

Basic Data Report for C-3976-4 (SSW2) for Waste Isolation Pilot Plant (WIPP)

May 2019
(revised August 2019)

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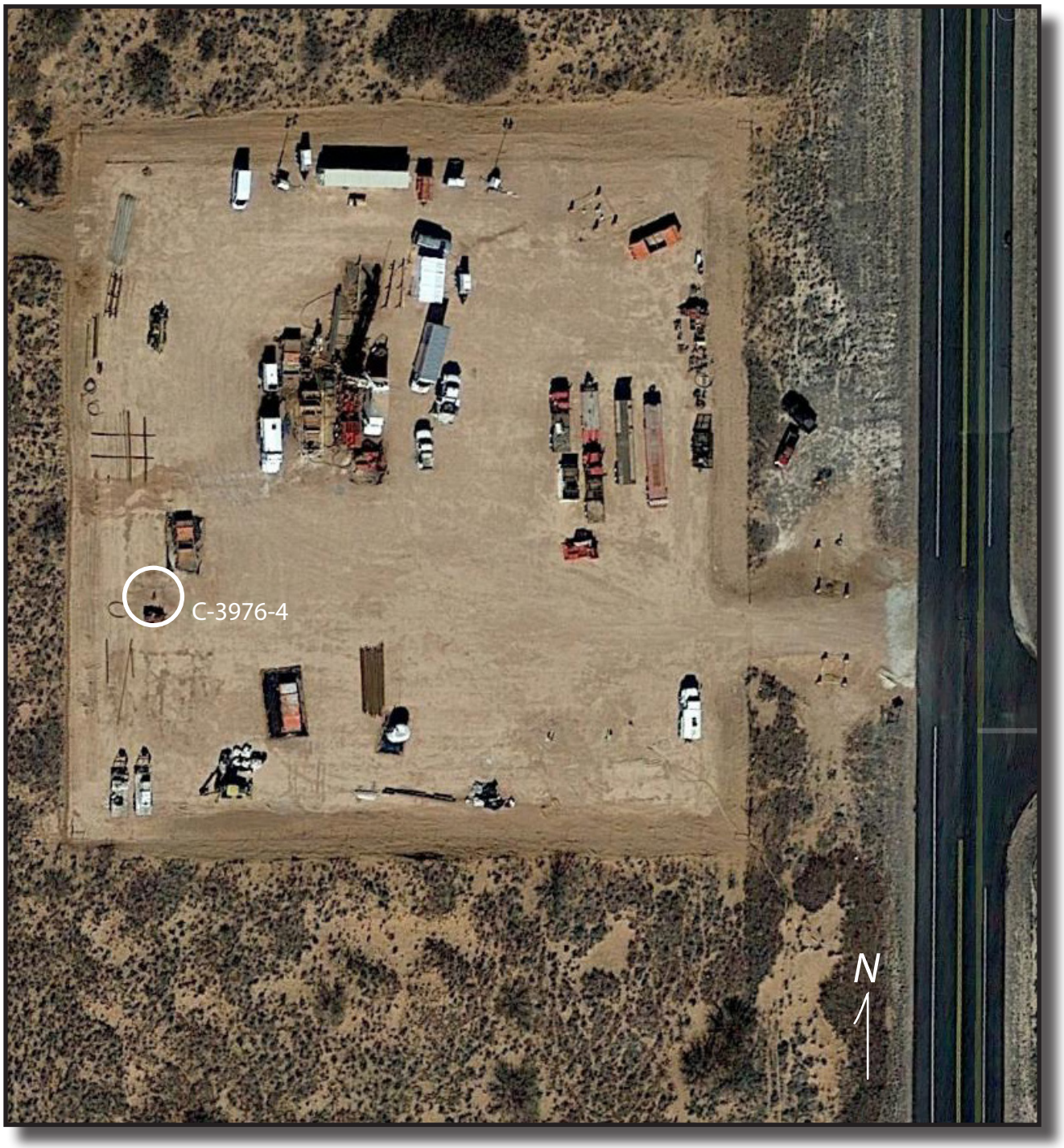

Drillpad for pre-shaft corehole (C-3977) and monitoring well locations at proposed location of unfiltered exhaust shaft (UES). Image from Google Earth, dated 2/1/2017. C-3976-4 is shown near the west side of the drillpad.

Front cover: Stewart Brothers drilling rig on location at C-3976-4 with core run #2 (20-40 ft) on trays for description. Geological team is making a first inspection while core dries for measuring and marking. Photograph December 18, 2016.

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Geology of C-3976-4 (Shallow Subsurface Water 2) for Waste Isolation Pilot Plant (WIPP)*

Dennis W. Powers
Allen Hall
John Thurston
Robert M. Holt
Richard Salness
Brett Seal

EXECUTIVE SUMMARY

August C-3976-4 is located in section 20, T22S, R31E, in Eddy County, NM. The location is west of the current main facilities at the Waste Isolation Pilot Plant (WIPP). The drillhole was permitted by the Office of the State Engineer (New Mexico) as a monitoring well. The objective was to test and monitor for the possible presence of shallow subsurface water (from infiltration through a tailings pile and/or retention pond at WIPP).

C-3976-4 was drilled and cored from ground level to 195 ft (by drill pipe tally) to obtain reference samples and provide direct data regarding the shallow (to ~200 ft) geology prior to completing the well for monitoring. The core was measured, photographed, and described in the field, then boxed and put into climate-controlled, secure storage. Core recovery was highly variable near the surface and improved with depth. Rock Quality Designation (RQD) data were recorded. Cores were re-examined in the lab, and these data are included in the descriptions.

C-3976-4 was logged in open-hole with a suite of geophysical tools including natural gamma, neutron, density, various electrical measurements, caliper, and spectral gamma at a few select depths. A deviation survey after reaching TD showed total deviation to the northwest of ~0.55 ft.

Known near-surface rocks and sediments were only partially recovered. These include dune sand, Berino soil, Mescalero caliche, Mio-pleistocene Gatuña Formation, and Triassic Santa Rosa Formation. The Permo-triassic(?) Dewey Lake Formation was encountered from 30.3 ft (based on core markings) to total depth (TD). The interval above ~164 ft was variably cemented by calcite. Below ~164 ft, the Dewey Lake displays fibrous gypsum that fills fractures or separations and becomes well cemented by gypsum.

The stratigraphy and lithologies encountered in C-3976-4 compare well to the air intake shaft (AIS); it also compares well with the pre-shaft corehole (C-3977), C-3976-1, and C-3976-3, all of which are on the same drillpad.

There was no observed water inflow at C-3976-4 while drilling and coring. This included both upper zones near the top of the Dewey Lake where the possibility existed for anthropogenic water as well as the interval at the natural cement change. Compressed air was used to core to 40 ft; air with mist and soap was used below 40 ft.

C-3976-4 was cemented from TD to 71 ft. The sandpack was placed from 71 ft to 25 ft, with screen from 40-60 ft. Pre-pumping water levels generally range ~27-31 ft below top of tubing; field measured specific gravity of the water is less than 1.00. Water levels in C-3976-2 did not respond to pumping in C-3976-4, and vice versa. The elevation of water in these two wells differs by 2-4 ft. The water in C-3976-4 is inferred to be from loading the borehole with water for logging.

*This report is based on a geological team effort by Rick Salness (RES), Brett Seal (RES), Allen Hall (RES), John Thurston (RES), Robert Holt (University of Mississippi), and Dennis Powers (Consulting Geologist).

INTRODUCTION

Purpose of Waste Isolation Pilot Plant (WIPP)

WIPP is a deep geologic repository for permanent disposal of transuranic and mixed waste that are byproducts of the US nuclear defense program. The facility is located ~25 miles (40 km) east of Carlsbad, NM (Figure 1) in Eddy County.

Purpose and Location of C-3976-4

C-3976-4 (also referred to as Shallow Subsurface Water 2 or SSW2) was proposed, permitted, cored, and completed to determine if natural shallow groundwater is present above the natural cement change in the upper Dewey Lake Formation.

Natural shallow groundwater above this natural cement change in the Dewey Lake was initially encountered in potash corehole P-9 (Jones, 1978). P-9 is located about 2.3 miles southeast of C-2976 -4.

WQSP-6 and WQSP-6A, approximately 0.9 mile south-southwest of C-3976-4, are the nearest encounters (relative to C-3976-4) of water above this cement change in the Dewey Lake. Both wells were drilled in 1994, and WQSP-6A specifically monitors the Dewey Lake (DOE, 1995). Damp cuttings were reported in WQSP-6 below 105 ft to 165 ft, and the driller's report estimated 40-50 gallons per minute flow. Geophysical logs for WQSP-6A show sharp deflections at ~163 ft; cuttings include gypsum above 165 ft.

There were earlier reports of moist cuttings at similar positions relative to this cement change. Monitor wells H-1 and H-3, both drilled in 1976, reported moisture/moist cuttings from the Dewey Lake at depths of ~172 ft and ~169 ft below ground level, respectively (Mercer and Orr, 1979). Geophysical logs indicate the cement change is ~178 ft and ~168 ft below ground level, respectively. The H-2(a,b,c) monitor wells are ~0.38 mile southwest of C-3976-4 and were drilled and completed mid-1977 (Mercer and Orr, 1979). The first well (H-2a) was drilled to 188 ft and tested in open hole for 5 hours with no appreciable liquid. H-2b produced moist cuttings at 185 ft. H-2c produced moist cuttings at 181 ft. Geophysical logs indicate probable cement changes at ~180 ft below ground level.

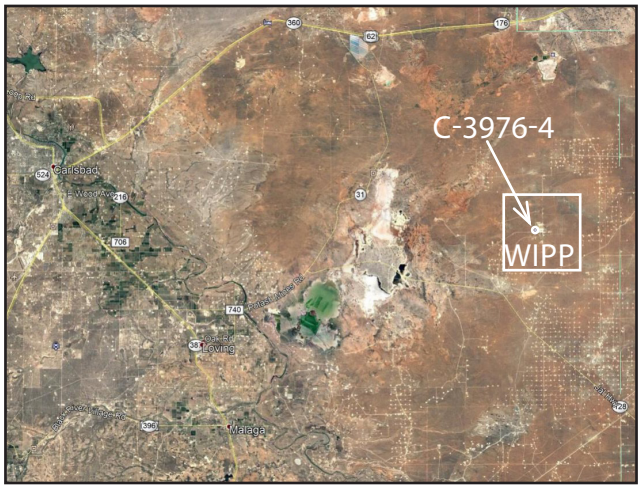
Holt and Powers (1990) noted the change in natural cements in the Dewey Lake in the air intake shaft and suggested that this change in cements might explain some of the encounters of water in the Dewey Lake south of the center of the WIPP site.

C-3976-1 and C-3976-3 (Powers et al, 2019a,b, respectively) were drilled prior to C-3976-4; they did not apparently encounter shallow subsurface water. In addition, no groundwater was observed in the upper 205 ft of C-3977 while drilling with air (Powers et al., 2018).

C-3976-4 is located about 100 ft north of the southwest corner of the drillpad and near the western side of the drillpad for the proposed location (Figure 2; see also inside cover) for a new shaft designated the unfiltered exhaust shaft (UES). Geophysical logs were to be obtained from C-3976-4. After coring and logging the borehole was to be completed for monitoring into the upper Dewey Lake for possible shallow subsurface water.

C-3976-4 is located in the southwest 1/4 of the southeast 1/4 of section 20, T22S, R31E. The lat/long for the north lip of PVC pipe (Figure 2) is 32° 22' 20.87" (32.37246389°), -103° 47' 58.01" (-103.7994472°). An adjacent benchmark is 3399.48 ft amsl (Figures 2 and 5).

Figure 1. Google Earth image showing location of WIPP and C-3976-4.



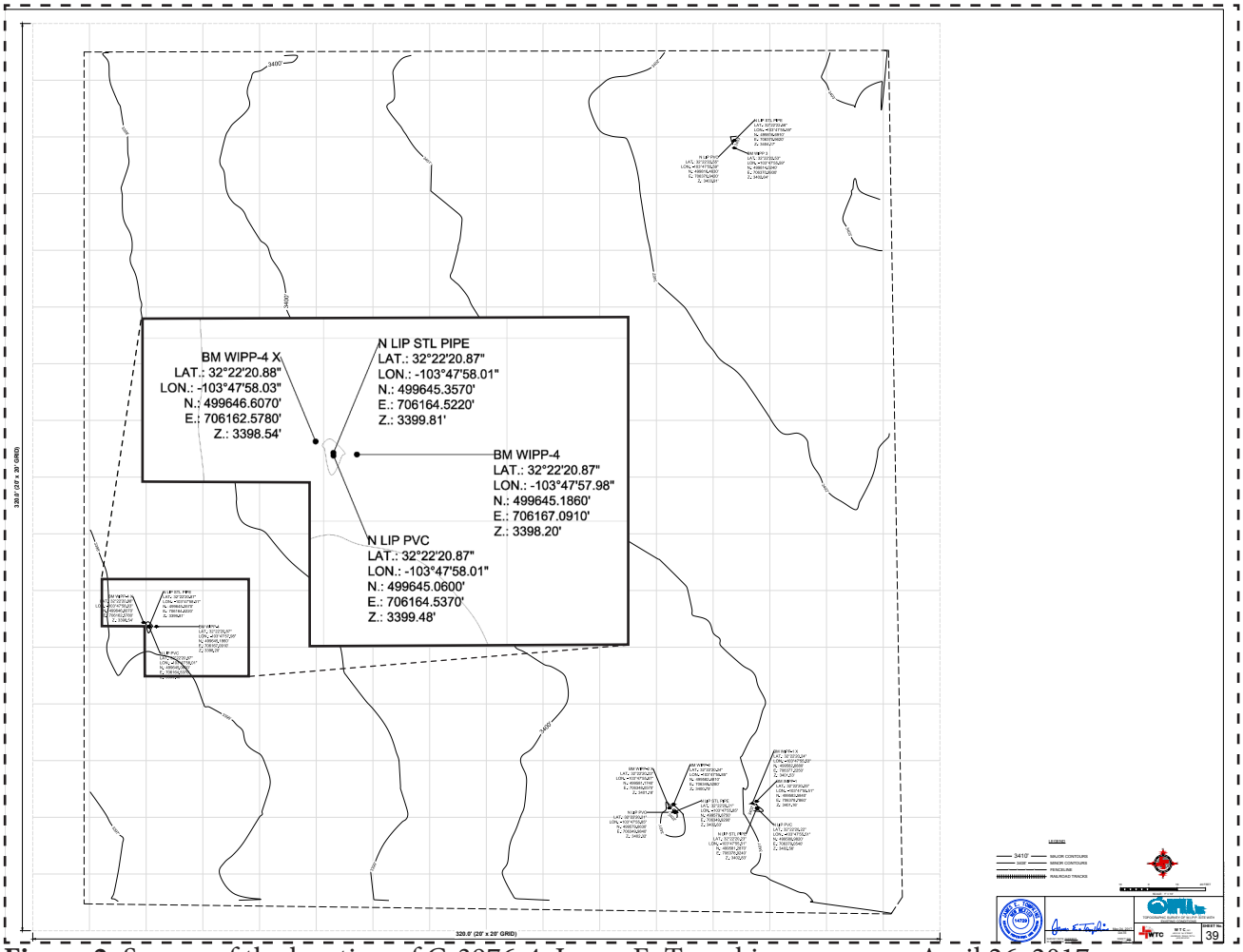


Figure 2. Survey of the location of C-3976-4. James E. Tompkins, surveyor, April 26, 2017.

C-3976-4 was permitted by the Office of the State Engineer (NM) on August 15, 2016 (Appendix A). The location as permitted was lat 32° 22' 21.88", long -103° 47' 56.99", which is on the drillpad location.

Purpose of Report and Remarks

This report provides basic to general information for C-3976-4. Complementary reports have been completed on three other similar shallow monitors wells on the same drillpad (Powers et al., 2019a,b,c). The deep corehole (C-3977) at the center of the proposed location of the UES on this drillpad has been reported (Powers et al., 2018).

Core run and recovery data are presented in Appendix B in tabular form with notes.

For most of this report, English units are used. We have mixed units in some of the detailed core descriptions, as metric units in the mm-cm range are much more convenient than either fractions of an inch or decimal ft.

Some of the descriptions are not as detailed as might be expected. The upper 20 ft is poorly represented, due mainly to limited recovery. In addition, all descriptions are based on features displayed on the outside of the core; none have been slabbed to date.

Samples from C-3976-1 and -2 were provided to Daniel B. Stephens and Associates (Albuquerque) for testing to confirm geotechnical parameters. The data from this testing are available as an attachment to the report for C-3976-1 (Powers et al.,2019a). Samples from C-3976-4 were preserved

for possible geotechnical testing but were not tested.

Geophysical logs in pdf and tif format are included as attachments.

The borehole was mainly cored, with a total depth of 195 ft below ground level (bgl) according to driller's measurements. Some geophysical logs reached a TD that is comparable.

General Activities Summary for C-3976-4

Drilling began December 16, 2016 and ended December 19, 2016. The well was logged on December 19, 2016, and was completed on December 20, 2016 (see Driller's Report at end of Appendix A and copy of NM Office of the State Engineer Point of Diversion Summary).

The well was cored from the surface to 20 ft on December 16; samples totaling 7.4 ft were recovered. The borehole was reamed to a larger diameter and a 10.5-inch casing was set.

Coring continued December 18 from 20 - 40 ft with compressed air. Core diameter was 4 inches (~10 cm) and hole diameter was 6.25-inches (20.5 cm). Recovery improved with depth. From 40 ft to TD, mist and soap were used while coring.

C-3976-4 was logged with standard geophysical tools at TD after coring was complete. The borehole was completed for monitoring the following day (December 20).

For the complete depth of C-3976-4, the sum of recovered core lengths for individual runs was 152.3 ft (87%). The sum of core segments >4 inches over the entire borehole depth is 70.8 ft or RQD of 46.4 (Appendix B).

Core was extruded into wooden troughs, fitted to the extent practical, marked, measured, photographed, described, and boxed. With a few exceptions, these tasks were completed prior to retrieving another core.

Core boxes were inventoried, put under chain of custody, and transferred to climate-controlled, secure storage in Carlsbad, NM. NWP retains custody of the core.

Photographs were taken in the field at ~0.5 ft (~15 cm) intervals with a frame width of ~1.2 ft (~36.5 cm) to provide good overlap. These photographs are an initial field record and have been supplemented with higher quality photographs, at ~0.25 ft intervals, under more carefully controlled conditions. Contact NWP for electronic files of these higher resolution photographs on transportable media.

Geophysical logs (Figure 3) taken prior to completing the well for monitoring include: deviation survey, resistivity, natural gamma, neutron, density, and spot spectral gamma measurements. See file attachments to this report for pdf and tif formats.

C-3976-4 was drilled and completed operating during daylight hours only.

C-3976-4 Well Completion

After geophysical logging of the well at TD, the lower part of the borehole was cemented (Figure 4). The borehole was reamed to a diameter of 8.75 inches to a depth of 71 ft bgl. PVC pipe (2-inch id) was placed in the hole with centralizers. Eleven ft of blank pipe with an end-cap is at the bottom with a 20-ft length of screen set from 60 to 40 ft bgl. The sand pack was brought up to 25 ft bgl using tremmie pipe and covered with 5 ft of bentonite. The annulus was cemented back to the surface using tremmie pipe. The surface pad and bollards (Figure 5) were placed after drilling was completed on the drillpad.

File Attachments

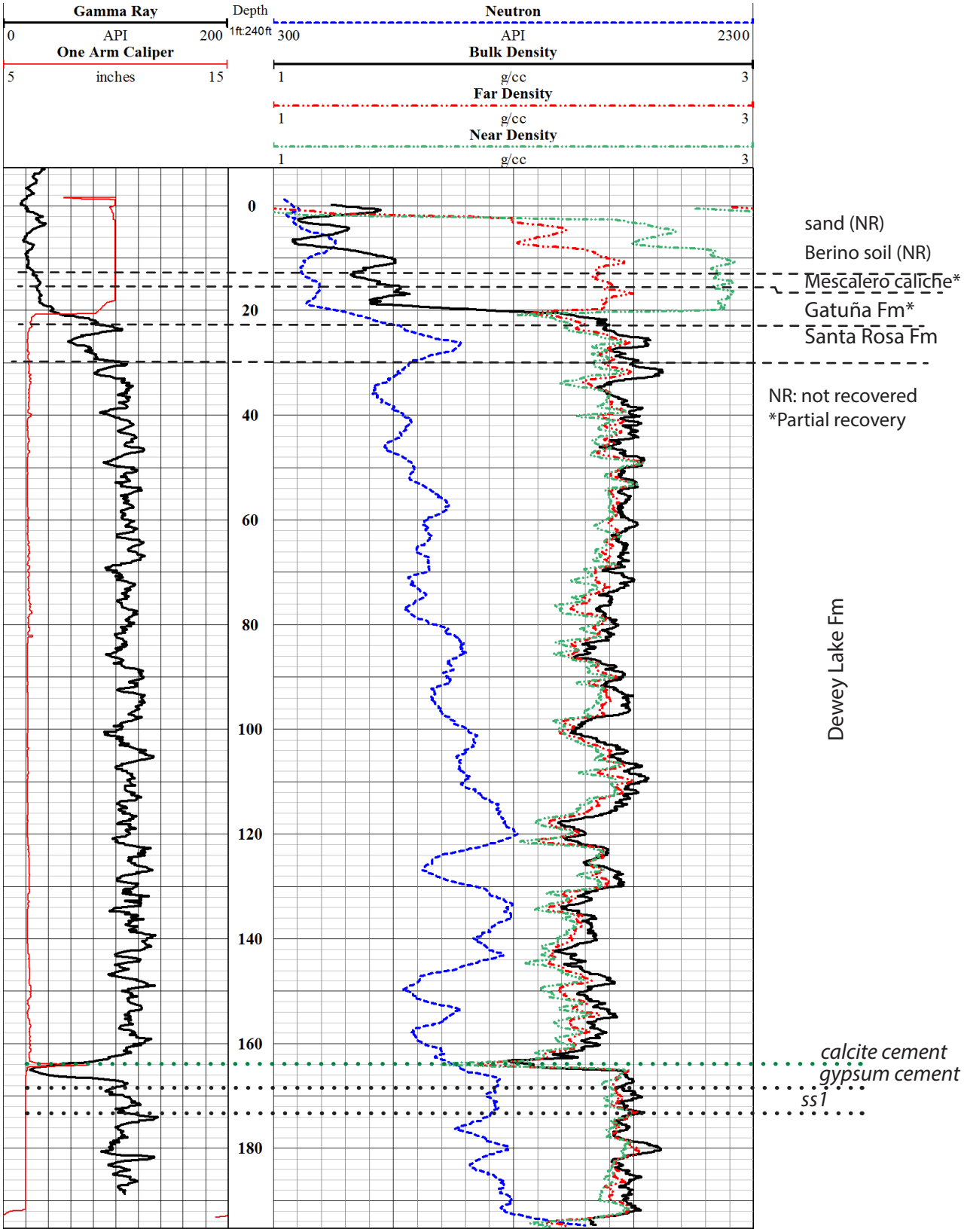
Log files are attached to this report in original formats. To access attachments, click the paperclip icon in the pdf file.

Geophysical logs by JetWest are included in two formats: pdf and tif files. Other formats (las and wcl) are included in records retained by NWP. These logs are attached (without file extensions):

C3976-4-Deviation Survey
C3976-4-Deviation Survey- Bulls Eye
C3976-4-Deviation Survey-Closure View
C3976-4-Electric (dual laterolog)
C3976-4-Neutron-Density

Figure 3

Open-hole geophysical logs run by JetWest December 19, 2016 for C-3976-4. Reference point is ground level. This figure is a composite of caliper, natural gamma, neutron, and density.



GEOLOGICAL OBSERVATIONS C-3976-4

The core from C-3976-4 was initially described in the field. The cores were re-examined in the lab in more detail. Field observations were revised as needed. Detailed geological observations are included in Appendix B.

In this section, important stratigraphic units and their lithologies and features are more generally described or summarized with illustrations of some of the salient features. Core data are presented in detail in the graphic logs. Comparable geology is described in the reports for C-3977 (Powers et al., 2018), C-3976-1 (Powers et al., 2019a), C-3976-3 (Powers et al., 2019b), and C-3976-2 (Powers et al., 2019c).

Many background references for the geology of C-3976-4 and the WIPP area are omitted to focus more clearly on the geology encountered in the upper 200 ft. Holt and Powers (1984, 1986, 1990) reported on shaft mapping that includes shallow geology. Early geologic information related to shallow subsurface water is included in Powers (1997).

Stratigraphy and Depths of Significant Units

The upper 20 ft of C-3976-4 were cored, but the recovered materials are unconsolidated sand to variably indurated rock. In this area, the construction material for the drill pad is known to be underlain by sand dunes but this dune sand was not recovered. Calcified rock assigned an uppermost depth of 12.6 ft is the Mescalero caliche. Calcified sand and sandstone from about 15 ft to about 23 ft are assigned to the Gatuña Formation.

Recovered samples from about 23 ft to 30.3 ft are provisionally assigned to the Santa Rosa Formation of the Dockum Group. The basal Gatuña can appear similar to Santa Rosa when composed of eroded Santa Rosa. Mapping of the shaft may resolve this uncertainty.

The Dewey Lake Formation is the first stratigraphic unit of significant thickness encountered and is present from 30.3 ft to TD.

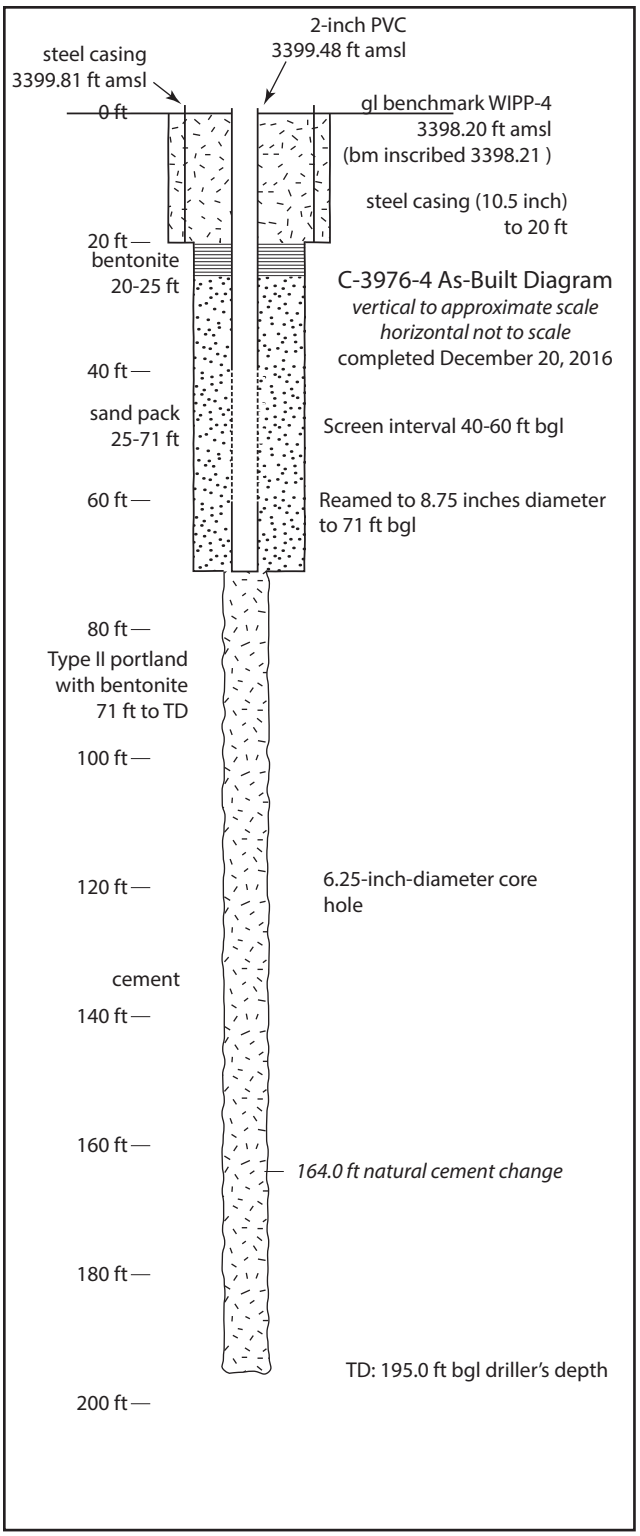


Figure 4
As-built diagram for C-3976-4.

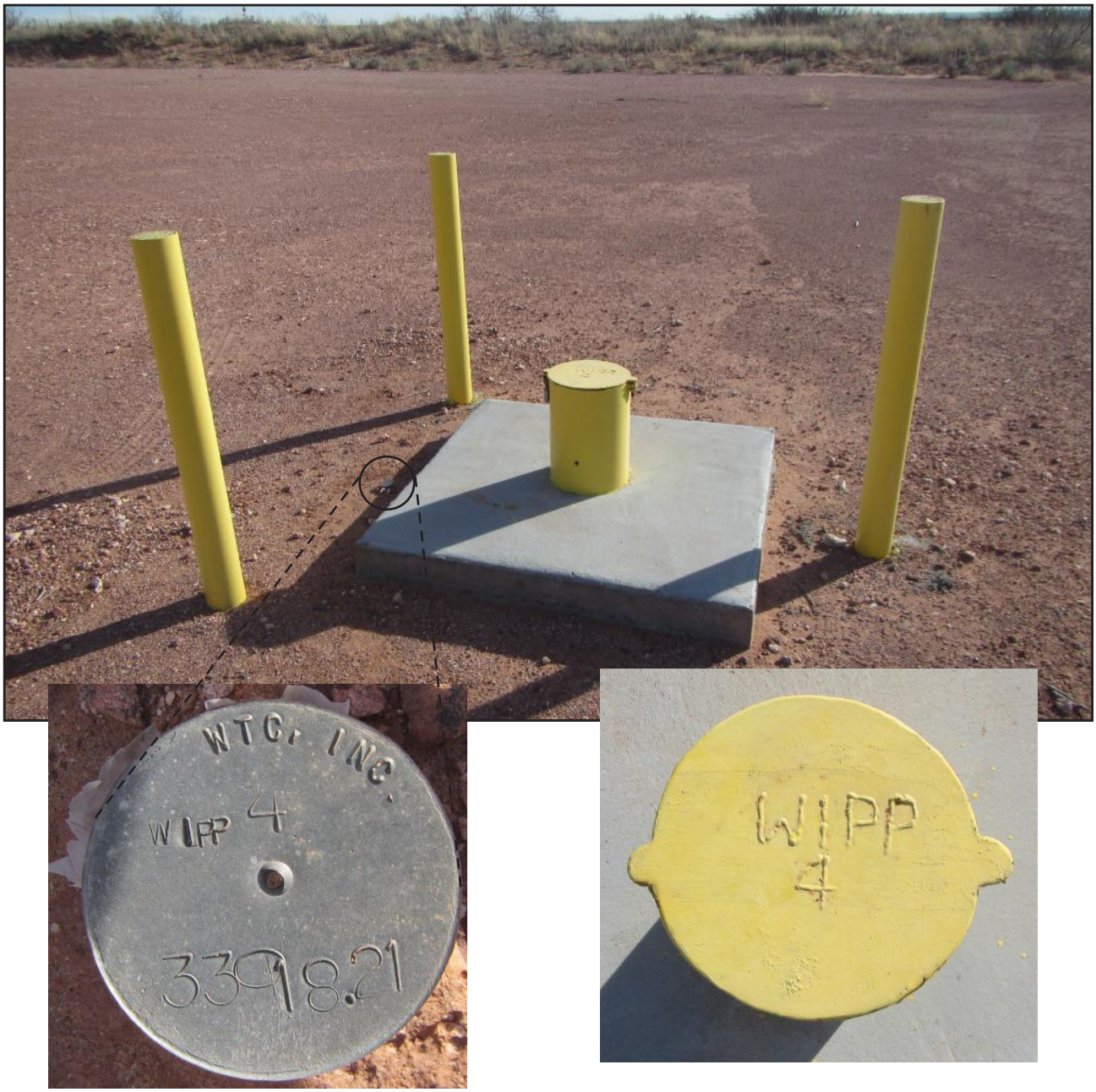


Figure 5
Completed well pad for C-3976-4, including closeup of cap and benchmark. The benchmark elevation is 3398.21 ft (see Figure 2); Photos taken 1/7/2019.

Table 1
Geology at Drillhole C3976-4

System/ Period/Epoch		Formation or unit	Depth below surface (ft) by core markings	Depth below surface (ft) by gamma/density log
Cenozoic	Holocene(?)	surface dune sand *	not recovered	not determined
	Pleistocene	Berino soil Mescalero caliche	not recovered 12.6?	12 ft?
	Pleistocene-Miocene	Gatuña	partial recovery - 23 ft?	15 ft? - 23 ft?
Mesozoic	**Triassic**	Santa Rosa	23 ft?- 30.3 ft	23 ft? - 30 ft
	Permian	Dewey Lake**	30.3 ft - 195.2 ft***	30 ft - 195 ft
**See text discussion of dune sand and Berino age. **Dewey Lake is often considered Permian. Recent work suggests the upper part may be Triassic.*			****TD by core markings 195.2 ft*	*Base of neutron-density log 195 ft*

Hall and Goble (2011) examined surficial sands in southeastern New Mexico, generally identifying three units, and providing optically-stimulated luminescence (OSL) age dates for these units. The "lower eolian sand" overlies Mescalero caliche. At a sample locality near present-day Intrepid West potash facility (T21S, R29E, section 2), Hall and Goble obtained ages of 87.0 ± 4.0 ka (thousand years) and 61.1 ± 3.0 ka for the lower eolian sand. The Berino paleosol identified by Hall and Goble is developed on the lower eolian sand. The "upper eolian sand" (overlying the Berino soil) yielded data (bottom to top) of 17.3 ± 0.7 ka and 13.9 ± 0.6 ka. The Bw paleosol (above the upper eolian sand) is dated at 7.18 ± 0.32 ka. Surficial material ("post-upper eolian sand") overlying the upper eolian sand is dated at 0.62 ± 0.04 ka. For this locality, the Bw paleosol and post-upper eolian sand are Holocene age. The lower sands are Pleistocene.

Dune sand at the WIPP site is loose and was not recovered during coring. This loose sand is most likely Holocene, as found by Hall and Goble (2011); Hall and Goble consider the coppice and parabolic dunes at the surface to have been formed during the 20th century.

The *Berino soil* (Chugg et al., 1971) normally overlies the Mescalero but was not recovered (Table 1). The isochron for U-series indicates the Berino formed about 330 ka (Rosholt and McKinney, 1980). Hall and Goble provide more precise and likely more accurate boundaries to the age of between 61.1 ± 3.0 ka and 17.3 ± 0.7 ka. Either estimate places the Berino as late Pleistocene in age.

The *Mescalero caliche* ranges from poorly lithified to hard in the area. The samples obtained from drilling C-3976-4 establish its presence as moderately to poorly lithified rock. The Mescalero caliche is a pedogenic calcrete (e.g., Bachman and Machette, 1977) and is generally 2-3 ft thick in the area around WIPP. The caliche is interrupted locally, mainly due to plant growth. The Mescalero began to form ~600 ka and may have ceased to form when the Berino sands accumulated (Rosholt and McKinney, 1980). Hall and Goble (2011) state that the upper Mescalero caliche was eroded regionally prior to deposition of the sand sheet.

The *Gatuña* is mainly sandstone with some siltstone in the vicinity of WIPP. Where the

Gatuña underlies the Mescalero caliche, the upper part is variably lithified by infiltrated carbonate during the formation of the pedogenic calcrete. Some light reddish brown calcareous sand and sandstone recovered from from 15 ft (?) to 23 ft is assigned to Gatuña. Bedding was not discernible in recovered samples. Based on geophysical logs (Figure 3), the contact between the Gatuña and underlying Santa Rosa Formation is apparently at ~23 ft depth. The Gatuña thickens to the west toward Nash Draw, where it displays a wider variety of lithofacies (Powers and Holt, 1993).



Figure 6
A. Sandstone assigned to Santa Rosa Formation.
B. Contact Dewey Lake - Santa Rosa at 30.3.

The interval from 23-30.3 has been assigned provisionally to *Santa Rosa*. The recovered samples resemble altered (weathered) Santa Rosa (Figure 6A), but it is also possible that it is eroded Santa Rosa deposited as part of the Gatuña. Geophysical log depths from 23-30 ft were assigned to the Santa Rosa. Greenish-gray sandstone in C-3967-1 and C-3967-3 was attributed to Santa Rosa but is not evident in C-3967-4. All of these well locations are near the erosional edge of the Santa Rosa/Dockum Group (Jones, 1973; plate 2).

The Permo-triassic(?) *Dewey Lake Formation* was encountered (Figure 6B) from 30.3 ft - 195 ft (driller depth at TD). P-3, an exploratory WIPP potash hole ~1200 ft southwest from C-3976-4, showed similar depth to top of Dewey Lake (Jones, 1978). C-3977, C-3976-1, C-3976-3, and the AIS also showed generally similar depths to the top of Dewey Lake. The contact is sharp (Figure 6B) and locally erosional across the site area.

There are no formal stratigraphic units within the Dewey Lake. The Dewey Lake above TD at C-3976-4 corresponds to the upper fining upward cycles noted in Holt and Powers (1990) and Powers (2003).

The Dewey Lake is characterized by fine-grained clastics, especially very fine sandstones and siltstones. Clay-sized particles are common, but true claystones are rare and are silty to sandy. The red to reddish-brown color is relatively uniform; small spots and zones of greenish-gray ("gg") color ("reduction spots") are present throughout the formation. These spots are a helpful identifier of the Dewey Lake but are not unique.

The Dewey Lake consists mainly of variably thick beds that begin with erosional basal sandstones and fine upward. Siltstone intraclasts occur near the base of some of these beds as well as at some changes to finer sediments. Bedding may be indistinct in the lower part of the bed. Very thin laminae to thin beds are most common and are generally paralled and horizontal with some slightly wavy. Small ripples (e.g., Figure 7) and cross-cutting increase upward from the base of a unit. Desiccation cracks were rarely observed in C-3976-4, and no pedogenic slickensides were

recorded. Laminar bedding in different intervals has been deformed while soft, likely due to shear during subsequent deformation.

Irregular ripples in siltstone are preserved below horizontal laminae at 168.8 ft (Figure 8A,B).

A relatively thick interval of coarser sandstone from 142 - 126 ft displays slightly coarser greenish -gray zones in the lower part (Figure 9) with inclined bedding in probable small subaqueous dunes.

Intraclasts are preserved in many intervals of the Dewey Lake. Intraclasts are eroded by drilling above the gypsum-cemented lower part of the Dewey Lake. The large, apparent porosity in some intervals above the gypsum cement is interpreted as erosion of siltstone intraclasts (Figure 10C).

No bioturbation was identified in the core from C-3976-4.

The natural gamma for C-3976-4 is significantly diminished in the intervals from ~164 ft - 167 ft (Figures 3, 11). The geologic logs (Appendix C) show equivalent gypsum sandstones at 164 ft - 166.5 ft (Figure 10A). Note that the cored interval for run #9 ended at 164.0 ft (driller's depth) and that there is an apparent lost core interval of 0.2 ft at that point. The sand in the heavily cemented portion below 164 ft is coarser than the sand above that from 161.5-164 ft; this higher sandstone does not have reduced natural gamma. The gypsum may be significantly influencing the natural gamma intensity from 164 - 167 ft.

Ss1 is an informal designation for a prominent sandstone bed in the upper half of the Dewey Lake (Powers, 2003). Ss1 can be defined based



Figure 7
Reddish-brown sandstone with ripple bedding with possible climbing ripples. Laminar bedding prevails below ripples. Core also shows examples of irregular high-angle to subhorizontal fibrous gypsum-filled separations. A few small reduction spots are present, as at 189.1. Tape moved slightly after initial marking.



Figure 8
A. Irregular ripples in siltstone at 168.8 from above.
B. Planar laminar surface just slightly above ripples in A.



Figure 9
(Right) Greenish-gray sandstones at base of thick fining upwards bed from 142.5 ft up. Inclined individual mm-scale bedding in probable subaqueous dunes.

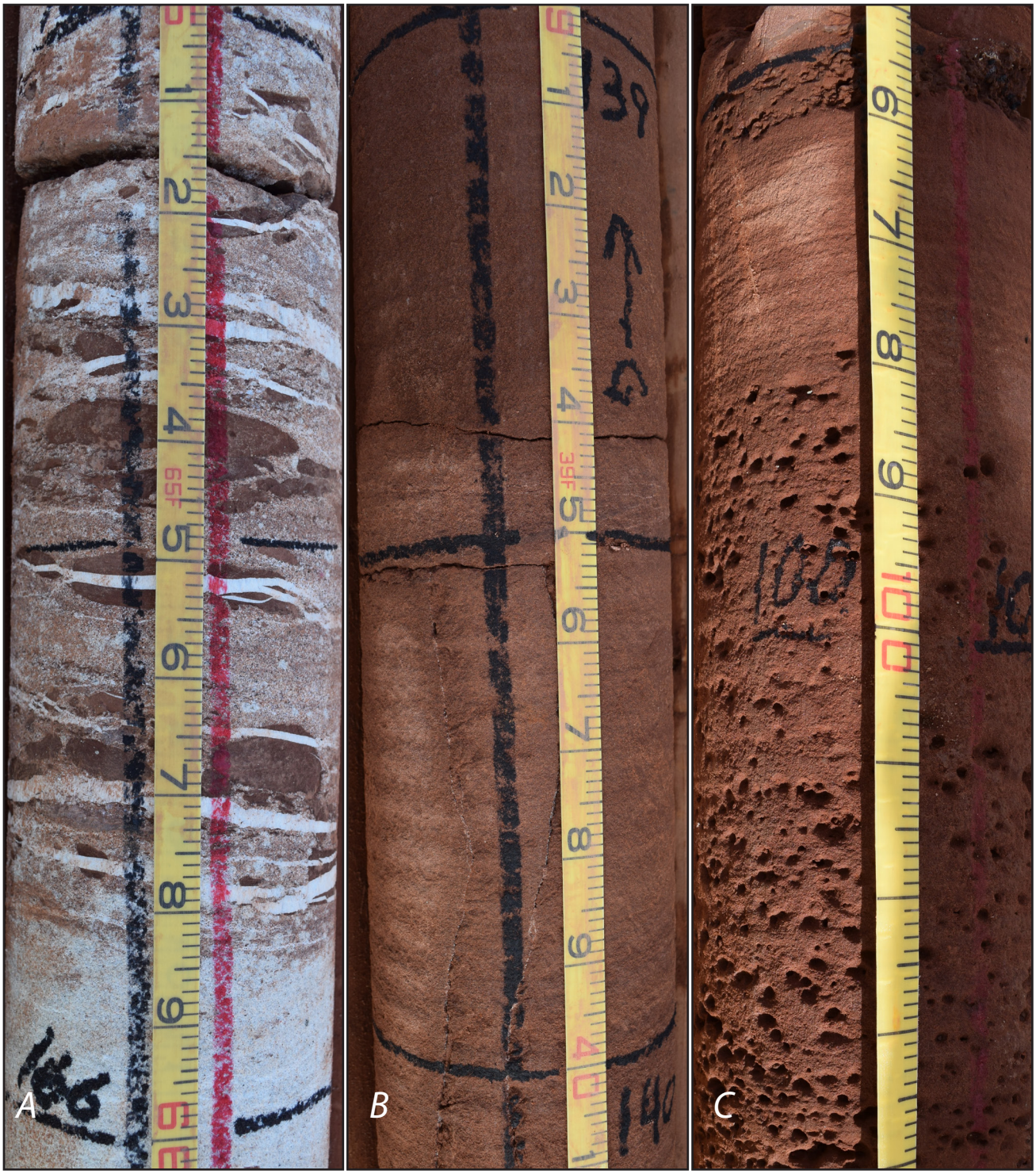
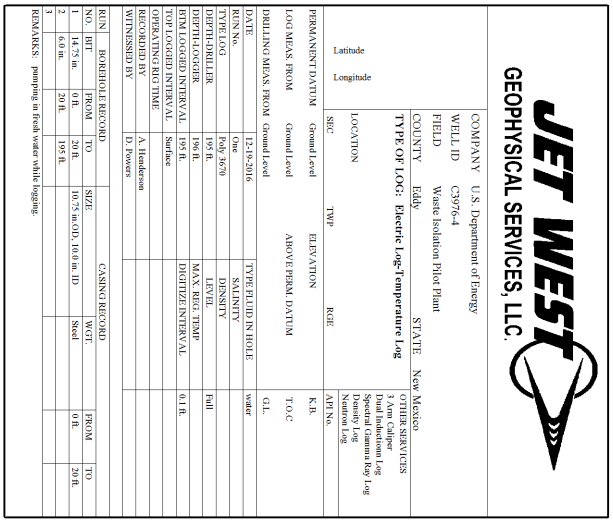
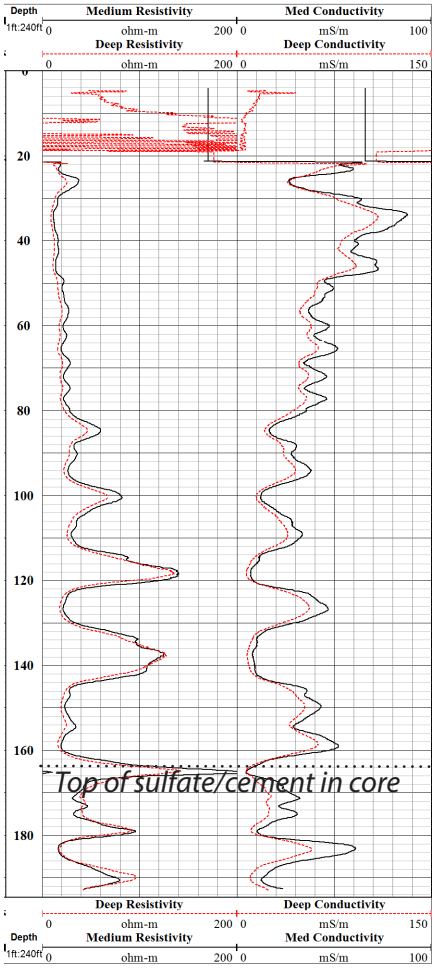
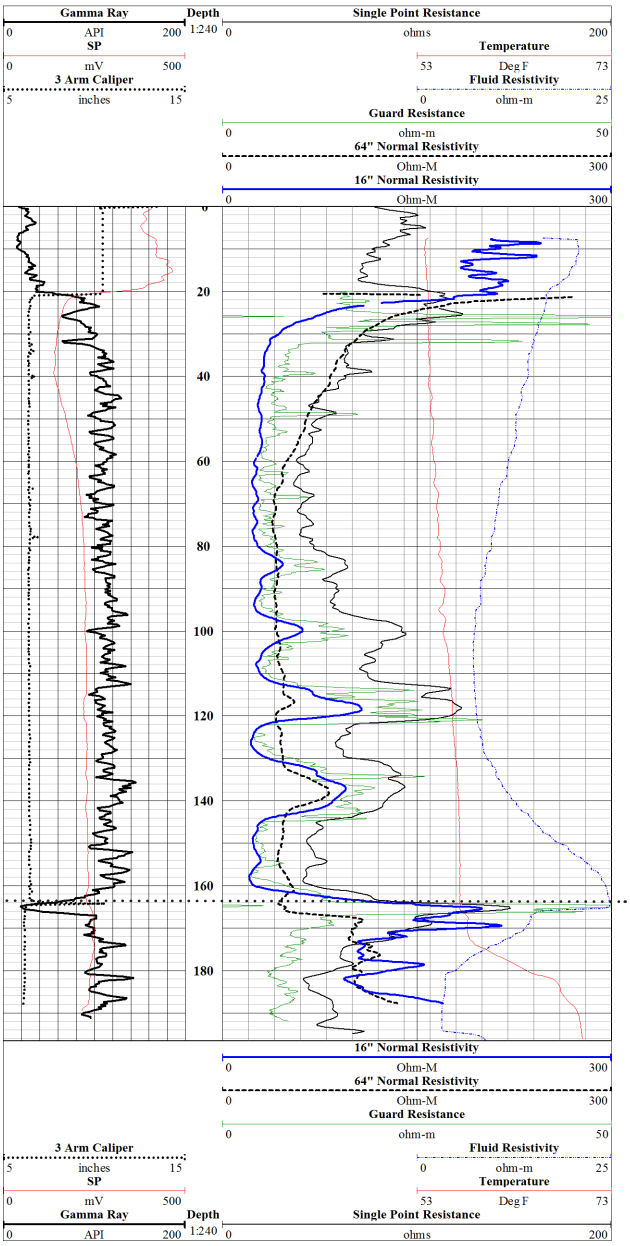


Figure 10. A. Core near the top of gypsum-cemented zone in C-3976-4 in which the sandstone includes large reddish-brown siltstone clasts and irregular sub-horizontal separations filled with fibrous gypsum. B. Irregular near-vertical separations below 139.5 ft are partially filled with calcite. C. Various zones display a surface with large, apparent porosity; these zones are interpreted as zones of intraclasts eroded by circulating drilling fluid. These core intervals haven't been broken or slabbed to verify this interpretation. All cores are 4 inches (10 cm) diameter.

Figure 11. Natural gamma, caliper, SP, resistivity/conductivity (electric), and fluid temperature/resistivity for C-3976-4 (right). Dual induction resistivity/conductivity log of C-3976-4 is shown below for comparison. See attachments for different formats for geophysical logs for this monitor well. NOTE: the natural gamma curve for the dual induction resistivity/conductivity log is not displayed. It is *not* the correct natural gamma for C-3976-4; it is instead the natural gamma for C-3976-3.







on natural gamma geophysical logs as well as in core or cuttings. At H-16, adjacent to the air intake shaft, the base of this sandstone is ~190 ft bgl (Mercer and Snyder, 1990). The sandstone mapped with a base at 195 ft in the air intake shaft (Holt and Powers, 1990) is interpreted as the same bed. Numerous drillholes or monitor wells have intercepted this sandstone (e.g., Powers and Richardson, 2004). At C-3977, ss1 is ~167 ft - ~172 ft bgl (Powers et al., 2018; figure 3). At C-3976-1 and C-3976-3 (Powers et al, 2019a,b), ss1 is interpreted at depths of 169 - 174.5 ft and 173.5 - 178 ft, respectively. Ss1 is the easiest correlation point within the upper Dewey Lake. Nevertheless, the lesser natural gamma signature in C-3976-3 and the heavy gypsum in C-3976-4 reveal that the distribution of this sandstone (or the log signature) may be less continuous than assumed (e.g., Powers, 2003).

Dewey Lake Cements

Calcification at C-3976-4 has fewer obvious manifestations than at C-3976-3. Parallel, subvertical fractures at 139.5 ft are at least partially filled with calcite (Figure 10B). A high-angle fracture at ~144 ft (Figure 9B) was partially filled with calcite. Four intervals of increased resistivity (Figure 10; 90-100 ft, 100-115 ft, 124-130 ft, 140-155 ft) show by inspection of core photos that these intervals are represented by longer unbroken core sections. Carbonate cementing through these intervals is apparently more complete.

There is a change in the natural cements of the Dewey Lake at ~164 ft (log and core depth) at C-3976-4. Above that point, carbonate cement is variable. Below ~164 ft, carbonate cements are not observed, but gypsum cement is common. It is especially marked in the core from C-3976-4 (Figure 10A).

Holt and Powers (1990) identified this natural cement change at a map depth of 164.5 ft in the air intake shaft. At C-3977, the cement change is at ~167.5 ft (Powers et al., 2018). At C-3976-1, the cement change is at ~165.5 ft (Powers et al., 2019a), and at C-3976-3, the cement change is at ~167.5 ft (Powers et al., 2019b).

The resistivity logs (Figure 11) for C-3976-4 show this cement change well developed at ~164 ft for each of the resistivity values (point, 16-inch, and 64-inch). This depth corresponds to the top of ss1.

Fluid temperature and fluid resistivity change significantly below ~165 ft in C-3976-4 (Figure 11). From inspection of these logs from each of the shallow monitor wells, it is apparent that generally similar changes occur about 25-30 ft above TD. As C-3976-2 (report in preparation) was only drilled to ~130 ft, there is no apparent relationship between these changes and the cement change.

Above the cement change, the resistivity logs delineate four higher resistivity zones that are 5-10 ft thick. The lower three are clearly associated with sandstones in the geophysical logs while the uppermost higher resistivity falls within a thicker siltstone interval.

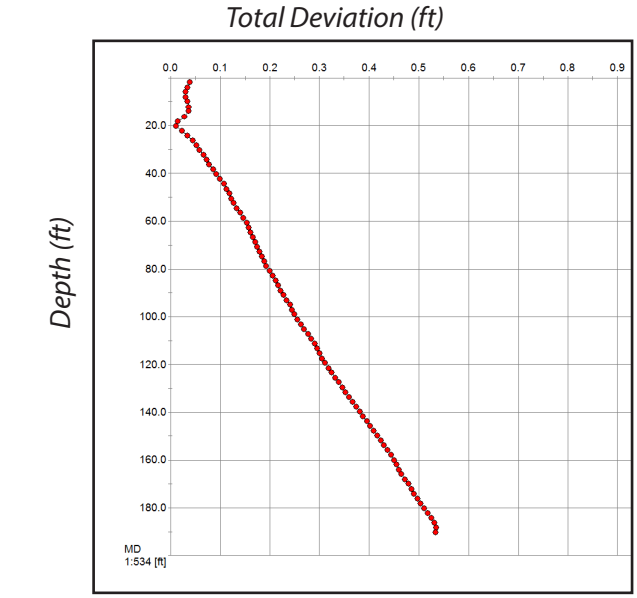
Although the Dewey Lake is generally well indurated and gypsum cements below 165.5 ft make sandstone or sandy zones hard, the cores tend to separate along bedding planes.

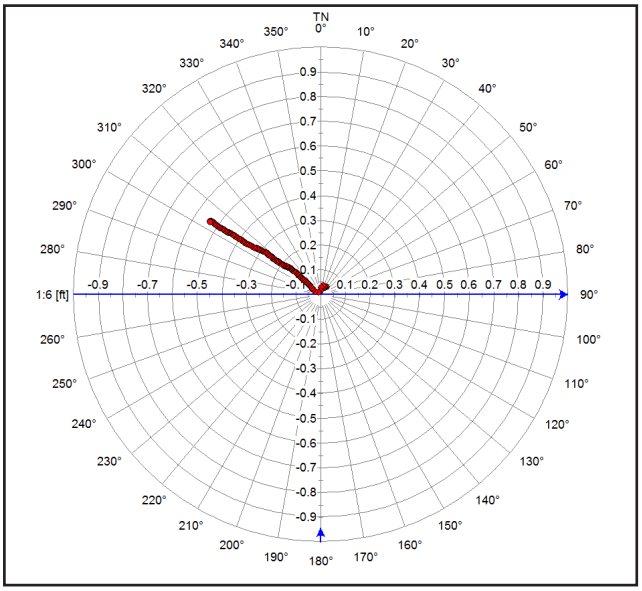
Below the cement change, separations or fractures filled with fibrous gypsum are common. These gypsum-filled separations generally fall into two classes: those following the bedding planes and a subvertical set (generally between ~45°-90° dip). The core will frequently separate at the junction of rock and gypsum.

GEOPHYSICAL LOGS OF C-3976-4

Prior to installing tubing for the monitor well, JetWest obtained a suite of logs (see attachments) that includes natural gamma, caliper, resistivity, neutron-density, and 3 spectral gamma surveys at stationary points.

The deviation survey of C-3976-4 at TD reached about 190 ft (Figure 12). Both the vertical log (with northing and easting) and the bullseye display indicate that the borehole is generally quite straight but tilted to the northwest from vertical, with a total deviation of ~0.55 ft.





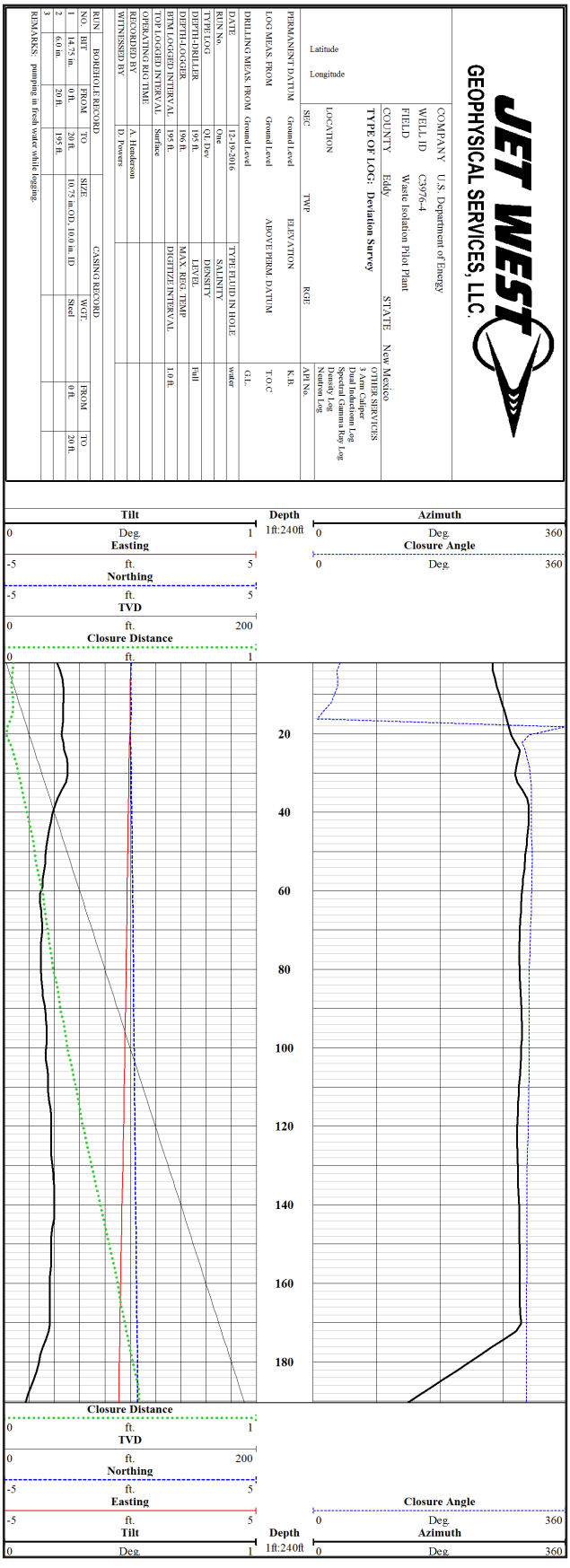


Figure 12. Deviation surveys of C-3976-4 at TD show a total deviation of ~0.55 ft, primarily to the northwest of the surface location. *Right:* Total survey with deviation expressed vertically. *Left bottom:* bulls-eye view of deviation expressed as azimuth and total deviation (ft). *Left upper:* Graph of total deviation (ft) by depth (ft).

GEOTECHNICAL WORK ON CORES

Of the four monitor wells (C-3976-1, -2, -3, and -4) that were cored, logged, and completed as monitor wells for possible shallow (<200 ft; <61 m) saturated zones, samples from C-3976-1 and C-3976-2 were taken for basic geotechnical analysis. Short intervals (generally less than 3 ft) from each of these monitor wells were preserved for geotechnical work by wrapping and waxing soon after recovery. Fourteen short (1.1 ft - 3.8 ft; 0.34 m - 1.16 m) intervals from C3976-1 and C-3976-2 were transported to Daniel B. Stephens and Associates lab in Albuquerque for testing.

The suite of tests includes: gravimetric moisture content (volume measurement method)

- particle size (wet sleeve, hydrometer)
- specific gravity
- Atterburg limits
- strength tests
  - unconfined compressive strength
  - unconsolidated undrained triaxial compression
  - consolidated undrained triaxial compression
  - consolidated drained triaxial compression
- slake durability

The tests have been completed and reported separately (DBSA, 2017) and are attached to the report for C-3976-1 (Powers et al., 2019a).

FIELD OBSERVATIONS RE SHALLOW GROUNDWATER

C-3976-4 was cored and drilled with air to ~40 ft and with mist and soap below 40 ft. There were no observed groundwater inflows, which includes the top of Dewey Lake where anthropogenic water has been found around the WIPP facility (e.g., Intera, 1997; Duke Engineering and Services, 1997) .

C-3976-4 was completed to monitor the interval of uppermost Dewey Lake and overlying Santa Rosa or Gatuña for shallow subsurface water (Figures 3, 4, 11). RES maintains records of water levels and other data for these monitor wells and provided information for this report.

Water levels have been monitored irregularly since 12/21/16, shortly after completion. The first water level measurement on 12/21/16 showed a depth of 27.18 ft, which converts to 3372.3 ft amsl (Figure 13). The well was bailed irregularly, generally removing a few tens of gallons. In total, 475 gallons were removed prior to the water level measurement of 2/2/17.

Following bailing on 12/21/16 and 12/27/16, water levels were remeasured. Depths to water were 53.04 and 58.80 ft, respectively; the bailing did not reduce water level below the screen (60 ft). In each case, the water level had recovered when next measured (6 days and 1 day later, respectively) to a level slightly higher than the initial reading on 12/21/16.

On May 23, 2019, the depth to water in C-3976-4 was 26.27 ft, equal to 3373.21 ft amsl.

Except for one point (Figure 13), Water levels have varied about 4 ft between minimum and maximum.

Field measurements of specific gravity of recovered samples has ranged from 0.995-0.999.

The specific gravity of the water recovered from C-3976-4 differs significantly from specific gravity of the shallow subsurface groundwater in monitor wells at WIPP surface facilities with one main exception (RES, 2019). PZ-10 is located adjacent to a large storm water pond east of C-2976-4. It

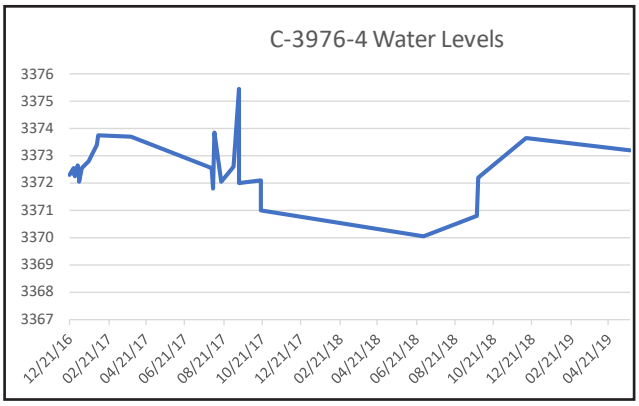


Figure 13. Plot showing water elevations (left axis) in ft amsl for C-3976-4. Depth to water was measured prior to any pumping/bailing that may have occurred the day of measurement.

responds to rainfall events, and it has the lowest total dissolved solids of any of the PZ series wells.

Elevations of the water in C-3976-4 differ by 2-4 ft from those in C-3976-2 (Powers et al., 2019c), and neither of these two wells show responses to pumping/bailing in the other well. In addition, neither borehole indicated water was encountered at shallow depths while drilling. The recovered water is most likely to be water taken by the shallow formations when the well was filled for logging.

SUMMARY POINTS

C-3976-4 was cored (4-inch diameter) and logged with geophysical logs to provide a record of the geology for a well to monitor for possible shallow subsurfacewater at the top of the Dewey Lake or in overlying sediments. Shallow subsurface water at the site is commonly saline.

Core recovery from C-3976-4 was intermittent near the surface and improved with depth. Shallow stratigraphic contacts (above 30 ft depth) were estimated largely on the basis of geophysical logs. The change in natural cements at ~164 ft in core corresponds to geophysical log changes in resistivity as well.

The recovered samples above the Dewey Lake only partially represent the geologic units and their character. The upper Dewey Lake displays mainly fine-grained siliciclastic beds with laminae, slight cross-bedding or ripples, and some distinctive erosional surfaces. An informal bed (ss1; sandstone 1) is observed in geophysical logs and corresponds to a sandstone interval in core. Below ~164 ft, the Dewey Lake also includes separations or fractures filled with fibrous gypsum and is well indurated due to gypsum cement. The uppermost cemented zone is unusually concentrated with gypsum.

The placement of screen in the completed well straddles the upper Dewey Lake and overlying Dockum and Gatuña across the interval where shallow subsurface water has been found on the WIPP site. Water was measured near the bottom of the tubing in the completed well above the base of the screen at 60 ft, and water levels have recovered after bailing. Specific gravity less the 1.0 and lack of observable response in C-3976-2 to bailing or pumping C-3976-4 (as well as the reverse) indicate the hydraulic system does not extend between the two wells and -4 is not connected to the shallow subsurface water at the site.

Samples from C-3976-1 and C-3976-2 (Powers et al., 2019a,c) for geotechnical studies were preserved shortly after recovery, initial photography, and field description. The results of the testing by Daniel B. Stephens & Associates are attached to the report for C-3976-1 (Powers et al., 2019a).

The final deviation survey for C-3976-4 indicates a total deviation ~0.55 ft near TD, with the deviation being mainly northwest of the surface location.

ACKNOWLEDGMENTS

Ashleigh Pope and Rodney Whisenhunt (both NWP) provided management support during drilling. Tom Goedjen and Richard Brugman (all NWP) supervised follow up reporting.

Stewart Brothers supervisors and drillers worked closely with us to obtain the cores and logging that was the objective of the program.

Michael Schuhen and Owen Lofton (Sandia National Laboratories) supplied critical support for core transport and handling. Sandia provided needed support in the form of storage at the secure, climate-controlled environment at Iron Mountain facilities in Carlsbad. NWP has taken custody of the core, and it continues to be stored at Iron Mountain.

Andy Ward (DOE-Carlsbad) provided useful comments and discussions during planning as well as observation and discussion during the execution of the drilling.

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APPENDIX A PERMIT FOR C-3976-4 (POD4)

OFFICE OF STATE ENGINEER

NEW MEXICO

AND

DRILLING RECORD

(STEWART BROTHERS DRILLING COMPANY)

Tom Blaine, P.E.
State Engineer

Roswell Office
1900 WEST SECOND STREET
ROSWELL, NM 88201

STATE OF NEW MEXICO
OFFICE OF THE STATE ENGINEER

Trn Nbr: 591694
File Nbr: C 03976

Aug. 19, 2016

GEORGE BASABILVAZO
ANDERSON WARD
US DEPARTMENT OF ENERGY
PO BOX 3090
CARLSBAD, NM 88221-3090

Greetings:

Enclosed is your copy of the above numbered permit that has been approved subject to the conditions set forth on the approval page. In accordance with the conditions of approval, the well can only be tested for 10 cumulative days, and the well is to be plugged on or before 08/31/2017, unless a permit to use the water is acquired from this office.

A Well Record & Log (OSE Form wr-20) shall be filed in this office within twenty (20) days after completion of drilling, but no later than 08/31/2017.

Appropriate forms can be downloaded from the OSE website www.ose.state.nm.us or will be mailed upon request.

Sincerely,

for Juan Hernandez
(575)622-6521

Enclosure

explore

UNIQUE #	DOE U.C.	DATE REC'VD	ADDRESSEES
1602087	5487	AUG 24 2016	G. Basabilvazo A. Ward

File No. C-3976

NEW MEXICO OFFICE OF THE STATE ENGINEER

APPLICATION FOR PERMIT TO DRILL A WELL WITH NO CONSUMPTIVE USE OF WATER

(check applicable box):

For fees, see State Engineer website: http://www.ose.state.nm.us/ 237412

Purpose:	☐ Pollution Control And / Or Recovery	☐ Geo-Thermal
☐ Exploratory	☐ Construction Site De-Watering	☐ Other (Describe):
■ Monitoring	☐ Mineral De-Watering	

A separate permit will be required to apply water to beneficial use.

☐ Temporary Request - Requested Start Date: Requested End Date:

Plugging Plan of Operations Submitted? ☐ Yes ■ No

STATE ENGINEER OFFICE ROSWELL, NEW MEXICO 2016 AUG 15 PM 1:15

1. APPLICANT(S)

Name: U.S.Department of Energy	Name: U.S.Department of Energy
Contact or Agent: George Basabilvazo check here if Agent ☐	Contact or Agent: Anderson Ward check here if Agent ☐
Mailing Address: P.O. Box 3090	Mailing Address: P.O. Box 3090
City: Carlsbad	City: Carlsbad
State: New Mexico Zip Code: 88221-3090	State: New Mexico Zip Code: 88221-3090
Phone: ☐ Home ☐ Cell Phone (Work): 575-234-7488	Phone: ☐ Home ☐ Cell Phone (Work): 575-234-7488
E-mail (optional): george.basabilvazo@cbfo.doe.gov	E-mail (optional): Anderson.ward@cbfo.doe.gov

FOR OSE INTERNAL USE — Application for Permit, Form wr-07, Rev 6/14/12

File No.: C-3976	Trn. No.: 591694	Receipt No.:
Trans Description (optional):	POD 1-4	
Sub-Basin: CUB	PCW/LOG Due Date: 8-31-17	

Page 1 of 3

2. WELL(S) Describe the well(s) applicable to this application.

Location Required: Coordinate location must be reported in NM State Plane (NAD 83), UTM (NAD 83), or Latitude/Longitude (Lat/Long - WGS84).
District II (Roswell) and District VII (Cimarron) customers, provide a PLSS location in addition to above.

■ NM State Plane (NAD83) (Feet)
☐ NM West Zone
■ NM East Zone
☐ NM Central Zone

☐ UTM (NAD83) (Meters)
☐ Zone 12N
☐ Zone 13N

☐ Lat/Long (WGS84) (to the nearest 1/10th of second)

Well Number (If known):	X or Easting or Longitude:	Y or Northing or Latitude:	Provide if known: -Public Land Survey System (PLSS) (*Quarters or Halves , Section, Township, Range*) OR - Hydrographic Survey Map & Tract; OR - Lot, Block & Subdivision; OR - Land Grant Name
#1	103 degrees 47' 56.99"	32 degrees 22' 21,88"	
#2	103 degrees 47' 56.99"	32 degrees 22' 21,88"	
#3	103 degrees 47' 56.99"	32 degrees 22' 21,88"	
#4	103 degrees 47' 56.99"	32 degrees 22' 21,88"	

NOTE: If more well locations need to be described, complete form WR-08 (Attachment 1 – POD Descriptions)
Additional well descriptions are attached: ■ Yes ☐ No **If yes, how many** _____

Other description relating well to common landmarks, streets, or other:
Well coordinates are the center of the well pad for which these wells will be located. Wells will be located east of the WIPP site adjacent to the WIPP North Access Road.

Well is on land owned by: U.S. Department of Energy

Well Information: NOTE: If more than one (1) well needs to be described, provide attachment. **Attached?** ■ Yes ☐ No
If yes, how many 4

Approximate depth of well (feet): 200-300 feet	Outside diameter of well casing (inches): 2-Inches
Driller Name: Not Determined yet	Driller License Number: TBD

3. ADDITIONAL STATEMENTS OR EXPLANATIONS

See attached scope of work and diagram.

FOR OSE INTERNAL USE — Application for Permit, Form wr-07

File No.: C 3976 — Trn No.: 591694

4. SPECIFIC REQUIREMENTS: The applicant must include the following, as applicable to each well type. Please check the appropriate boxes, to indicate the information has been included and/or attached to this application:

Exploratory:	**Pollution Control and/or Recovery:**	**Construction De-Watering:**	**Mine De-Watering:**
☐ Include a description of any proposed pump test, if applicable.	☐ Include a plan for pollution control/recovery, that includes the following: ☐ A description of the need for the pollution control or recovery operation. ☐ The estimated maximum period of time for completion of the operation. ☐ The annual diversion amount. ☐ The annual consumptive use amount. ☐ The maximum amount of water to be diverted and injected for the duration of the operation. ☐ The method and place of discharge.	☐ Include a description of the proposed dewatering operation, ☐ The estimated duration of the operation, ☐ The maximum amount of water to be diverted, ☐ A description of the need for the dewatering operation, and, ☐ A description of how the diverted water will be disposed of.	☐ Include a plan for pollution control/recovery, that includes the following: ☐ A description of the need for mine dewatering. ☐ The estimated maximum period of time for completion of the operation. ☐ The source(s) of the water to be diverted. ☐ The geohydrologic characteristics of the aquifer(s). ☐ The maximum amount of water to be diverted per annum. ☐ The maximum amount of water to be diverted for the duration of the operation. ☐ The quality of the water. ☐ The method of measurement of water diverted. ☐ The recharge of water to the aquifer. ☐ Description of the estimated area of hydrologic effect of the project. ☐ The method and place of discharge. ☐ An estimation of the effects on surface water rights and underground water rights from the mine dewatering project. ☐ A description of the methods employed to estimate effects on surface water rights and underground water rights. ☐ Information on existing wells, rivers, springs, and wetlands within the area of hydrologic effect.
Monitoring: ■ Include the reason for the monitoring well, and, ■ The duration of the planned monitoring.	☐ The method of measurement of water produced and discharged. ☐ The source of water to be injected. ☐ The method of measurement of water injected. ☐ The characteristics of the aquifer. ☐ The method of determining the resulting annual consumptive use of water and depletion from any related stream system. ☐ Proof of any permit required from the New Mexico Environment Department. ☐ An access agreement if the applicant is not the owner of the land on which the pollution plume control or recovery well is to be located.	**Geo-Thermal:** ☐ Include a description of the geothermal heat exchange project, ☐ The amount of water to be diverted and re-injected for the project, ☐ The time frame for constructing the geothermal heat exchange project, and, ☐ The duration of the project. ☐ Preliminary surveys, design data, and additional information shall be included to provide all essential facts relating to the request.	

ACKNOWLEDGEMENT

I, We (name of applicant(s)), George T. Basabilvazo
Print Name(s)

affirm that the foregoing statements are true to the best of (my, our) knowledge and belief.

George T. Basabilvazo
Applicant Signature

Applicant Signature

STATE ENGINEER OFFICE
2016 AUG 15 P 1:36

ACTION OF THE STATE ENGINEER

This application is:

☒ approved ☐ partially approved ☐ denied

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 and further subject to the attached conditions of approval.

Witness my hand and seal this 19th day of August 20 16, for the State Engineer,

Tom Blaine, P.E., State Engineer

By: _____
Signature

_____
Print

Title: Juan Hernandez, Engr Specialist Supervisor
Print

FOR OSE INTERNAL USE — Application for Permit, Form wr-07

File No.: C-3976	Trn No.: 591694

Page 3 of 3

1.0 Introduction and Background

The Waste Isolation Pilot Plant is a research and development facility designed to demonstrate the safe disposal of transuranic wastes in embedded salt 2,150 feet below the ground surface. Figure 1 shows the WIPP Land Withdrawal Area (LWA) and surrounding outer areas.

Near the center of the WIPP site, shallow subsurface water (SSW), derived at least in part from anthropogenic sources, exists in a saturated zone that is generally less than 100 ft below ground level. Farther south (WQSP-6A), natural perched water in the Dewey Lake can be found above the change in natural cement from sulfate to carbonate. This statement of work (SOW) covers coring/drilling up to four monitor wells that will be completed according to regulations of the New Mexico Office of the State Engineer (NMOSE). The monitor well drilling is required to penetrate through the saturated interval to determine the base of the SSW. One well will be drilled to test for the presence of perched Dewey Lake water. NWP will monitor these wells for a period of time expected to be a few weeks to months.

STATE ENGINEER OFFICE
2015 DEC 15 P 1:

The main purpose of three wells is to determine the static water level (potentiometric surface) for the SSW, if it exists at the proposed shaft location. The coring and logging will provide more direct evidence of the base of the saturated zone to infer thickness of the saturated zone for developing shaft construction plans. Geotechnical observations on core samples will also provide useful information for construction plans.

One well will initially be drilled deep enough to test for the presence of perched Dewey Lake water, although it appears unlikely to be present. If the perched water is found as a separate saturated zone, the well will be completed for observation of the Dewey Lake water. The annulus will be cemented to isolate the SSW from Dewey Lake water. If no separate Dewey Lake saturated zone is found, the lower part of the hole will be cemented back to near the base of the SSW, and the well will be completed as one of up to three SSW wells.

Where decision points and/or hold points may be required for this SOW, these points will need to be approved by the WIPP Site Technical Representative (STR) who will be, or confer as needed with, a geologist or hydrologist. In cases involving discharges and chemicals, Site Environmental Compliance (SEC) will provide approval prior to continuing work. Approvals may be obtained verbally via phone. Verbal approvals will be documented in the driller's log and/or field notes.

Figure 2 represents a generalized geologic cross section of the WIPP. For this activity, only shallow sediments and rocks will be relevant.

- The near-surface formations or sediments, from surface down, are expected to include: pad material, dune sand that has been flattened, reddish brown Berino soil (friable to moderately indurated sand), Mescalero caliche (up to several feet of variably indurated white carbonate), and Gatuña Formation (friable to moderately indurated sands, sandstone, and siltstone to mudstone).

- Santa Rosa Formation (expected to be very thin or absent) is variegated, intensely hued sandstone, siltstone, and mudstone or claystone of variable induration.

- The Dewey Lake ("redbed") Formation is relatively homogeneous reddish brown, moderate to well indurated very fine sandstone, siltstone, and claystone.

In general, the SSW is expected to have saturated a part of the Gatuña, any Santa Rosa that may be present, and an undetermined zone of the upper Dewey Lake. NWP best estimate at this time is that the saturated zone is likely to be less than 100 ft, but the driller should be prepared to go to at least 300 ft. The initial drillhole is likely to be deeper to test for a natural Dewey Lake perched zone above cement changes in the upper Dewey Lake.

Monitor wells shall be installed in accordance with the *NM Environment Department – Ground Water Pollution Prevention Section Monitoring Well Construction and Abandonment Guidelines*.

2.0 Scope of Work

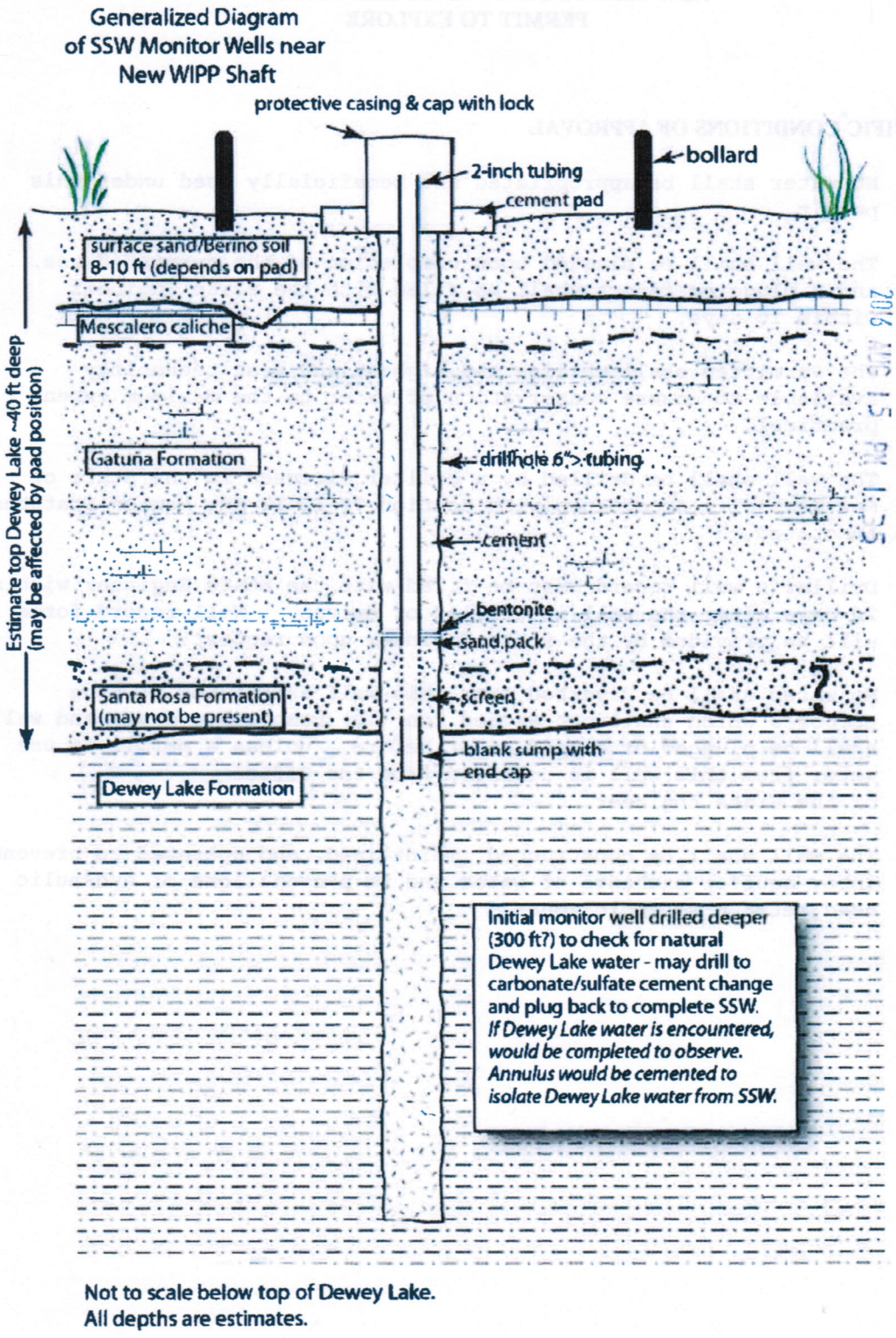
The general scope of work to be performed will be to:

- Core/drill 1 to 4 monitor wells that penetrate through the base of the SSW (to be determined in the field during drilling) at locations selected by NWP at the edge of a large drilling pad. If no SSW is encountered at the first location, NWP reserves the right to end further coring/drilling.
- Complete all wells for monitoring by installing 2 inch PVC tubing (casing and screen) with end cap and ~10 ft of screen at depths directed by the Site Hydrologist or representative. A removable surface cap will be placed to enable access for monitoring. Note Table 1 specifications.
- Limited development at direction of STR.
- Contract for geophysical logging with recognized suppliers.
- Support temporary monitoring of water levels at direction of STR

P&A monitor wells according to NMOSE regulations based on a decision by NWP. The method and means will be determined in consultation with the NMOSE during the permitting process. Plugging typically involves leaving the casing intact and tremmie cement from the bottom to the surface. Cement will be sulfate and chloride compatible, and portland neat Type V will be used. The cement will ensure that cross contamination of ground water zones will not occur.

Figure 1 is a diagram of the expected construction of the wells.

Figure 1



STATE ENGINEER OFFICE
ROSWELL, NEW MEXICO
2016 AUG 15 PM 1 53

NEW MEXICO STATE ENGINEER OFFICE
PERMIT TO EXPLORE

SPECIFIC CONDITIONS OF APPROVAL

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

6 The well shall be plugged upon completion of the permitted use, and a plugging report shall be filed with the State Engineer within 10 days.

7 The Permittee shall utilize the highest and best technology available to ensure conservation of water to the maximum extent practical.

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 20 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.

P The well shall be constructed, maintained, and operated to prevent inter-aquifer exchange of water and to prevent loss of hydraulic head between geologic zones.

Trn Desc: C 03976 POD1-4

File Number: C 03976
Trn Number: 591694

page: 1

NEW MEXICO STATE ENGINEER OFFICE
PERMIT TO EXPLORE

SPECIFIC CONDITIONS OF APPROVAL (Continued)

Q The State Engineer retains jurisdiction over this permit.

R Pursuant to section 72-8-1 NMSA, the permittee shall allow the State Engineer and his representatives entry upon private property for the performance of their respective duties, including access to the ditch or acequia to measure flow and also to the well for meter reading and water level measurement.

LOG The Point of Diversion C 03976 POD1 must be completed and the Well Log filed on or before 08/31/2017.

LOG The Point of Diversion C 03976 POD2 must be completed and the Well Log filed on or before 08/31/2017.

LOG The Point of Diversion C 03976 POD3 must be completed and the Well Log filed on or before 08/31/2017.

LOG The Point of Diversion C 03976 POD4 must be completed and the Well Log filed on or before 08/31/2017.

IT IS THE PERMITTEES RESPONSIBILITY TO OBTAIN ALL AUTHORIZATIONS AND PERMISSIONS TO DRILL ON PROPERTY OF OTHER OWNERSHIP BEFORE COMMENCING ACTIVITIES UNDER THIS PERMIT.

SHOULD THE PERMITTEE CHANGE THE PURPOSE OF USE TO OTHER THAN MONITORING PURPOSES, AN APPLICATION SHALL BE ACQUIRED FROM THE OFFICE OF THE STATE ENGINEER.

THE MAXIMUM DEPTH OF THE PROPOSED WELL(S), UNDER THIS PERMIT, SHALL NOT EXCEED A DEPTH OF 300FT.

CEMENT TYPE USED IN WELL CONSTRUCTION SHALL BE COMPATIBLE WITH ENCOUNTERED FORMATION CHEMISTRIES TO INCLUDE SULFATES AND HIGH SALT CONTENT.

Trn Desc: C 03976 POD1-4 File Number: C 03976
Trn Number: 591694

page: 2

NEW MEXICO STATE ENGINEER OFFICE
PERMIT TO EXPLORE

ACTION OF STATE ENGINEER

Notice of Intention Rcvd: Date Rcvd. Corrected:
Formal Application Rcvd: 08/15/2016 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 19th day of Aug A.D., 2016

Tom Blaine, P.E., State Engineer

By: _____
Juan Hernandez

Trn Desc: C 03976 POD1-4 File Number: C 03976
Trn Number: 591694

page: 3

Locator Tool Report

General Information:

Application ID:29 Date: 08-18-2016 Time: 11:14:45

WR File Number: C-#1
Purpose: OTHER

Applicant First Name: USDOE-G BASABILVAZO
Applicant Last Name: USDOE-A WARD

GW Basin: CARLSBAD
County: EDDY

Critical Management Area Name(s): NONE
Special Condition Area Name(s): NONE
Land Grant Name: NON GRANT

PLSS Description (New Mexico Principal Meridian):

NW 1/4 of NW 1/4 of SW 1/4 of SE 1/4 of Section 20, Township 22S, Range 31E.

Coordinate System Details:

Geographic Coordinates:

Latitude:	32 Degrees	22 Minutes	21.9 Seconds	N
Longitude:	103 Degrees	47 Minutes	57.0 Seconds	W

Universal Transverse Mercator Zone: 13N

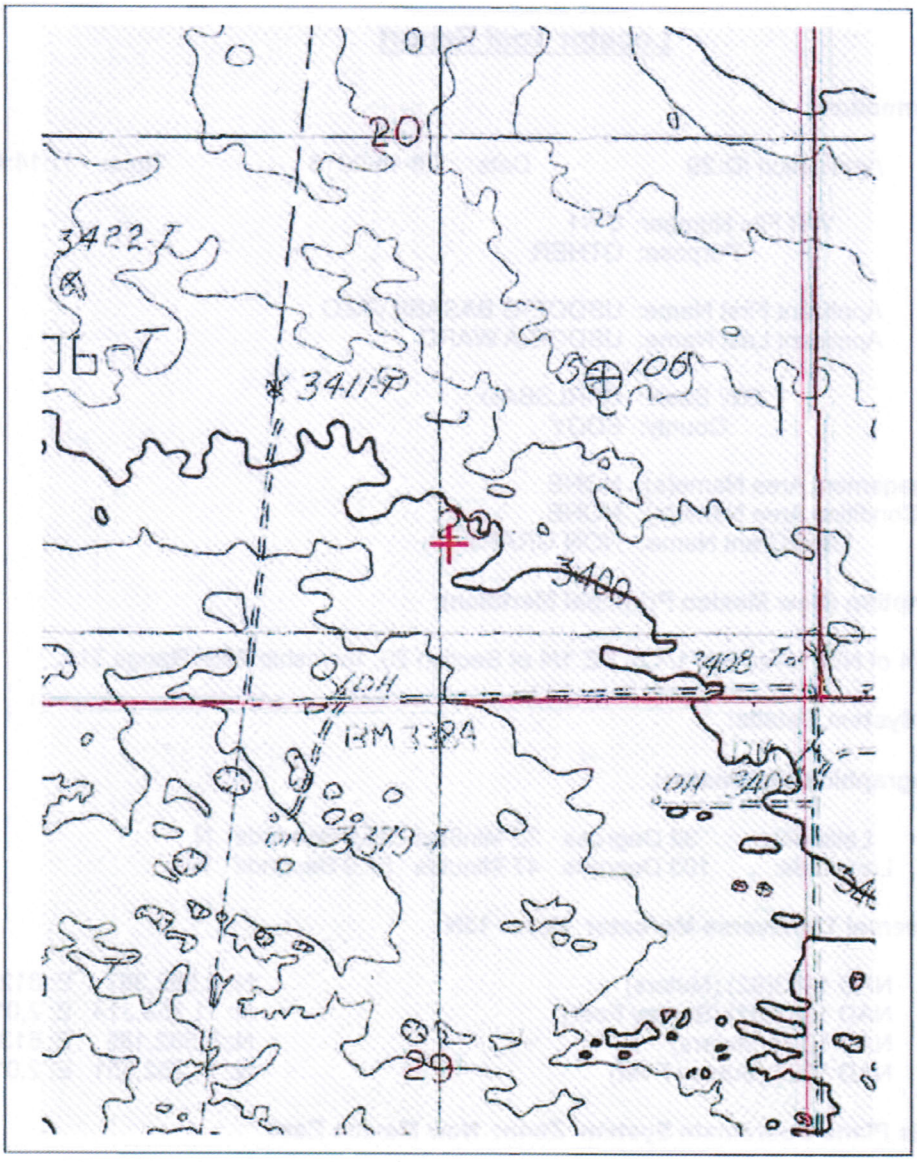
NAD 1983(92) (Meters)	N: 3,582,387	E: 612,968
NAD 1983(92) (Survey Feet)	N: 11,753,214	E: 2,011,045
NAD 1927 (Meters)	N: 3,582,185	E: 613,016
NAD 1927 (Survey Feet)	N: 11,752,551	E: 2,011,205

State Plane Coordinate System Zone: New Mexico East

NAD 1983(92) (Meters)	N: 152,323	E: 215,266
NAD 1983(92) (Survey Feet)	N: 499,748	E: 706,251
NAD 1927 (Meters)	N: 152,305	E: 202,713
NAD 1927 (Survey Feet)	N: 499,687	E: 665,069

NEW MEXICO OFFICE OF STATE ENGINEER

Locator Tool Report



WR File Number: C-#1 Scale: 1:14,368

Northing/Easting: UTM83(92) (Meter): N: 3,582,387 E: 612,968

Northing/Easting: SPCS83(92) (Feet): N: 499,748 E: 706,251

GW Basin: Carlsbad

Print Date: 08/18/2016

New Mexico Office of the State Engineer

Point of Diversion Summary

Well Tag	POD Number	(quarters are 1=NW 2=NE 3=SW 4=SE) (quarters are smallest to largest) Q64	Q16	Q4	Sec	Twp	Rng	(NAD83 UTM in meters) X	Y
	C 03976 POD4	1	3	4	20	22S	31E	612968	3582386

Driller License: 331 **Driller Company:** SBQ2, LLC DBA STEWART BROTHERS DRILLING CO.

Driller Name:

Drill Start Date:	12/17/2016	**Drill Finish Date:**	12/20/2016	**Plug Date:**	12/20/2016
Log File Date:	01/04/2017	**PCW Rcv Date:**		**Source:**	
Pump Type:		**Pipe Discharge Size:**		**Estimated Yield:**	
Casing Size:		**Depth Well:**	71 feet	**Depth Water:**	

The data is furnished by the NMOSE/ISC and is accepted by the recipient with the expressed understanding that the OSE/ISC make no warranties, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the data.

WELL RECORD & LOG

OFFICE OF THE STATE ENGINEER

www.ose.state.nm.us

1. GENERAL AND WELL LOCATION

OSE POD NUMBER (WELL NUMBER): C-3976-POD 4	OSE FILE NUMBER(S):
WELL OWNER NAME(S): U.S. Department of Energy	PHONE (OPTIONAL): 575-234-7488
WELL OWNER MAILING ADDRESS: P O Box 3090	CITY: Carlsbad STATE: NM ZIP: 88221

WELL LOCATION (FROM GPS)		DEGREES	MINUTES	SECONDS	
	LATITUDE	32	22	21.9	N
	LONGITUDE	103	47	57	W

* ACCURACY REQUIRED: ONE TENTH OF A SECOND

* DATUM REQUIRED: WGS 84

DESCRIPTION RELATING WELL LOCATION TO STREET ADDRESS AND COMMON LANDMARKS – PLSS (SECTION, TOWNSHIP, RANGE) WHERE AVAILABLE

west of WIPP site plant on Louis Whitlock rd

2. DRILLING & CASING INFORMATION

LICENSE NUMBER	NAME OF LICENSED DRILLER			NAME OF WELL DRILLING COMPANY
WD-331	Joel Stewart			Stewart Brothers Drilling Co
DRILLING STARTED	**DRILLING ENDED**	**DEPTH OF COMPLETED WELL (FT)**	**BORE HOLE DEPTH (FT)**	**DEPTH WATER FIRST ENCOUNTERED (FT)**
12-17-20	12-20-2016	71	195	n/a

COMPLETED WELL IS: ☐ ARTESIAN ☑ DRY HOLE ☐ SHALLOW (UNCONFINED) — STATIC WATER LEVEL IN COMPLETED WELL (FT): n/a

DRILLING FLUID: ☑ AIR ☐ MUD ADDITIVES – SPECIFY: foamer

DRILLING METHOD: ☑ ROTARY ☐ HAMMER ☐ CABLE TOOL ☐ OTHER – SPECIFY:

DEPTH (feet bgl) FROM	TO	BORE HOLE DIAM (inches)	CASING MATERIAL AND/OR GRADE (include each casing string, and note sections of screen)	CASING CONNECTION TYPE	CASING INSIDE DIAM. (inches)	CASING WALL THICKNESS (inches)	SLOT SIZE (inches)
0	40	8 3/4	2 inch pvc	threaded	2	sched 40	
40	60	8 3/4	2 inch pvc screen	threaded	2	sched 40	.010
60	71	8 3/4	2 inch pvc	threaded	2	sched 40	

3. ANNULAR MATERIAL

DEPTH (feet bgl) FROM	TO	BORE HOLE DIAM. (inches)	LIST ANNULAR SEAL MATERIAL AND GRAVEL PACK SIZE-RANGE BY INTERVAL	AMOUNT (cubic feet)	METHOD OF PLACEMENT
195	71	8 3/4	neat cement	30	tremie
71	25	8 3/4	24x24 silica sand	18	tremie
25	20	8 3/4	bentonite pellets	3.5	tremie
20	0	8 3/4	cement grout well mix	10	tremie

FOR OSE INTERNAL USE — WR-20 WELL RECORD & LOG (Version 10/29/15)

FILE NUMBER	POD NUMBER	TRN NUMBER
LOCATION		PAGE 1 OF 2

4. HYDROGEOLOGIC LOG OF WELL

DEPTH (feet bgl) FROM	DEPTH (feet bgl) TO	THICKNESS (feet)	COLOR AND TYPE OF MATERIAL ENCOUNTERED - INCLUDE WATER-BEARING CAVITIES OR FRACTURE ZONES **(attach supplemental sheets to fully describe all units)**	WATER BEARING? (YES / NO)	ESTIMATED YIELD FOR WATER-BEARING ZONES (gpm)
0	20	20	sandy red clay	Y ✓ N	
20	195	175	red clay with calcite lens	Y ✓ N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	

METHOD USED TO ESTIMATE YIELD OF WATER-BEARING STRATA:

☐ PUMP ☐ AIR LIFT ☐ BAILER ☑ OTHER – SPECIFY: n/a

TOTAL ESTIMATED WELL YIELD (gpm): 0.00

5. TEST; RIG SUPERVISION

WELL TEST — TEST RESULTS - ATTACH A COPY OF DATA COLLECTED DURING WELL TESTING, INCLUDING DISCHARGE METHOD, START TIME, END TIME, AND A TABLE SHOWING DISCHARGE AND DRAWDOWN OVER THE TESTING PERIOD.

MISCELLANEOUS INFORMATION:

PRINT NAME(S) OF DRILL RIG SUPERVISOR(S) THAT PROVIDED ONSITE SUPERVISION OF WELL CONSTRUCTION OTHER THAN LICENSEE:

william brunson

6. SIGNATURE

THE UNDERSIGNED HEREBY CERTIFIES THAT, TO THE BEST OF HIS OR HER KNOWLEDGE AND BELIEF, THE FOREGOING IS A TRUE AND CORRECT RECORD OF THE ABOVE DESCRIBED HOLE AND THAT HE OR SHE WILL FILE THIS WELL RECORD WITH THE STATE ENGINEER AND THE PERMIT HOLDER WITHIN 20 DAYS AFTER COMPLETION OF WELL DRILLING:

w.l. brunson — SIGNATURE OF DRILLER / PRINT SIGNEE NAME

12 29 2016 — DATE

FOR OSE INTERNAL USE — WR-20 WELL RECORD & LOG (Version 10/29/2015)

FILE NUMBER	POD NUMBER	TRN NUMBER
LOCATION		PAGE 2 OF 2

APPENDIX B CORE RECOVERY AND RQD FOR C-3976-4

C3976-4

Core Run #	Depth top (ft)	Depth Base (ft)	Sum of Recovered length (ft)	Sum of Length (ft) of segments > 4 inches	Recovery (%)	RQD
1	0.0	20.0	7.4	0.9	37.0%	12.2
2	20.0	40.0	16.6	8.3	83.0%	50.0
3	40.0	60.0	19.0	16.3	95.0%	85.8
4	60.0	80.0	17.4	1.4	87.0%	8.0
5	80.0	100.0	15.5	8.0	77.5%	51.6
6	100.0	116.0	20.5	10.3	128.1%	50.2
7	116.0	136.0	13.7	4.9	68.5%	35.8
8	136.0	153.0	20.4	7.9	120.0%	38.7
9	153.0	164.0	11.0	5.6	100.0%	50.9
10	164.0	175.0	10.8	7.2	98.2%	66.7
11*	175.0	195.0	20.2	12.8	101.0%	63.4
TOTALS			152.3	70.8	87.0%	46.5

* Core RQD Run 11 determined by inspection of field photographs

APPENDIX C
CORE DESCRIPTIONS

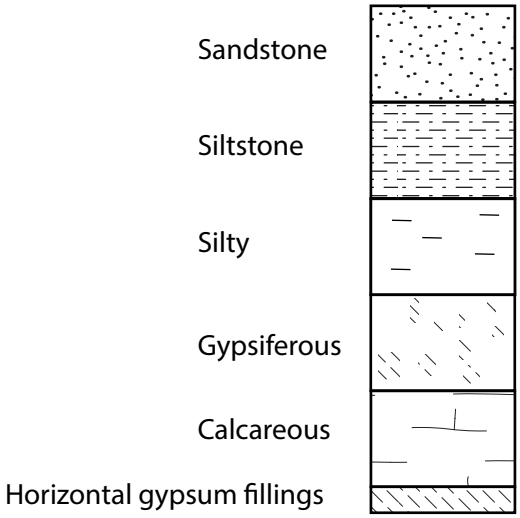
Features and Structures
(used as needed)

- $f_g/_{0°}$ fracture with fill (gypsum) and dip
- ic_{slt} ic_g intraclasts of gypsum or siltstone
- *sl* pedogenic slickensides
- 1.0+' desiccation crack (some with height indication)
- bioturbation
- soft sediment deformation
- small cross-bedding
- ripple bedding
- wavy bedding
- laminar bedding (~horizontal)

Contacts and Bedding

- sharp contact or erosional surface within unit
- gradational contact or erosional surface within unit

Lithologies



Abbreviations
(used as needed)

arg	argillaceous
c	coarse
calc	calcareous
clayst	claystone
cm	centimeter
f	fine
gen	generally
gg	greenish gray
hz	hard (drilling) zone
ind	induration/indurated
lam	laminae
ls	limestone
m	medium
mm	millimeter
mod	moderate
rb	reddish brown
sep(s)	separation(s)
ss	sandstone
sltst	siltstone

CORE LOG Sheet 1 of 6

Hole ID: C-3976-4 Location: sw 1/4, section 20, T22S, R31E, Eddy County, NM

Drill Date: 12/16/2016 begin
Drill Crew: Mike King and crew (Stewart Brothers Drilling Company)
Drill Method: rotary with air; core with air
Hole Diameter: cored interval: 6.25 inch
Hole Depth: 195 ft
Hole Orient: vertical
Drill Make/Model: Schram T-130
Barrel Specs: 4 in. core; 6.25 in. hole
Drill Fluid: air; air-mist; foam
Core Preserv: waxed core box

Logged by: DW Powers and others Date: 12/16-19/2016 Scale: 1 inch = 5 feet

	Northing	Easting	Elevation
Survey Coordinate: (m)			gl BM: 3398.20 ft amsl

Comments: lat 32˚ 22' 20.87" (32.37246389˚); long -103˚ 47' 58.01" (-103.7994472˚) (N lip steel pipe)

Run Number	Depth (feet)	Recovered (ft/ft cored)	RQD (ft/ft)	Profile Lithology	Features	ave. grain size (clay silt sand granule)	Description	Remarks
1	0	7.4 / 20.0	0.9 / 7.4	No recovery 0' - 17.4'				cored with air Reamed 14.75" diameter to 20 ft'; set 10.5 inch steel casing to 20 ft.
	5							
	10							
	12.6						12.5-20.0: Limestone, sandy, arg (Mescalero caliche) at top; underlain by sand, pink (7.5YR7/3); vf to m, subang to round; no sedimentary structures visible; calcareous clasts (nodules?).	
	15				ic			
	20	20		LC: 20.0-23.4				end 12/16/16 @20'; begin 12/17/16
2	25	16.6 / 20.0	8.3 / 16.6		f/80		23.4-30.4: SS, silty, coarser at base with intraclasts; light gray (5Y7/1) and rb (2.5YR4/4); apparently structureless at base, mm-scale lam and ripples (<1 cm); non-calc, variably indurated; intraclasts at 30.1 include carbonates; base in rubble zone.	
	30							

Hole ID: C-3976-4 (SSW-2) CORE LOG (cont. sheet) Sheet 2 of 6

Logged by: geological team Date: 12/18/2016

Run Number	Depth (feet)	Recovered (ft/ft cored)	RQD (ft/ft)	Description	Remarks
	30			30.4	
				30.4-35.0: Ss, silty, red (2.5YR5/6), gg zone 33-33.2; vf; above 33.2, generally alternating beds (5-10 cm thick) with more or less silt; also mm-scale lam that may include small intraclasts; mod to poor induration; base sharp.	
	35			35.0	
				few features discernible	
2		16.6 / 20.0	8.3 / 16.6	35.0-40.0: Ss at base, silty, arg, v calc; yellowish red (2.5YR5/6) to rb (2.5YR4/4), large gg spot and thin gg zones in lower 2-3 ft; vf f, trace opaques; overlain by v arg siltst with little apparent bedding; slightly calc; base undetermined.	
	40	40.0		LC: 40.0-41.0	Begin coring with mist and foam at 40 ft
				41.0-49.3: Sltst, sandy at base to arg; yellowish red (5YR5/6), few gg zones and spots at ~48; lam mainly flat with some slightly wavy, platy appearance; small desiccation cracks filled with calcite; high-angle open fracture at ~49; sharp base.	
	45				
3				49.3	
	50	19.0 / 20.0	16.3 / 19.0	49.3-53.7: Sltst, sandy, arg, rb with some gg lam; slight apparent fining upward; flat to slightly wavy lam, ripples or ?cross-cutting lam; sharp base	
				53.7	
	55			53.7-60.0: Sltst, arg, vf sand lam/zones lower 3 ft, slight fining upward from ~57; pink (5YR7/4), some gg spots and zones throughout; little visible bedding lower 3 ft; thin flat to wavy lam above 57; intraclasts ~55; base undetermined.	
	60	60.0		LC: 60.0-62.6	
				62.6-92.1: Sltst, generally yellowish red (2.5YR5/6) below ~80 ft, rb (2.5YR4/4-4/3) above ~80 ft; slightly sandy at base; dominated by planar to slightly wavy lam, sparse ripples and minor cross-cutting; intraclasts identified at ~66, 75, 83.5, 89; apparent porosity zones attributed to intraclast erosion during drilling occur at ~81, 81.5, 82, 83.5, and 85; high-angle open fractures were identified at ~82.6, 83.5, and 94.6; basal contact sharp.	
4	65	17.4 / 20.0	1.4 / 17.4		

Hole ID: C-3976-4 (SSW-2) CORE LOG (cont. sheet) Sheet 3 of 6

Logged by: geological team Date: 12/18-19/2016

Run Number	Depth (feet)	Recovered (ft/ft cored)	RQD (ft/ft)	Description	Remarks
4	75	17.4/20.0	1.4/17.4	see page 2 for description of this interval	
	80	80			
5	85				
	90				Core run #5 assigned depths 80.0-95.5
		15.5/20.0	8.0/15.5		
	92.1 ft			92.1-101.8: Ss, silty; yellowish red (5YR4/6), overlain by sltst, arg upward; red (2.5YR5/6) to light rb (2.5YR6/4); ss is vf; thin wavy lam to slight cross-cutting bedding; slight possible soft deformation; sltst fines upward; wavy lam, slight cross-cutting bedding, some ripples; variable induration; sharp base.	
	95				
	100	100			end drilling 12/18; begin 12/19/2016
	101.8 ft			101.8-112.5: Series of thin ss fining upward to sltst or sandy sltst; gg zone (N 8/; white) at the base, yellowish red (5YR4/6) above base; f-vf; some intraclasts and apparent porosity from intraclasts eroded during drilling; generally slightly wavy lam; near vertical fracture above 107 with some calcite; sharp base to each bed.	
	103.5 ft				
	105				Core run #6 assigned depths 95.5-116.0
6		20.5/16.0	10.3/20.5		
	107.2 ft				
	110				

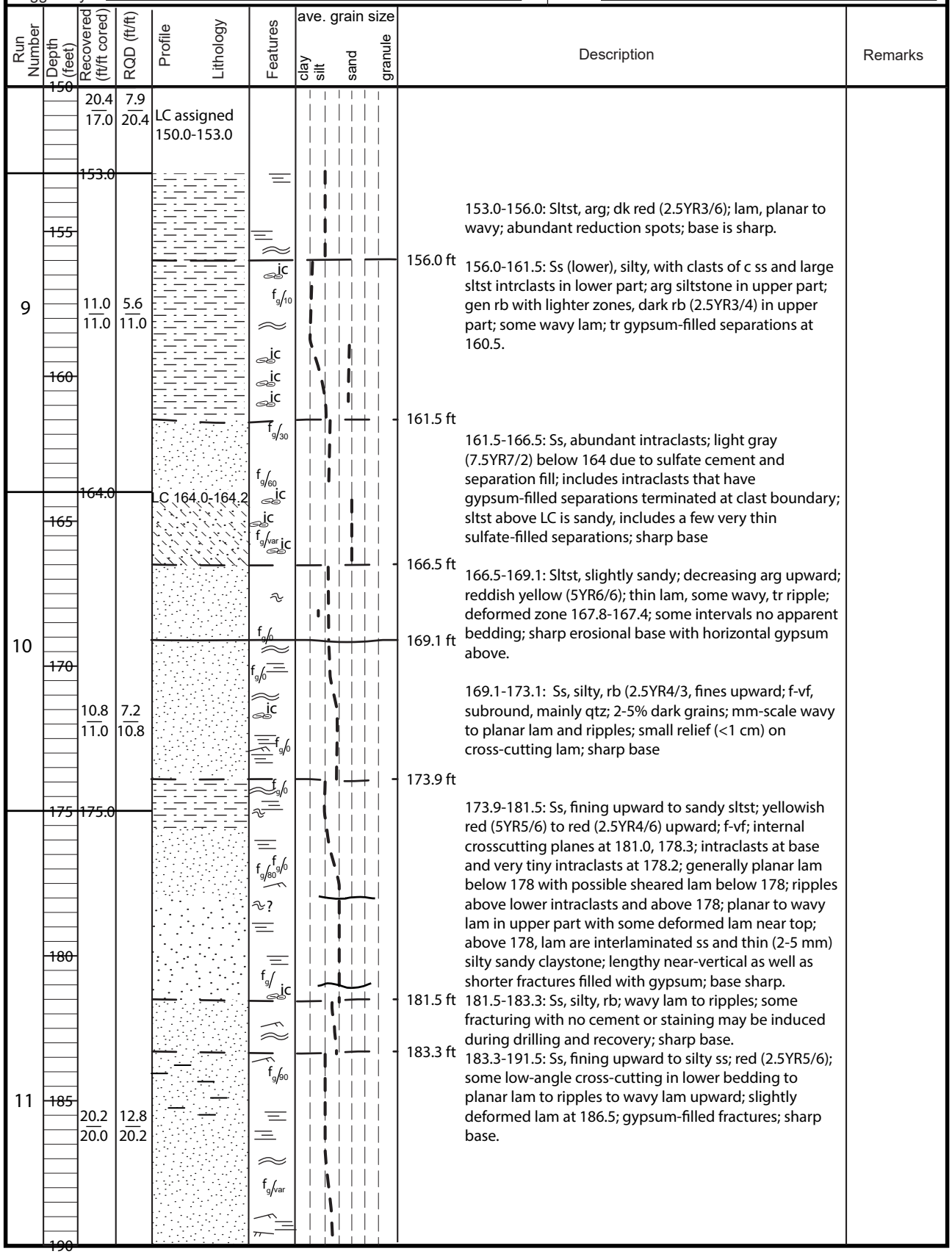
Hole ID: C-3976-4 (SSW-2) CORE LOG (cont. sheet) Sheet 4 of 6

Logged by: geological team Date: 12/19/2016

Run Number	Depth (feet)	Recovered (ft/ft cored)	RQD (ft/ft)	Description	Remarks
6	110	20.5/16.0	10.3/20.5	112.5 ft 112.5-121.5: Ss, silty, fining upward; red (2.5YR4/6); f-vf, subang; planar to wavy thin lam common with local ripples; zone of intraclasts in upper part of ss; calcite cement, also porous; mod ind; sharp base.	Core run 6 assigned to 95.5-116.0
	115				
	116.0				
	120			121.5ft 121.5-142.5: Ss, silty, with overlying siltst; pale brown (10YR6/3) with gg zones near base to red (2.5YR5/6)-4/6) to pinkish white (2.5YR8/2) to red (2.5YR5/6) to light rb (2.5YR7/4) to red (2.5YR5/4) at top; planar to wavy lam common throughout, with ripples in different intervals; fractures with some calicification, both high and low angle; sharp basal contact.	
7	125	13.7/20.0	4.9/13.7		Core run 7 assigned to 121.5-129.5
	130				
	135				
	136.0				
	140				Core run 8 assigned to 129.5-150.0
8		20.4/17.0	7.9/20.4	142.5 142.5-150.0: Sltst, arg; rb (2.5YR4/4) to dark rb (2.5YR3/4) upward; common thin lam, planar to wavy; short vertical fracture ~145, without staining, of uncertain origin; basal contact may be in lost core zone.	
	145				
	150				

Hole ID: C-3976-4 (SSW-2) CORE LOG (cont. sheet) Sheet 5 of 6

Logged by: geological team Date: 12/19/2016



Hole ID: C-3976-4 (SSW-2) CORE LOG (cont. sheet) Sheet 6 of 6

Logged by: geological team Date: 12/19/2016

Run Number	Depth (feet)	Recovered (ft/ft cored)	RQD (ft/ft)	Profile / Lithology	Features	ave. grain size: clay / silt / sand / granule	Description	Remarks
11	190	20.2 20.0	12.8 20.2		f_g ic f_g		191.5 ft 193.5	191.5-193.5: Sltst, sandy; r-b (2.5YR4/4); wavy lam, small intraclasts, desiccation crack near base, ripples near top; abundant gg reduction spots; abundant gypsum-filled fractures. 193.5-TD: Ss, silty, rb, f-vf, subround-subang; 2-3% opaques; mm-scale laminae, slight cross-cutting; arg sltst at top	End drilling 12/19/16; driller's depth 195′
	195							
	200							
	205							