to prevent circulation into M-3/H-3.

To provide adequate space below the screened interval for pumping, a minimum 10 ft long blank casing should be added below the screened casing. The lower part of the hole should be cemented up into A-1, the anhydrite below the Culebra, or above, with top of cement in the interval from 776–790 ft below the top of the conductor casing to minimize circulation into the lower Los Medaños Member, even though there is no evidence of halite in the Rustler Formation at SNL-3. The top of cement may be drilled to provide room for the casing below Culebra.

I believe this letter summarizes our discussions and presents the hydrological and geological justification for setting the screened interval and preparing SNL-3 for completion.

Sincerely,

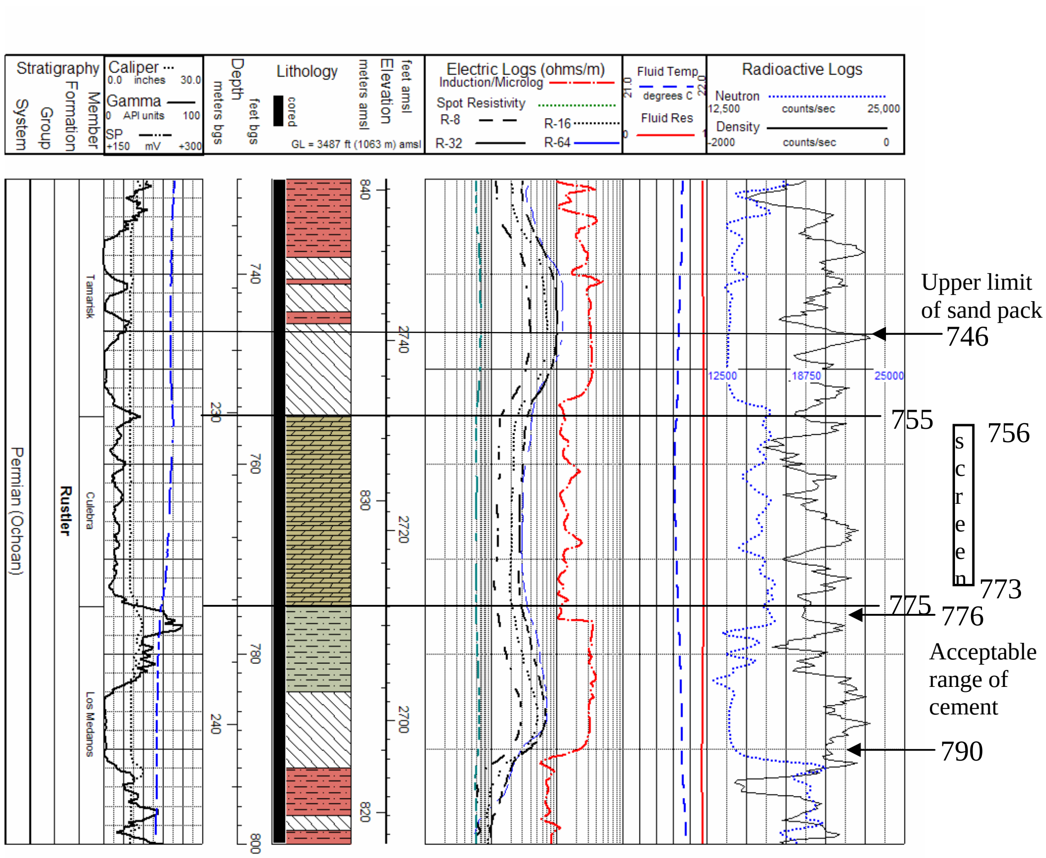
Dennis W Powers

Dennis W. Powers

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

Dennis W. Powers, Ph. D.
Consulting Geologist

Partial Geophysical Log of SNL-3



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

Dennis W. Powers, Ph. D.

Consulting Geologist

September 1, 2003

Rey Carrasco
Geotechnical Engineering
Washington TRU Solutions
Carlsbad, NM 88220

Storage and Retention of Cores and Rock Samples from SNL-3

Background
Cores and cutting samples have been collected from drillhole SNL-3 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-3 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-3 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-3 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 <u>cores</u> obtained from SNL-3 be maintained indefinitely under normal storage conditions because of their relevance to hydrology and monitoring programs. The <u>cores</u> 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 <u>cuttings</u> samples be retained under normal storage conditions through the approval by EPA of the second CRA. The <u>cuttings</u> are commonly very fine in shallow sections and add little to the geologic record from initial observations as well as geophysical logs. <u>Cuttings</u> 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 approved for publication in the basic data report for SNL-3.

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*

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

STATE OF NEW MEXICO
OFFICE OF THE STATE ENGINEER

Roswell Office
1900 WEST SECOND STREET
ROSWELL, NM 88201

Trn Nbr: 258325
File Nbr: C 02949

Feb. 14, 2003

DOUG LYNN
US DEPT OF ENERGY CARLSBAD FIELD OFFICE, WIPP
PO BOX 3090
CARLSBAD, NM 88221-3090

Greetings:

Enclosed is your copy of the Exploratory Permit which has been approved. In accordance with the conditions of approval, the well can only be tested for 10 cumulative days, and the well is to be completed on or before 02/14/2004, unless a permit to use the water is acquired from this office.

Sincerely,

Mike Stapleton
(505)622-6467

Enclosure

cc: Santa Fe Office

explore

Revised August 1967

IMPORTANT - READ INSTRUCTIONS ON BACK BEFORE FILLING OUT THIS FORM

APPLICATION FOR PERMIT

To appropriate (explore & monitor) the Underground Waters of the State of New Mexico

Date Received February 12, 2003 File No. C-2949 Expl

1. Name of applicant U.S. Department of Energy, Carlsbad Field Office, WIPP
   Mailing address P.O. Box 3090, Carlsbad, New Mexico 88221-3090
   City and State Carlsbad, New Mexico, 88221

2. Source of water supply Artesian - Culebra (Artesian or shallow water aquifer), located in Carlsbad, (Name of underground basin)

3. The well is to be located in the n/w 1/4 n/w 1/4 s/e 1/4, Section 34 Township 21 South Range 31 East N.M.P.M., or Tract No. n/a of Map No. n/a of the Carlsbad, District, on land owned by U.S. Department of Energy, Carlsbad Field Office, WIPP

4. Description of well: name of driller West Texas Water Well Service,
   Outside Diameter of casing 5.5" fiberglass inches; Approximate depth to be drilled 940' bgs feet;

5. Quantity of water to be appropriated and beneficially used N/A acre feet, (Consumptive use, diversion)
   for N/A purposes.

6. Acreage to be irrigated or place of use N/A acres.

Subdivision	Section	Township	Range	Acres	Owner

7. Additional statements or explanations This well is to be drilled as an exploration/monitoring well only. It will be drilled to a total depth of 940' bgs in order to acquire core samples from Marker Bed 103. After cores are taken, the well will be cemented back to the Culebra dolomite interval @ 699'-745' bgs. Casing and cement inspections have been identified as hold points pending on site inspections by personnel from the New Mexico Office of the State Engineer. After the initial drilling, pump tests will be conducted to determine the production capacity of the Culebra. These will occur for approximately 96 hours @ 20 gallons per minute. After the completion of the initial pump test, this well will be used for routine monitoring purposes (e.g., water level measurements).

2003 FEB 12 AM 7:38
STATE ENGINEER OFFICE
ROSWELL, NEW MEXICO

I, Harold Johnson, affirm that the foregoing statements are true to the best of my knowledge and belief and that development shall not commence until approval of the permit has been obtained.

U.S. Dept. of Energy - Carlsbad Field Office, Permittee,

By: Harold Johnson

Subscribed and sworn to before me this 11th day of Feb., A.D., 2003

My commission expires Oct. 3, 2005 Sharon Warren-Briggs
Notary Public

T 258325

Number of this permit C-2949 Expl

ACTION OF STATE ENGINEER

Alter notice pursuant to statute and by authority vested in me, this application is approvedprovided it is not exercised to the detriment of any others having existing rights; further provided that all rules and regulations of the State Engineer pertaining to the drilling of ______________ wells be complied with; and further subject to the following conditions: see attached conditions

Proof of completion of well shall be filed on or before ______________, 20____

Proof of application of water to beneficial use shall be filed on or before ______________, 20____

Witness my hand and seal this 14th day of February, A.D., 2003
John R. D' Antonio, Jr., P.E., State Engineer

By: [signature]
Art Mason, District II Supervisor

INSTRUCTIONS

This form shall be executed, preferably typewritten, in triplicate and shall be accompanied by a filing fee of $25.00. Each of triplicate copies must be properly signed and attested.

A separate application for permit must be filed for each well used.

Secs. 1-4 - Fill out all blanks fully and accurately.

Sec. 5 - Irrigation use shall be stated in acre feet of water per acre per annum to be applied on the land. If for municipal or other purposes, state total quantity in acre feet to be used annually.

Sec. 6 - Describe only the lands to be irrigated or where water will be used. If on unsurveyed lands describe by legal subdivision "as projected" from the nearest government survey corners, or describe by metes and bounds and tie survey to some permanent, easily located natural object.

Sec. 7 - If lands are irrigated from any other source, explain in this section. Give any other data necessary to fully describe water right sought.

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

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.

C2 No water shall be diverted from this well except for testing purposes which shall not exceed ten (10) cumulative days, and well shall be plugged or capped on or before , unless a permit to use water from this well is acquired from the Office of the State Engineer.

LOG The Point of Diversion C 02949 EXPL must be completed and the Well Log filed on or before 02/14/2004.

ACTION OF STATE ENGINEER

Notice of Intention Rcvd: Date Rcvd. Corrected:
Formal Application Rcvd: 02/12/2003 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 14 day of Feb A.D., 2003

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

By: ______________________
Art Mason

Trn Desc: C 02949 EXPL File Number: C 02949
Trn Number: 258325

Revised June 1972

STATE ENGINEER OFFICE

WELL RECORD

Section 1. GENERAL INFORMATION

(A) Owner of well WASHINGTON TRU SOLUTIONS
Street or Post Office Address P.O. BOX 2078 Owner's Well No. SNL-3
City and State CARLSBAD, NEW MEXICO 88221

Well was drilled under Permit No. C-2949 EXPL. and is located in the:

a. N/W ¼ N/W ¼ S/E ¼ ____ ¼ of Section 34 Township 21 S Range 31 E N.M.P.M.

b. Tract No. N/A of Map No. N/A 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. WD-1184

Address 3410 MANKINS ODESSA, TEXAS 79764

Drilling Began 08-14-03 Completed 09-11-03 Type tools MUD ROTARY Size of hole 12-1/4 in.

Elevation of land surface or ____ at well is 3486.54 ft. Total depth of well 785 ft.

Completed well is ☐ shallow XXX 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)
754	775	21	GRAY DOLOMITE RUSTLER FORMATION	10 GPM

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
13-3/8	48	8	2.5 AGL	30	32-½			
5" FIBERGLASS	3.2	4	2" AGL	783-½	785-½	FIBERGLASS CAP ON BOTTOM	.020 SCREEN 773	755

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	30	18" 13-3/8 CSG		27	TRIMMIE
776	970	7-7/8		65	TRIMMIE
0	744	12-1/4" HOLE 5" CSG		513	TRIMMIE

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	1.5	1.5	PAD CONSTRUCTION FILL
1.5	16	14.5	SAND, YELLOWISH-RED, UNCONSOLIDATED (DUNE SAND)
16	29	13	CALICHE, WHITE, SANDY & PEBBLY (MASCALERO CALICHE)
29	95	66	SANDSTONE, YELLOWISH RED TO DARK REDDISH BROWN, CALCAREOUS, PEBBLY (GATUNA FORMATION)
95	225	130	INTERBEDDED SILTSTONE, CLAYSTONE, & FINE GRAINED SANDSTONE RED W/SMALL GREENISH GRAY REDUCTION SPOTS, CALCAREOUS (DEWEY LAKE FORMATION)
225	577	352	AS ABOVE, EXCEPT GRYPSIFEROUS & NOT CALCAREOUS (DEWEY LAKE FORMATION)
577	610	33	ANHYDRITE & GYPSUM, GRAY TO WHITE (A-S, OF FORTY-NINER MEMBER, RUSTLER FORMATION)
610	622	12	CLAYSTONE, REDDISH BROWN, NON-CALCAREOUS, OVERLAYING SILTSTONE, GRAY (M4/H4, FORTY-NINER MEMBER, RUSTLER FORMATION)
622	638.6	16.6	GYPSUM & ANHYDRITE, GRAY (A-4, FORTY-NINER MEMBER, RUSTLER FORMATION)
638.6	662.1	23.5	DOLOMITE & GYPSUM, GRAY TO GRAYISH BROWN, LAMINATED TO THIN BEDDED (MAGENTA DOLOMITE MEMBER, RUSTLER FORMATION)
662.1	721.5	59.4	ANHYDRITE & GYPSUM, GRAY, BEDDED (A3, TAMARISK MEMBER, RUSTLER FORMATION)
721.5	735.2	13.7	CLAYSTONE, SILTY, & SILTSTONE, REDDISH-BROWN, W/SOME GYPSUM (M3/H3, TAMARISK MEMBER, RUSTLER FORMATION)
735.2	754.2	19	ANHYDRITE & GYPSUM, GRAY, W/SOME CLAYSTONE INTERDEDDED (A2, TAMARISK MEMBER, RUSTLER FORMATION)
754.2	775	20.8	DOLOMITE, GRAY, VUGGY (CULEBRA DOLOMITE MEMBER, RUSTLER FORMATION)
775	782	7	CLAYSTONE (M2/H2, LOS MEDANOS MEMBER, RUSTLER FORMATION)
782	792	10	ANHYDRITE, GRAY (A1, LOS MEDANOS MEMBER, RUSTLER FORMATION)
792	863.4	71.4	SANDSTONE, REDDISH BROWN TO GRAY, VERY FINE GRAINED, MODERATELY LITHIFIED (M1/H1, LOS MEDANOS MEMBER, RUSTLER FORMATION)
863.4	932	68.6	HALITE (UPPER SALADO FORMATION)
932	948	16	POLYHALITE, RED (MARKER BED 103, SALADO FORMATION)
948	970	22	HALITE (SALADO 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.

Tommy Pruitt

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 fo[illegible] is used as a plugging record, only Section 1([illegible] d Section 5 need be completed.

PATRICK H. LYONS
COMMISSIONER

State of New Mexico
Commissioner of Public Lands
310 OLD SANTA FE TRAIL
P.O. BOX 1148
SANTA FE, NEW MEXICO 87504-1148

COMMISSIONER'S OFFICE
Phone (505) 827-5760
Fax (505) 827-5766
www.nmstatelands.org

August 29, 2003

Doug Lynn
US Department of Energy
PO Box 3090
Carlsbad, NM 88221-3090

Re: Right-of-Way Easement No. RW-28537

Dear Mr. Lynn:

Enclosed is an approved copy of the captioned grant of right-of-way easement. Also, enclosed are "Affidavit of Completion" forms to be completed and returned to this office upon completion of the project.

If any corrections are necessary, please let us know and we will retype or amend this lease as necessary.

If you have any questions, please feel free to contact this office at the above address or at (505) 827-5728 or 5729.

Sincerely,

Lorrie Gasca

Lorrie Gasca, Management Analyst
Surface Resources Division

PATRICK H. LYONS
COMMISSIONER

State of New Mexico
Commissioner of Public Lands

310 OLD SANTA FE TRAIL
P.O. BOX 1148
SANTA FE, NEW MEXICO 87504-1148

COMMISSIONER'S OFFICE
Phone (505) 827-5760
Fax (505) 827-5766
www.nmstatelands.org

August 26, 2003

Doug Lynn
US Department of Energy
PO Box 3080
Carlsbad, NM 88221

Re: Water Development Easement No. WD-119

Dear Mr. Lynn:

Enclosed is an approved copy of the captioned of water development easement.

If you have any questions, please feel free to contact this office at (505) 827-5728 or 5729.

Sincerely,

Lorrie Gasca

Lorrie Gasca, Management Analyst
Surface Resources Division

"WORKING FOR EDUCATION"

CONTROLLED RECOVERY, INC.
P.O. Box 388 • Hobbs, New Mexico 88241-0388
(505) 393-1079

Bill to JTW
Address

Company/Generator West Texas Water Well Service
Lease Name WIPP SNL-3 10/21/03
Trucking Company JTW | Vehicle Number 704 | Driver (Print) Tim Briones
Date 9 19 03 | Time 930 a.m. / p.m.

Type of Material

☐ Exempt ☐ Tank Bottoms ☒ Fluids
☐ Non-Exempt C117 ☐ Other Material
C138 ☐ Soils List Description Below

NMED C

DESCRIPTION

Non Hazardous Purged Ground Water

Volume of Material ☐ Bbls. ☐ Yard ☒ Gallons 5040

☐ Wash Out ☐ Call Out ☐ After Hours ☐ Debris Charge

This statement applicable to exempt waste only.
I represent and warrant that the wastes are: generated from oil and gas exploration and production operations: exempt from Resource Conservation and Recover Act (RCRA) Subtitle C Regulations; and not mixed with non-exempt wastes.

Agent Tim Briones 636
(Signature)

CRI Representative
(Signature)

TANK BOTTOMS

	Feet	Inches			
1st Gauge			BBLS Received		BS&W %
2nd Gauge			Free Water		
Received			Total Received		

№ 48899

White - CRI Canary - CRI Accounting Pink - CRI Plant Gold - Transporter

SUPERIOR PRINTING SERVICE, INC.

CONTROLLED RECOVERY, INC.
P.O. Box 388 • Hobbs, New Mexico 88241-0388
(505) 393-1079

Bill to ____________________
Address ____________________

Company/Generator West Texas Water Well Service
Lease Name WIPP SNL-3 10/21/03.
Trucking Company F+W | Vehicle Number 704 | Driver (Print) Tim Briggs
Date 9 19 03 | Time 130 a.m. p.m.

Type of Material

- ☐ Exempt
- ☐ Non-Exempt
- C138 ____________
- ☐ Tank Bottoms
- C117 ____________
- ☐ Soils
- ☒ Fluids
- ☐ Other Material
- List Description Below

NMED C

DESCRIPTION

Non Hazardous Purged Ground Water

Volume of Material ☐ Bbls. ________ ☐ Yard ________ ☒ Gallons 5,040

☐ Wash Out ☐ Call Out ☐ After Hours ☐ Debris Charge

This statement applicable to exempt waste only.
I represent and warrant that the wastes are: generated from oil and gas exploration and production operations: exempt from Resource Conservation and Recover Act (RCRA) Subtitle C Regulations; and not mixed with non-exempt wastes.

Agent Tim Briggs 656
(Signature)

CRI Representative ____________________
(Signature)

TANK BOTTOMS

	Feet	Inches			
1st Gauge			BBLS Received		BS&W %
2nd Gauge			Free Water		
Received			Total Received		

№ 48923

White - CRI Canary - CRI Accounting Pink - CRI Plant Gold - Transporter

SUPERIOR PRINTING SERVICE, INC.

CONTROLLED RECOVERY, INC.
P.O. Box 388 • Hobbs, New Mexico 88241-0388
(505) 393-1079

Bill to
Address

Company/Generator West Texas Water Well Service
Lease Name WIPP SNL-3 10/21/03.
Trucking Company FTW | Vehicle Number 704 | Driver (Print) Tim Briones
Date 9 19 03 | Time 400 a.m. / p.m.

Type of Material

☐ Exempt ☐ Tank Bottoms ☒ Fluids
☐ Non-Exempt C117 ☐ Other Material
C138 ☐ Soils NMED C List Description Below

DESCRIPTION

Non Hazardous Purged Ground Water

Volume of Material ☐ Bbls. ☐ Yard ☒ Gallons 5,040

☐ Wash Out ☐ Call Out ☐ After Hours ☐ Debris Charge

This statement applicable to exempt waste only.
I represent and warrant that the wastes are: generated from oil and gas exploration and production operations: exempt from Resource Conservation and Recover Act (RCRA) Subtitle C Regulations; and not mixed with non-exempt wastes.

Agent Tim Briones 636
(Signature)

CRI Representative
(Signature)

TANK BOTTOMS

	Feet	Inches			
1st Gauge			BBLS Received		BS&W %
2nd Gauge			Free Water		
Received			Total Received		

№ 48927

White - CRI Canary - CRI Accounting Pink - CRI Plant Gold - Transporter

SUPERIOR PRINTING SERVICE, INC.

West Texas Water Well Services Rig #15 set up on SNL-3. Compressed air and foam are being used to lift cuttings from the drillhole into the lined pit.

Appendix F
Archeological Clearance Report

The report from Mesa Field 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 section of Washington Regulatory and Environmental Services for the WIPP Project.

TITLE PAGE/ABSTRACT/ NEGATIVE SITE REPORT CARLSBAD FIELD OFFICE

BLM/CFO

1. BLM Report No.:	**2. (ACCEPTED) (REJECTED)**	**3. NMCRIS No.:** 82101
4. Title of Report (Project Title): An Archaeological Survey for a the SNL-3 Water Monitoring Well		**5. Project Date(s):** January 30, 2003 **6. Report Date:** February 7, 2003
7. Consultant Name & Address **Direct Charge:** Sean Simpson **Name:** Mesa Field Services **Address:** P.O. Box 3072 Carlsbad, NM 88221-3072 **Author's Name:** Theresa Straight **Field Personnel Names:** Theresa Straight **Phone:** (505) 628-8885		**8. Permit No.:** 153-2920-02-L **9. Consultant Report No.:** MFS – 823
10. Sponsor Name and Address **Individual Responsible:** Ron Richardson **Name:** Westinghouse TRU Solutions, LLC **Address:** P.O. Box 2078 Carlsbad, NM 88221 **Phone:** (505) 234-8395		**11. For BLM use only** **12. Acreage** **Total acres surveyed:** 2.07 **Per Surface Ownership** **Federal:** 1.06 **State:** 1.01 **Private:** 0

13. Location & Area (maps attached if negative survey)

- **a. State:** New Mexico
- **b. County:** Eddy
- **c. BLM Field Office:** Carlsbad
- **d. Nearest City or town:** Carlsbad, NM
- **Location:** T 21S, R 31E, Section 34: NW¼ NW¼ SE¼, NE¼ NE¼ SW¼
  - **Well Pad Footages:** N/A
- **f. 7.5' Map Name(s)and Code Number(s):** Livingston Ridge, NM Provisional Edition 1985 (32103-D7)
- **g. Area**
  - **Block: Impact:** 100 ft by 100 ft
    - **Surveyed:** 200 ft by 450 ft
  - **Linear: Impact:** 82.71 ft by 20 ft
    - **Surveyed:** N/A

14. a. Records Search

Location: Bureau of Land Management – Carlsbad Field Office and the Archaeological Records Management System (ARMS) via modem
Date: January 29, 2003 by Natalie Allen

List by LA # all sites within .25 miles of the project (those sites within 500' are to be shown on the project map): No previously recorded archaeological sites are within 0.25 miles of the project area.

b. Description of Undertaking (client's activities): Westinghouse TRU Solutions, LLC plans on drilling a water monitoring well. The pad for the well will be 100 ft by 100 ft, yet a 200 ft by 200 ft area was surveyed to ensure the protection of cultural resources. Originally the access road began at Louis Witlock Road and extended west for 260 ft to the well location. Ron Richardson with Westinghouse TRU Solutions, LLC requested that a 100 ft wide corridor on either side of the access road centerline be surveyed so the well location could be shifted east if need be. This resulted in a 450 ft long by 200 ft wide block survey with the acreage totaling 2.07. Since the time of the survey, the well location was shifted east approximately 178 ft. The new location is reflected on the plat map.

c. Environmental Setting (NRCS soil designation, vegetative community, etc.): The project is located within a dune field. The soil is a light brown sand that has been wind worked into dunes up to 3 m high. It is of the Kermit-Berino soil association as defined by the Soil Conservation Service of the U.S. Department of Agriculture. Project elevations average 3,480 ft above mean sea level. Local vegetation is characteristic of Chihuahuan Desert Scrub and includes mesquite, yucca, bunch grasses, and noxious weeds. Due to this vegetative cover, ground surface visibility averaged 70 percent.

d. Field Methods
Transect Intervals: 15 m
Crew Size: 1
Time in Field: 1 hour
Collections: None

15. Cultural Resource Findings: No cultural resources were observed within the project area.
Identification and Description (location shown on project map):

16. Management Summary (recommendations): Because no cultural material was encountered archaeological clearance is recommended for the project area as staked. If any cultural material is encountered during construction activities, work at that location should stop and archaeologists at the BLM-CFO should be notified.

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

Responsible Archaeologist:
Signature_____________________________________**Date**___________________

THE ABOVE COMPLETES A NEGATIVE REPORT. IF ELIGIBLE OR POTENTIALLY ELIGIBLE PROPERTIES ARE INVOLVED, THEN THE ABOVE WILL BE THE TITLE PAGE AND ABSTRACT FOR A COMPLETE REPORT.

Survey for the SNL-3 Water Monitor Well

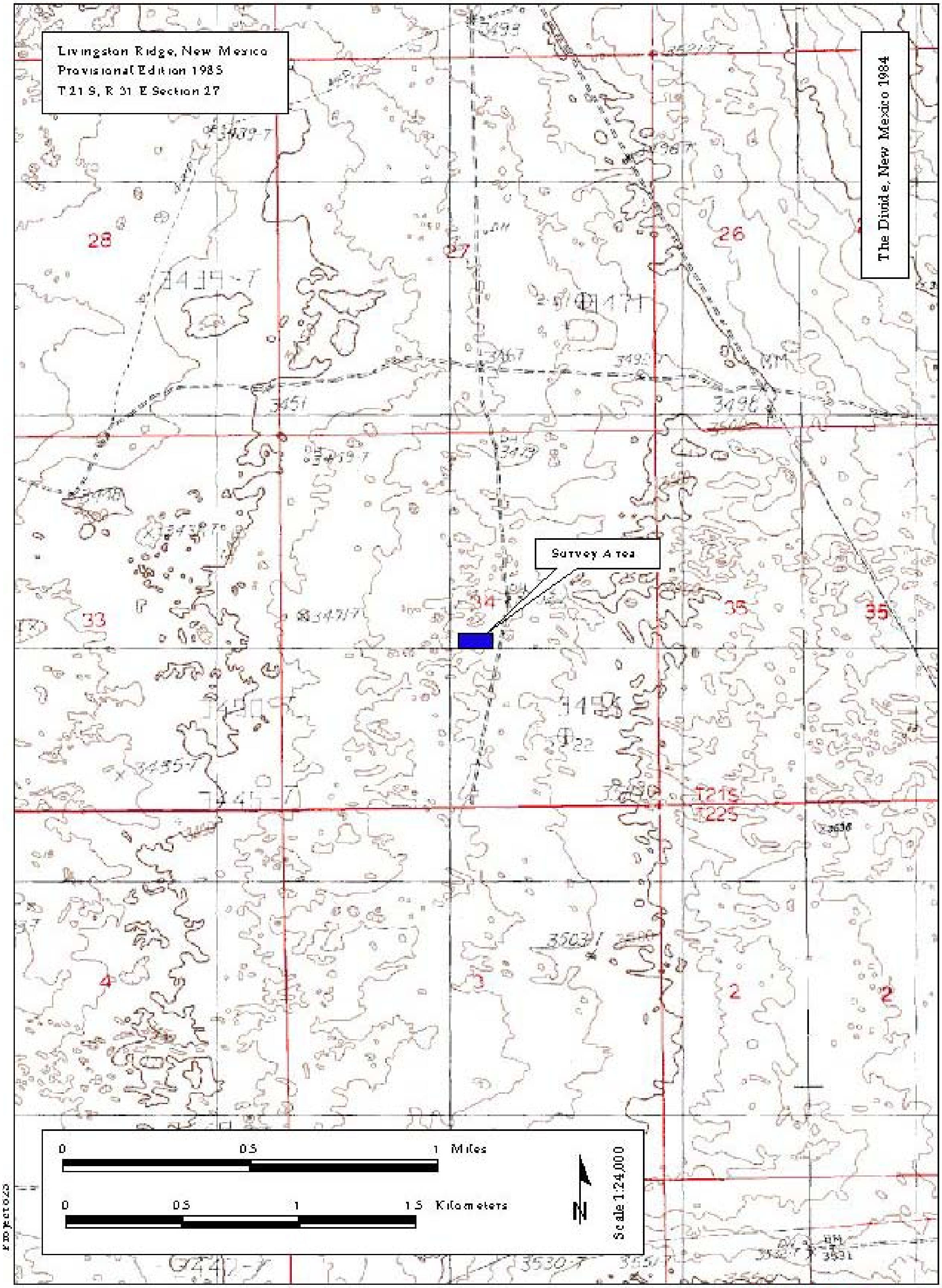


Figure 1. Project Area Map

Mesa Field Services

Appendix F
Photograph Logs

Digital photographs were taken of the cores from SNL-3. These photographs have been compiled into a listing of consecutive photos beginning with the uppermost core (lower Forty-niner Member of the Rustler Formation) and ending with the lowermost (upper Salado Formation). Most of 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.

Photograph Log Sheet

File	DATE	LOCATION	DESCRIPTION OF SUBJECT (includes individual/group names, direction, etc. as appropriate)	PHOTOGRAPHER (initials and dept.)
SNL-3_Core001.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Forty-niner Mbr core, 630.9 - 632.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core002.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Forty-niner Mbr core, 631.8 - 633.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core003.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Forty-niner Mbr core, 632.8 - 634.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core004.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Forty-niner Mbr core, 633.8 - 635.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core005.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Forty-niner Mbr core, 634.8 - 636.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core006.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Forty-niner Mbr core, 635.8 - 637.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core007.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Forty-niner Mbr core, 636.8 - 638.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core008.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Forty-niner / Magenta Dolomite Mbrs core, 637.7 - 639.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core009.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Forty-niner / Magenta Dolomite Mbrs core, 638.4 - 639.5 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core010.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 639.5 - 640.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core011.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 639.8 - 641.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core012.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 640.8 - 642.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core013.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 641.7 - 643.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core014.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 642.7 - 644.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core015.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 643.7 - 645.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core016.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 644.8 - 646.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS

Camera: Casio QV-3500EX **Resolution**: 2048 x 1536 **Page** 1 **of 11**

Photograph Log Sheet

File	DATE	LOCATION	DESCRIPTION OF SUBJECT (includes individual/group names, direction, etc. as appropriate)	PHOTOGRAPHER (initials and dept.)
SNL-3_Core017.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 645.6 - 647.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core018.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 646.6 - 648.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core019.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 647.6 - 649.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core020.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 648.7 - 650.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core021.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 649.7 - 651.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core022.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 650.8 - 652.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core023.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 651.8 - 653.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core024.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 652.7 - 654.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core025.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 653.8 - 655.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core026.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 654.8 - 656.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core027.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 655.8 - 657.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core028.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 656.4 - 657.4 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core029.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 657.4 - 658.4 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core030.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 657.8 - 659.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core031.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 658.7 - 660.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core032.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 659.8 - 661.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS

Camera: Casio QV-3500EX **Resolution**: 2048 x 1536 **Page 2 of 11**

Photograph Log Sheet

File	DATE	LOCATION	DESCRIPTION OF SUBJECT (includes individual/group names, direction, etc. as appropriate)	PHOTOGRAPHER (initials and dept.)
SNL-3_Core033.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite Mbr core, 660.7 - 662.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core034.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Magenta Dolomite / Tamarisk Mbrs core, 661.7 - 663.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core035.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 662.7 - 664.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core036.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 663.7 - 665.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core037.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 664.8 - 666.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core038.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 665.8 - 667.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core039.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 666.8 - 668.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core040.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 667.8 - 669.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core041.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 668. - 670.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core042.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 669.7 - 671.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core043.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 670.7 - 672.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core044.jpg	8-18-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 671.7 - 672.9 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core045.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 710.5 - 720.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core046.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 719.9 - 721.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core047.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 721.0 - 722.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core048.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 722.0 - 723.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS

Photograph Log Sheet

File	DATE	LOCATION	DESCRIPTION OF SUBJECT (includes individual/group names, direction, etc. as appropriate)	PHOTOGRAPHER (initials and dept.)
SNL-3_Core049.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 722.9 - 724.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core050.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 724.0 - 725.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core051.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 725.0 - 726.4 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core052.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 726.0 - 727.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core053.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 727.0 - 728.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core054.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 727.8 - 729.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core055.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 729.0 - 730.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core056.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 730.0 - 731.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core057.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 730.9 - 732.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core058.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 731.6 - 733.0 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core059.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 732.8 - 734.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core060.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 733.8 - 735.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core061.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 734.6 - 736.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core062.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 735.7 - 737.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core063.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 736.6 - 738.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core064.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 737.7 - 739.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS

Camera: Casio QV-3500EX **Resolution**: 2048 x 1536 **Page 4 of 11**

Photograph Log Sheet

File	DATE	LOCATION	DESCRIPTION OF SUBJECT (includes individual/group names, direction, etc. as appropriate)	PHOTOGRAPHER (initials and dept.)
SNL-3_Core065.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 738.7 - 740.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core066.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 739.7 - 741.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core067.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 740.6 - 742.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core068.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 741.7 - 743.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core069.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 742.7 - 744.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core070.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 743.7 - 745.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core071.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 744.7 - 746.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core072.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 745.8 - 757.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core073.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 746.7 - 748.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core074.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 747.8 - 749.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core075.jpg	8-19-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 748.7 - 750.0 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core076.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 749.9 - 751.4 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core077.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 750.9 - 752.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core078.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 751.9 - 753.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core079.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk Mbr core, 752.8 - 754.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core080.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Tamarisk / Culebra Dolomite Mbrs core, 753. - 755.0 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS

Photograph Log Sheet

File	DATE	LOCATION	DESCRIPTION OF SUBJECT (includes individual/group names, direction, etc. as appropriate)	PHOTOGRAPHER (initials and dept.)
SNL-3_Core081.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Culebra Dolomite Mbr core, 754.9 - 756.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core082.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Culebra Dolomite Mbr core, 755.8 - 757.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core083.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Culebra Dolomite Mbr core, 756.8 - 757.8 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core084.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Culebra Dolomite Mbr core, 762.4 - 763.6 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core085.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Culebra Dolomite Mbr core, 762.8 -764.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core086.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Culebra Dolomite Mbr core, 763.8 -765.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core087.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Culebra Dolomite Mbr core, 764.8 - 766.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core088.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Culebra Dolomite Mbr core, 765.8 - 767.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core089.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Culebra Dolomite Mbr core, 766.8 - 768.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core090.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Culebra Dolomite Mbr core, 767.8 - 769.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core091.jpg	8-20-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Culebra Dolomite Mbr core, 768.7 - 769.9 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core092.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 782.0 - 783.6 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core093.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 782.8 - 784.4 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core094.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 783.8 - 785.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core095.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 784.8 - 786.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core096.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 785.9 - 787.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS

Camera: Casio QV-3500EX **Resolution**: 2048 x 1536 **Page 6 of 11**

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File	DATE	LOCATION	DESCRIPTION OF SUBJECT (includes individual/group names, direction, etc. as appropriate)	PHOTOGRAPHER (initials and dept.)
SNL-3_Core097.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 786.8 - 788.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core098.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 787.8 - 789.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core099.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 788.8 - 790.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core100.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 789.8 - 791.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core101.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 790.8 - 792.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core102.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 791.7 - 793.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core103.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 792.8 - 794.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core104.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 793.8 - 795.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core105.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 794.8 - 796.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core106.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 796.1 - 797.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core107.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 796.5 - 797.9 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core108.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 796.8 - 798.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core109.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 797.8 - 799.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core110.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 798.9 - 800.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core111.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 799.9 - 801.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core112.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 800.8 - 802.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS

Camera: Casio QV-3500EX **Resolution**: 2048 x 1536

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File	DATE	LOCATION	DESCRIPTION OF SUBJECT (includes individual/group names, direction, etc. as appropriate)	PHOTOGRAPHER (initials and dept.)
SNL-3_Core113.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 801.8 - 803.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core114.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 802.8 - 804.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core115.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 803.8 - 805.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core116.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 804.8 - 806.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core117.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 805.7 - 807.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core118.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 806.8 - 808.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core119.jpg	8-21-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 807.7 - 808.9 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core120.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 823.9 - 825.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core121.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 824.8 - 826.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core122.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 825.8 - 827.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core123.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 826.8 - 828.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core124.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 827.7 - 829.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core125.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 828.7 - 830.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core126.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 829.7 - 831.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core127.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 830.7 - 832.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core128.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 831.8 - 833.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS

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File	DATE	LOCATION	DESCRIPTION OF SUBJECT (includes individual/group names, direction, etc. as appropriate)	PHOTOGRAPHER (initials and dept.)
SNL-3_Core129.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 832.8 - 834.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core130.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 833.7 - 835-2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core131.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 834.7 - 836.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core132.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 835.8 - 837.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core133.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 836.7 - 838.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core134.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 837.6 - 839.0 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core135.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 846.0 - 847.4 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core136.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 846.8 - 848.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core137.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 847.8 - 849.1 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core138.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 848.8 - 850.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core139.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 849.8 - 851.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core140.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 850.7 - 852.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core141.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 851.8 - 853.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core142.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 852.8 - 854.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core143.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 853.9 - 855.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core144.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 854.8 - 856.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS

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SNL-3_Core145.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 858.5 - 859.5 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core146.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 858.9 - 860.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core147.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 859.9 - 861.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core148.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 860.9 - 862.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core149.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 861.8 - 862.6 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core150.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 862.6 - 863.8 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core151.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 862.8 - 864.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core152.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 863.8 - 865.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core153.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 864.8 - 866.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core154.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 865.8 - 867.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core155.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 866.8 - 868.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core156.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 867.8 - 869.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core157.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 868.8 - 870.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core158.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 869.8 - 871.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core159.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr core, 870.8 - 872.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core160.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Los Medaños Mbr Salado Fm core, 871.8 - 873.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS

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SNL-3_Core161.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Salado Fm core, 872.8 - 874.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core162.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Salado Fm core, 873.8 - 875.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core163.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Salado Fm core, 874.8 - 876.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core164.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Salado Fm core, 875.9 - 877.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core165.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Salado Fm core, 876.8 - 878.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core166.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Salado Fm core, 877.9 - 879.2 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core167.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Salado Fm core, 878.8 - 880.3 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS
SNL-3_Core168.jpg	8-22-03	SNL-3 drillpad; T21S, R31E, sec 34	Close-up photo of Salado Fm core, 879.7 - 881.0 ft bgl, with markings, scale, and time-date stamp	DW Powers Consultant to WTS

Camera: Casio QV-3500EX **Resolution**: 2048 x 1536 **Page 11 of 11**