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Depleted Uranium Investigation at Missile Impact Sites in White Sands Missile Range

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by

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ABSTRACT

An investigation for residual depleted uranium was conducted at Pershing missile impact sites on the White Sands Missile Range. Subsurface core soil samples were taken at Chess, Salt Target, and Mine Impact Sites. A sampling pump was installed in a monitoring well at Site 65 where a Pershing earth penetrator was not recovered. Pumping tests and water samples were taken at this site. Chess Site, located in a gypsum flat, was the only location showing elevated levels of depleted uranium in the subsurface soil or perched groundwater. Small fragments can still be found on the surface of the impact sites. The seasonal flooding and near surface water has aided in the movement of surface fragments.

I. INTRODUCTION

White Sands Missile Range (WSMR) requested site investigations of Pershing missile impact sites to determine the distribution, if any, of depleted uranium from the impact of the missile's earth penetrator. In most cases, the earth penetrator had been recovered and scrap resulting from the impact was cleaned up; however, small particles of depleted uranium may remain. Two types of investigation were undertaken.

The first study was conducted to determine the effect on an aquifer penetrated by a Pershing missile. The study was made at Site 65 where a Pershing earth penetrator containing depleted uranium was tested in June 1976. The missile penetrated the earth to a depth of about 200 ft into an aquifer in the area. Recovery operations taken at the time were unsuccessful. A monitoring well was completed adjacent to the missile in August 1986 to monitor the aquifer. Part of the investigation involved installing a pump in the well and monitoring the aquifer to determine the quality of water with reference to depleted uranium.

Water from the aquifer was analyzed for total uranium and the ratio of $^{235}U/^{238}U$, to determine if depleted uranium was being leached from the weapon or fragments of the weapon. Uranium and the uranium ratios analyses were performed by Inductively Coupled Plasma Mass Spectrometry (ICPMS). Standard methods of analyses were performed to determine chemical quality of water.

The second study was done to determine the distribution and concentration in the subsurface at impact sites of missile earth penetrators containing depleted uranium. The sites chosen were (a) Chess Site which is underlain by gypsum, (b) Salt Target Site which is underlain by anhydride and clays, and (c) Mine Site which is underlain by siltstones, sandstones, and occasional lens of limestone and gypsum. The earth penetrators had been recovered; however, some very small fragments of depleted uranium may still remain. The study obtained samples for analyses in the missile impact area. One core hole was located in the impact area of the weapon and several satellite holes were cored to assess the area adjacent to the actual earth penetrator impact point.

Cores from the impact area were analyzed using the ICPMS method for total uranium and the ratio of $^{235}U/^{238}U$. Cores from the satellite holes were analyzed for total uranium by Delayed Neutron Activation (DNA). The DNA analyses are not as sensitive as those done by ICPMS and are used for screening purposes.

Natural uranium occurs in all earth materials in varying concentrations according to rock type. Both the ICPMS and DNA methods of analyses for total uranium include the natural uranium. If fragments of depleted uranium are present in the sample, the reported concentration will be excessive. ICPMS analyses for the ratio of $^{235}U/^{238}U$ are used to determine depleted uranium. The normal ratios range from 0.0060 to 0.0080 or average about .0070. Samples in the area ranged from 0.0076 ± 0.0003 to 0.0092 ± 0.0020 (Table 1). A report by Becker (Becker 1991) established the ratio to be 0.0072 ± 0.0008.

II. SITE 65

Site 65 is a missile impact site located in the southern part of the Missile Range near the center of the valley just north of U.S. Highway 70 (Fig. 1).

The background material in the following paragraphs was summarized from the U. S. Geological Survey (USGS) report on drilling and completion of a monitoring well at Site 65 (USGS 1986).

In June 1976, a Pershing D-38 Earth Penetrating Missile containing about 80 lbs of depleted uranium impacted at the site. An investigation and recovery effort took place in 1977; however, there is no record of the outcome of the effort. The recovery operations included two test holes and a shaft sunk over the missile (Fig. 2). The shaft was sunk to the top of the earth penetrator at a depth of about 194 ft and was cased with a 4 ft-diameter steel casing that extends about 2 ft above land surface (LSD).

In August 1986 the USGS drilled a monitoring well about 15 ft southeast of the shaft (Fig. 3). The hole was drilled using water ard a rock bit of 9-7/8 in. diameter. The well was cased with 4-in. diameter PVC plastic pipe.

During the recovery effort in 1977, a 4-ft diameter casing set above the earth penetrator was grouted in and backfilled with bentonite slurry to a depth of 122 ft. The casing was found to contain water to a depth of 95.9 ft during a site visit in February 1991 (Fig. 2). The log indicates that the earth penetrator penetrated a sand that is saturated. The USGS indicated that the sand is probably part of a regional aquifer that moves to the southeast with a gradient of about 7.5 ft/mile.

A. Investigation 1991 and 1992

Site 65 was visited and data collected in February, March, and June of 1991, and in March of 1992.

1. February 1991

The site visit of February 25, 1991, was made to evaluate the conditions of the monitoring well with reference to installation of a pump. Water level in the monitoring well was 69.7 ft below LSD. The depth of the well was determined to be 197 ft below LSD. Seven ft of screen opening (190 to 197 ft) were left opposite the earth penetrator or impact area of the earth penetrator in the sand (Figs. 2 and 3).

Prior to determination of the depth of the well water, samples were collected at depths of 75, 100, 150, 175, 190, and 197 (bottom) ft (Tables 1 and 2). The total uranium in the samples ranged from 17.2 to 19.4 μg/L. The ratio $^{235}U/^{238}U$ ranged from 0.0061 to 0.0077, within the range of natural uranium. There was no indication of the dispersion of depleted uranium from the earth penetrator or fragments of the earth penetrator in the sand and aquifer.

A water sample was also collected from the shaft at the bottom at a depth of 122 ft. The total dissolved uranium was 1 μg/L while the uranium concentrations were too low to determine the ratio of $^{235}U/^{238}U$. A background sample collected from a water tanker at the NASA operations strip indicated a total dissolved uranium concentration of 1.9 μg/L. Uranium concentrations were too low to determine ratios.

2. March 1991

During a site visit a small monitoring pump was installed in the well and samples were collected on March 19 and 20, 1991. The pump is an air-driven bladder-type in which the water sample does not come in contact with the air. The pump was set at a depth of 180 ft, about 10 ft above the top of the screens (Fig. 3). The pumping rate of the bladder pump is low, 0.5 gallons per minute (gpm).

Prior to setting the pump on March 19, an additional water sample was collected from the bottom of the hole with a bailer. The total uranium was 20.3 μg/L with a $^{235}U/^{238}U$ ratio of 0.0078 (Table 2).

The well was pumped for about 30 minutes removing about 15 gallons of water from the well. The total uranium was 15.2 μg/L with a ratio of 0.0088 (Table 2).

On March 20 the well was pumped for 70 minutes with about 35 gallons of water removed from the well. The water level declined from 68.7 to 73.8 ft. The water coming through the screen section was muddy. Samples were collected at 50, 60, and 70 minutes of pumping (Table 2).

A water sample taken 20 minutes prior to fresh water entering the pump from the screen section was 14.3 μg/L with a $^{235}U/^{238}U$ ratio of 0.0070 (Table 2). At 40 minutes to 70 minutes, when water was muddy, the total uranium ranged from 14.2 to 15.2 μCi/L with $^{235}U/^{238}U$ ratios of 0.0075 to 0.0085. The uranium levels and ratios indicate uranium in water pumped from the well is natural.

The suspended solids were filtered from the samples collected at 60 and 70 minutes and were analyzed for total uranium in the suspended sediments. The total uranium reported was 5.0 and 5.8 μg/L (Table 2).

Analyses of the drawdown and recovery of the water level of this pumping period indicated that the sand unit has a coefficient of permeability of about 8 gallons per day/sq ft. With a gradient of 7.5 ft/mile, the velocity of movement in the aquifer is very slow, probably in the range of 15 to 25 ft/year.

3. June 1991

The monitoring well was sampled again on June 12, 1991. The samples were collected at 5, 120, and 130 minutes of pumping (Table 2). Total uranium ranged from 14.2 to 14.8 μg/L in the range of natural uranium.

The chemical quality of water determined from three samples indicated the water was of a sodium-sulfate type with high chlorides. The total dissolved solids were high, ranging from 4,000 to 4,800 milligrams/L. The water quality is typical for the area in part due to the underlying or adjacent gypsum formation (Table 3).

4. March 1992

The monitoring well was sampled again on March 7, 1992. The well was pumped for a 9 hour period at a rate of about 0.65 gpm. The water level declined from 70 ft at the start of the test to 76.5 ft when the last sample was taken. Sixteen water samples were collected during the nine hours of pumping. The total uranium was about 11 μg/L during the first 30 minutes of pumping and declined to range from 7.1 to 9.1 μg/L. The uranium ratio varied from sample to sample; however, with the error term, remained within the range of natural uranium with a average of 0.0072 ± 0.0008 (Table 2).

III. Missile Impact Areas at Chess, Salt Target, and Mine Sites

Subsurface investigations were made at individual missile impact areas at these three sites by collecting cores from select depth intervals. The cores were collected using a continuous coring within an auger. The auger removed the excess cuttings and the samples taken came in contact with only the core barrel. No fluids, water or air, were used in the coring operations. The core runs are 5 ft in depth. Core barrels are decontaminated after each core run before being used again.

At each of the three sites, the missile earth penetrator had been recovered. The depth of penetration was 20 ft or less. All scrap and fragments of the missile were collected and the excavation was filled with soil or material excavated from the hole. The initial hole was cored at this impact area, in the refilled excavated material. On the surface, small fragments of metal, wire, plastic, and scrap remain as a result of the missile impact. Visual examination of the surface at the sites indicated only small fragments of depleted uranium (less than 0.25-in dia) at Salt Site.

Five holes were drilled at each site, one in the impact area and four adjacent holes north, east, south, and west of the impact area hole. The distances of the four adjacent holes varied from the impact hole, allowing for the direction of the missile fragments after impact. In addition, background holes were cored at a distance from the main area of investigation to allow comparison of the analytical results. The cores were logged, at which time visual inspection did not detect any debris fragments, metal, plastic, or depleted uranium in the cores either from the hole cored in the impact (refilled area) or from the satellite holes. The geologic logs of cores described during coring operations are found in Appendix A.

A. Chess Site

Chess Site is located in a gypsum flat and is underlain by an unknown thickness of gypsum. The site is in the lower part of the valley north of White Sands National Monument and south of the NASA landing strip (Fig. 1).

Five holes were cored at and adjacent to the impact area (Fig. 4). The holes ranged in depth from 9 to 28 ft. Water was encountered in all the holes at a depth of 6 to 10 ft. Two of the holes were cased as observation wells and two, including the background hole located about 400 ft to the north, were left uncased to allow for collection of water samples (Fig. 5). The other two holes were plugged and abandoned.

1. Water Analyses

On June 18, 1991, four water samples were collected from the test holes in and adjacent to the impact area and one sample was collected from the background hole. Two volumes of water were removed from the cased holes prior to the collection of samples (Holes CI-Hole and N-Hole). Hole CI-Hole was bailed dry and a second sample collected. The two uncased holes, S-Hole and Bkg-Hole, were also sampled.

The chemical quality of water from the three holes is a predominate sodium-sulfate with high chlorides that is typical of the gypsum where the water was encountered. The concentration of total dissolved solids is high, ranging from 10,000 to about 40,000 milligrams/L. The variations in concentrations in some of the chemical constituents are due in part to cased or uncased holes where the concentrations are elevated; the error terms are enlarged to as much as 20% (Table 4).

The total uranium in the water was high, ranging from a low of about 13 (one sample) to 489 μg/L. If the chemistry for the sample would support ratios of $^{235}U/^{238}U$, the measurement would determine if the elevated uranium is natural or from missile fragments. Ratios of 0.0017 (S-Hole), 0.0037 (N-Hole), and 0.0051 (CI-Hole, impact hole) indicate depleted uranium from the missile fragments (Table 4). The uranium was leached from the missile fragments and is moving with the water in the gypsum.

2. Core Analyses

The total uranium from the background hole averaged 1.3 μg/g while the ratios averaged 0.0079. The total uranium in the impact hole (CI-Hole) was elevated near the surface at 16 μg/g (Table 5). The ratios in the upper two samples, 3 and 8 ft, were 0.0002 and 0.0058 respectively indicating some depleted uranium from missile fragments. The total uranium in S-Hole was slightly elevated with some concentrations ranging from 3 to 5 μg/g. Both the cores and water from S-Hole were above natural levels, indicating the presence of depleted uranium fragments in and adjacent to the impact area.

B. Salt Target Site

Salt Target Site is located near the center of the missile range (Fig. 1). The site is underlain by silts, clays, and anhydrides. No water or excessive moisture was encountered in coring in the area. Five holes were cored at the site (Fig. 6). The holes ranged in depth from 24 to 29 ft. Two background holes were cored about 500 ft to the northwest.

1. Core Analyses

Total uranium in the cores from the background hole averaged 1.4 μg/g while the average ratios were 0.0080, in the range of natural uranium. No significant difference in the concentrations of total uranium and ratios in the S-Hole (impact area) and the total uranium in the satellite holes SW-Hole, SE-Hole, NE-Hole, and NW-Hole was found when compared to the data from the background hole (Table 6). Depleted uranium from the missile impact was not detected upon analyses of the core.

C. Mine Site

Mine Site is located in the north end of the missile range (Fig. 1). The site is underlain by silts, clays, sandstones, and limestone lens. Four holes were cored at the site (Fig. 7) in areas that would reflect the maximum effect of the impacted missile. The core holes ranged from 29 to 49 ft in depth. The background hole is located about 600 ft to the west. The holes were dry and moisture content was at a minimum.

1. Core Analyses

Total uranium concentration in cores from the background hole was 1.0 μg/g while the average ratio was 0.0074. S-Hole (impact area) average total uranium was 1.3 μg/g with a ratio of 0.0088 which is in the range of natural uranium. The total uranium from cores from E-Hole, C-Hole, and W-Hole indicated no depleted uranium from the impact of the missile in the area (Table 7).

IV. CONCLUSIONS

Analysis of water samples from the aquifer adjacent to the missile at Site 65 showed that uranium in the aquifer was natural and no dispersion of depleted uranium from the earth penetrator or fragments of the earth penetrator was indicated.

Water and core samples from Chess Site indicated that missile fragments were present in the area and that water encountered in the hole was contaminated with depleted uranium leached from the missile earth penetrator or fragments.

Concentrations of total uranium and uranium ratios from cores from test holes at Salt and Mine Sites showed only natural uranium with no indication of depleted uranium in samples collected at these sites.

V. REFERENCES

Becker 1991: Becker, N. M., "Influence of Hydraulic and Geomorphology Components of Semi-Arid Watershed on Depleted Uranium Transport," Doctoral Thesis, University of Wisconsin-Madison (1991).

USGS 1986: U. S. Geological Survey, "Depleted Uranium Monitoring Well, Site 65, White Sands Missile Range," Administrative Report to WSMR, Las Cruces, N. M. (1986).

Table 1. Uranium Analyses from Miscellaneous Sources in or near White Sands Missile Range.

Source	Total U (μg/L)	Ratio $^{235}U/^{238}U$
Main Post	1.5 ± 0.2	—[a]
White Sands Monument	2.3 ± 0.2	—[a]
HELSTF	3.1 ± 0.2	0.0092 ± 0.0020
HTA Well	77.8 ± 3.9	0.0076 ± 0.0003
Site 65 Shaft[b] (2/25/91)	1.0 ± 0.2	—[a]
Water from Tank-NASA Operation Strip (2/25/91)	1.9 ± 0.2	—[a]

[a] ^{235}U concentration too low to measure.

[b] Sample bailed from 4 ft diameter shaft bottom at 122 ft; water level 95.1 ft LSD 2/25/91.

Table 2. Total Uranium and Ratio $^{235}U/^{238}U$ in Water from Site 65 Monitoring Well.[a]

February 25, 1991[b]

Depth (ft)	Total U (μg/L)	Ratio $^{235}U/^{238}U$
75	17 ± 0.8	0.0072 ± 0.0002
100	19 ± 1.0	0.0075 ± 0.0017
150	17 ± 0.9	0.0065 ± 0.0009
175	16 ± 0.8	0.0061 ± 0.0024
190	18 ± 0.9	0.0077 ± 0.0007
197	18 ± 0.9	0.0077 ± 0.0009
$\bar{x}$	17.5 ± 1.1	0.0071 ± 0.0007

March 19, 1991

Pumped (min)	Total U (μg/L)	Ratio $^{235}U/^{238}U$
Bailed	20 ± 0.8	0.0078 ± 0.0004
Pumped 30 min	15 ± 0.6	0.0088 ± 0.0005
$\bar{x}$	17.5 ± 3.5	0.0083 ± 0.0007

March 20, 1991

Pumped (min)	Total U (μg/L)	Ratio $^{235}U/^{238}U$
20	14 ± 0.6	0.0070 ± 0.0015
40	15 ± 0.6	0.0075 ± 0.0005
50	15 ± 0.6	0.0085 ± 0.0005
60	15 ± 0.6	0.0077 ± 0.0010
70	14 ± 0.6	0.0083 ± 0.0002
$\bar{x}$	14.6 ± 0.6	0.0078 ± 0.0006

June 17, 1991

Pumped (min)	Total U (μg/L)
5	14.2 ± 0.7
120	14.7 ± 0.8
130	14.8 ± 0.6
$\bar{x}$	14.6 ± 0.3

Table 2. (Cont.)

March 7, 1992

Pumped (min)	Total U (μg/L)	Ratio $^{235}U/^{238}U$
14	11.5 ± 1.2	0.0083 ± 0.0010
30	11.1 ± 1.1	0.0071 ± 0.0002
60	8.6 ± 0.9	0.0068 ± 0.0012
90	8.9 ± 0.9	0.0068 ± 0.0011
120	9.1 ± 0.9	0.0067 ± 0.0016
150	8.5 ± 0.9	0.0082 ± 0.0007
180	9.0 ± 0.9	0.0068 ± 0.0009
210	9.1 ± 0.9	0.0072 ± 0.0004
330	8.0 ± 0.8	0.0064 ± 0.0013
360	7.4 ± 0.7	0.0087 ± 0.0013
390	7.1 ± 0.7	0.0071 ± 0.0012
420	7.6 ± 0.8	0.0058 ± 0.0010
450	7.8 ± 0.8	0.0078 ± 0.0010
480	7.7 ± 0.8	0.0078 ± 0.0017
510	7.7 ± 0.8	0.0070 ± 0.0006
540	7.8 ± 0.8	0.0074 ± 0.0002
$\bar{x}$	8.6 ± 1.2	0.0072 ± 0.0008

[a]Analyses by inductively coupled plasma mass spectrometry (ICPMS).

[b]Samples bailed from select zones for background prior to installation of pump.

Table 3. Chemical and Miscellaneous Analyses of Water from Site 65 Monitoring Well.

	Pumped 5 min	Pumped 120 min	Pumped 130 min
Chemical Analyses			
(mg/L)			
SiO_2	30	28	28
Ca	420	470	470
Mg	140	150	150
K	9	9	10
Na	790	930	880
Cl	285	358	346
F	—	1	—
Total Alkalinity	81	70	82
SO_4	3 600	3 700	3 600
NO_3-N	4	5	4
TDS	4 000	4 800	4 500
Total Hardness	1 625	1 791	1 791
pH	—	8	—
Miscellaneous Analyses			
Thorium (μg/L)	1.2 ± 1.0	2.4 ± 1.0	1.0 ± 1.0
Tritium (pCi/L)	700.0 ± 300	600.0 ± 300.0	300.0 ± 300.0
Total U (μg/L)	14.8 ± 0.6	14.2 ± 0.7	14.7 ± 0.8
Ratio $^{235}U/^{238}U$	—[a]	—[a]	—[a]

[a] ^{235}U concentration too low to measure.

Table 4. Chemical and Miscellaneous Analyses of Water from Holes at Chess Site.

	Background Hole	CI Hole	CI Hole[a]	N Hole	S Hole
Chemical Analyses (mg/L)					
SiO_2	18	25	12	18	17
Ca	1 100	680	540	490	630
Mg	1 100	470	1 400	900	1 200
K	500	61	480	840	610
Na	62 000	2 800	8 400	5 200	7 400
Cl	17 000	4 000	18 000	13 000	17 000
F	2	1	1	<1	2
Total Alkalinity	180	197	138	160	160
SO_4	16 900	4 800	14 000	16 200	14 800
NO_3-N	6	3	7	4	7
TDS	39 500	10 900	37 300	36 800	37 800
Total Hardness	7 276	3 633	7 114	4 930	6 515
pH	7.4	8.3	7.9	7.3	7.6
Miscellaneous Analyses					
Thorium (μg/L)	1.0 ± 1.0	1.0 ± 1.0	1.0 ± 1.0	1.0 ± 1.0	1.0 ± 1.0
Tritium (pCi/L)	200.0 ± 200.0	800.0 ± 300.0	200.0 ± 300.0	300.0 ± 300.0	1 300.0 ± 300.0
Total U (μg/L)	39.0 ± 2.0	17.8 ± 0.7	40.0 ± 2.0	87.0 ± 4.4	489.0 ± 25.0
Ratio $^{235}U/^{238}U$	—[b]	—[b]	0.0051 ± 0.0031	0.0037 ± 0.0010	0.0017 ± 0.0004

[a]Hole bailed dry, sample taken after well recovered.

[b]^{235}U concentration too low to measure.

Table 5. Total Uranium and Ratio $^{235}U/^{238}U$ from Test Holes at Chess Site.

Background Hole

Depth (ft)	Total U (μg/g)	Ratio $^{235}U/^{238}U$
4	0.63 ± 0.06	0.0096 ± 0.0017
9	0.98 ± 0.10	0.0083 ± 0.0020
14	1.40 ± 0.14	0.0083 ± 0.0010
19	0.84 ± 0.08	0.0076 ± 0.0034
24	1.80 ± 0.18	0.0068 ± 0.0008
29	1.90 ± 0.52	0.0068 ± 0.0020
$\bar{x}$	1.30 ± 0.52	0.0079 ± 0.0011

CI Hole (Impact Area)

Depth (ft)	Total U (μg/g)	Ratio $^{235}U/^{238}U$
3	16.0 ± 1.60	0.0019 ± 0.0002
8	1.4 ± 0.14	0.0058 ± 0.0019
13	2.0 ± 0.20	0.0064 ± 0.0006
18	1.5 ± 0.15	0.0074 ± 0.0008
23	1.9 ± 0.19	0.0074 ± 0.0004
$\bar{x}$	4.6 ± 6.40	0.0058 ± 0.0023

S Hole

Depth (ft)	Total U (μg/g)
3	4.0 ± 0.40
8	5.0 ± 0.50
13	3.0 ± 0.40
18	0.6 ± 0.06
23	3.0 ± 0.30
28	2.0 ± 0.20
$\bar{x}$	2.9 ± 1.50

E Hole

Depth (ft)	Total U (μg/g)
4	0.9 ± 0.1
9	1.0 ± 0.1
14	0.6 ± 0.1
16	1.0 ± 0.2
$\bar{x}$	0.9 ± 0.2

N Hole

Depth (ft)	Total U (μg/g)
4	1.0 ± 0.10
9	1.0 ± 0.20
$\bar{x}$	1.0 ± 0.00

W Hole

Depth (ft)	Total U (μg/g)
4	1.0 ± 0.2
9	2.0 ± 0.2
14	2.0 ± 0.2
18	1.0 ± 0.2
$\bar{x}$	1.5 ± 0.6

Table 6. Total Uranium and Ratio $^{235}U/^{238}U$ from Test Holes at Salt Site.

Background Hole

Depth (ft)	Total U (μg/g)	Ratio $^{235}U/^{238}U$
4	0.85 ± 0.09	0.0084 ± 0.0029
9	0.79 ± 0.08	0.0082 ± 0.0014
14	1.80 ± 0.18	0.0086 ± 0.0011
19	2.40 ± 0.24	0.0073 ± 0.0019
24	1.30 ± 0.13	0.0068 ± 0.0015
29	1.30 ± 0.13	0.0077 ± 0.0010
34	1.10 ± 0.11	0.0083 ± 0.0011
39	0.50 ± 0.05	0.0087 ± 0.0012
$\bar{x}$	1.40 ± 0.57	0.0080 ± 0.0007

S Hole (Impact Area)

Depth (ft)	Total U (μg/g)	Ratio $^{235}U/^{238}U$
4	1.50 ± 0.15	0.0084 ± 0.0004
9	1.50 ± 0.15	0.0085 ± 0.0019
14	1.80 ± 0.20	0.0082 ± 0.0022
19	3.60 ± 0.40	0.0076 ± 0.0011
24	0.35 ± 0.04	0.0084 ± 0.0014
29	0.94 ± 0.09	0.0095 ± 0.0007
$\bar{x}$	1.60 ± 1.10	0.0084 ± 0.0006

SW Hole

Depth (ft)	Total U (μg/g)
4	2.0 ± 0.20
9	1.0 ± 0.10
14	2.0 ± 0.20
19	3.0 ± 0.30
24	0.6 ± 0.06
29	0.1 ± 0.01
$\bar{x}$	1.5 ± 1.10

SE Hole

Depth (ft)	Total U (μg/g)
4	2.0 ± 0.20
14	2.0 ± 0.20
19	3.0 ± 0.30
24	0.6 ± 0.06
$\bar{x}$	1.9 ± 1.00

Table 6. (Cont.)

NE Hole

Depth (ft)	Total U (µg/g)
4	2.0 ± 0.20
9	2.0 ± 0.20
14	2.0 ± 0.20
19	3.0 ± 0.30
24	0.5 ± 0.05
29	1.0 ± 0.10
$\bar{x}$	1.8 ± 0.88

NW Hole

Depth (ft)	Total U (µg/g)
4	0.4 ± 0.04
9	2.0 ± 0.20
14	2.0 ± 0.20
19	3.0 ± 0.30
24	5.0 ± 0.50
29	1.0 ± 0.10
$\bar{x}$	2.2 ± 1.60

Table 7. Total Uranium and Ratio $^{235}U/^{238}U$ from Test Holes at Mine Site.

Background Hole

Depth (ft)	Total U (µg/g)	Ratio $^{235}U/^{238}U$
4	1.20 ± 0.10	0.0073 ± 0.0013
9	0.74 ± 0.07	0.0102 ± 0.0038
14	0.65 ± 0.07	0.0072 ± 0.0014
19	0.75 ± 0.08	0.0063 ± 0.0011
24	0.90 ± 0.09	0.0073 ± 0.0008
29	1.10 ± 0.11	0.0078 ± 0.0010
34	0.74 ± 0.07	0.0065 ± 0.0022
39	0.71 ± 0.07	0.0062 ± 0.0016
44	1.80 ± 0.18	0.0078 ± 0.0004
49	1.70 ± 0.17	0.0075 ± 0.0004
$\bar{x}$	1.03 ± 0.42	0.0074 ± 0.0011

S Hole (Impact Area)

Depth (ft)	Total U (µg/g)	Ratio $^{235}U/^{238}U$
4	0.83 ± 0.08	0.0085 ± 0.0038
9	0.84 ± 0.08	0.0100 ± 0.0032
14	0.87 ± 0.09	0.0118 ± 0.0010
19	1.20 ± 0.10	0.0095 ± 0.0007
24	1.20 ± 0.12	0.0079 ± 0.0007
29	1.20 ± 0.12	0.0095 ± 0.0010
34	1.20 ± 0.11	0.0073 ± 0.0014
39	1.20 ± 0.10	0.0072 ± 0.0009
44	1.80 ± 0.18	0.0085 ± 0.0005
49	2.30 ± 0.20	0.0076 ± 0.0009
$\bar{x}$	1.26 ± 0.46	0.0088 ± 0.0014

E Hole

Depth (ft)	Total U (µg/g)
4	2.0 ± 0.20
9	1.0 ± 0.10
14	1.0 ± 0.10
19	1.0 ± 0.10
24	1.0 ± 0.10
29	1.0 ± 0.10
$\bar{x}$	1.2 ± 0.41

C Hole

Depth (ft)	Total U (µg/g)
4	2.0 ± 0.20
9	1.0 ± 0.10
14	1.0 ± 0.10
19	1.0 ± 0.10
24	2.0 ± 0.20
29	1.0 ± 0.10
34	1.0 ± 0.10
39	2.0 ± 0.20
$\bar{x}$	1.4 ± 0.52

Table 7. (Cont.)

W Hole

Depth (ft)	Total U (μg/g)
4	2.0 ± 0.20
9	1.0 ± 0.10
14	1.0 ± 0.10
19	1.0 ± 0.10
24	2.0 ± 0.20
29	1.0 ± 0.10
34	1.0 ± 0.10
39	2.0 ± 0.20
$\bar{x}$	1.4 ± 0.52

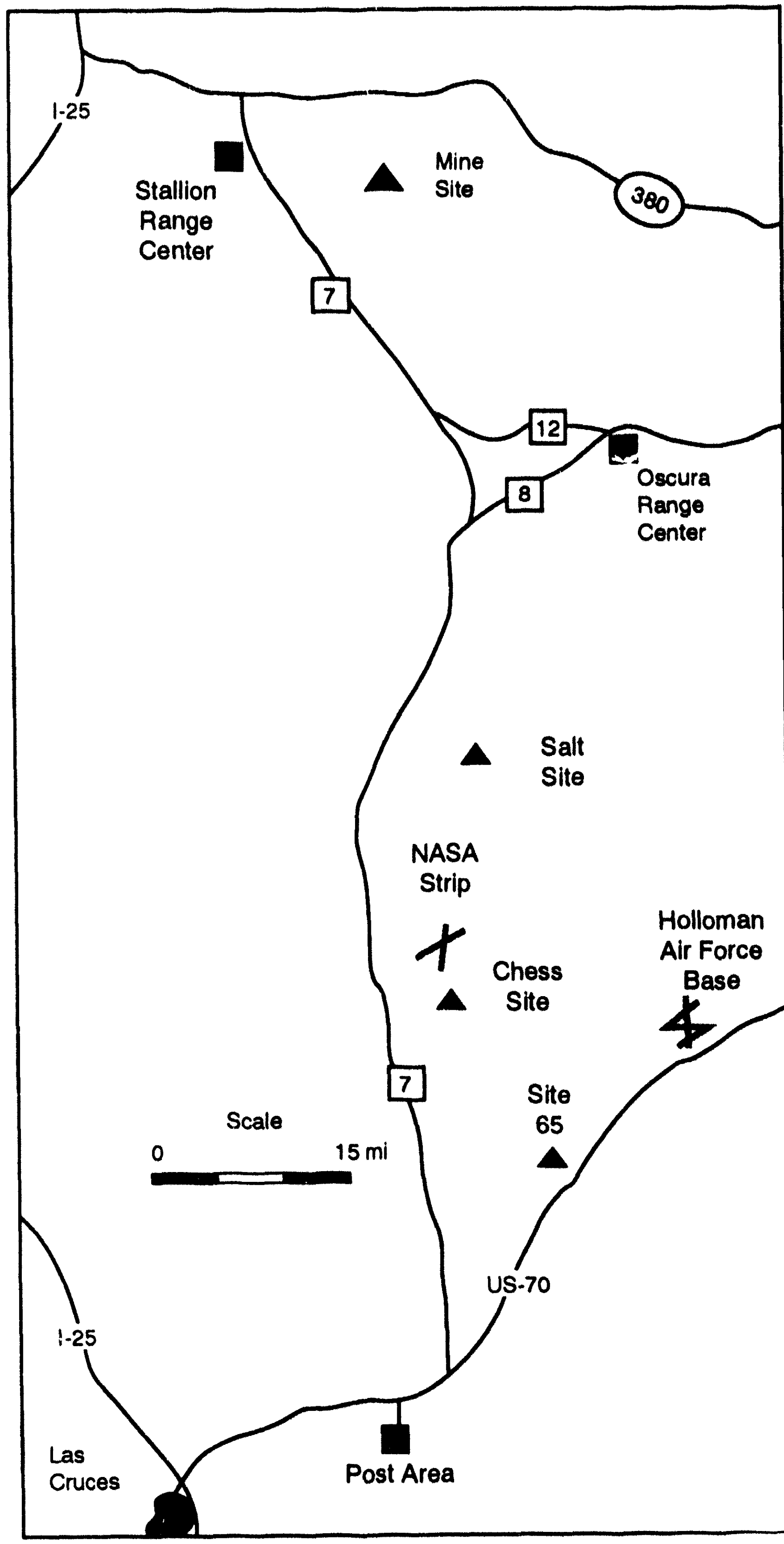

Figure 1. Generalized location of Site 65, Chess, Salt, and Mine Sites on White Sands Missile Range in southern New Mexico.

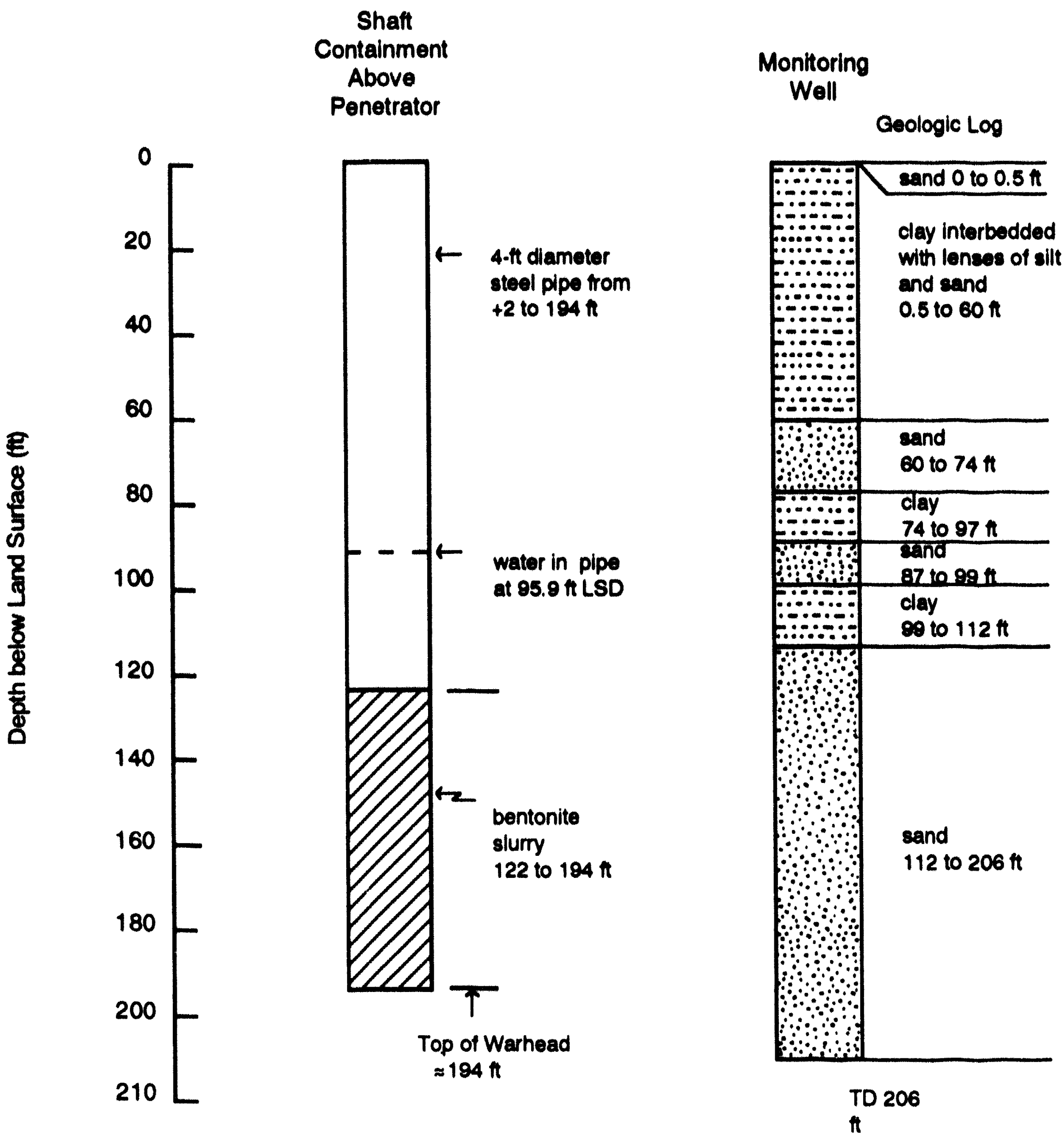

Figure 2. Shaft containment above warhead compared to Geologic Log of monitoring well (well located 15 ft southeast of shaft).

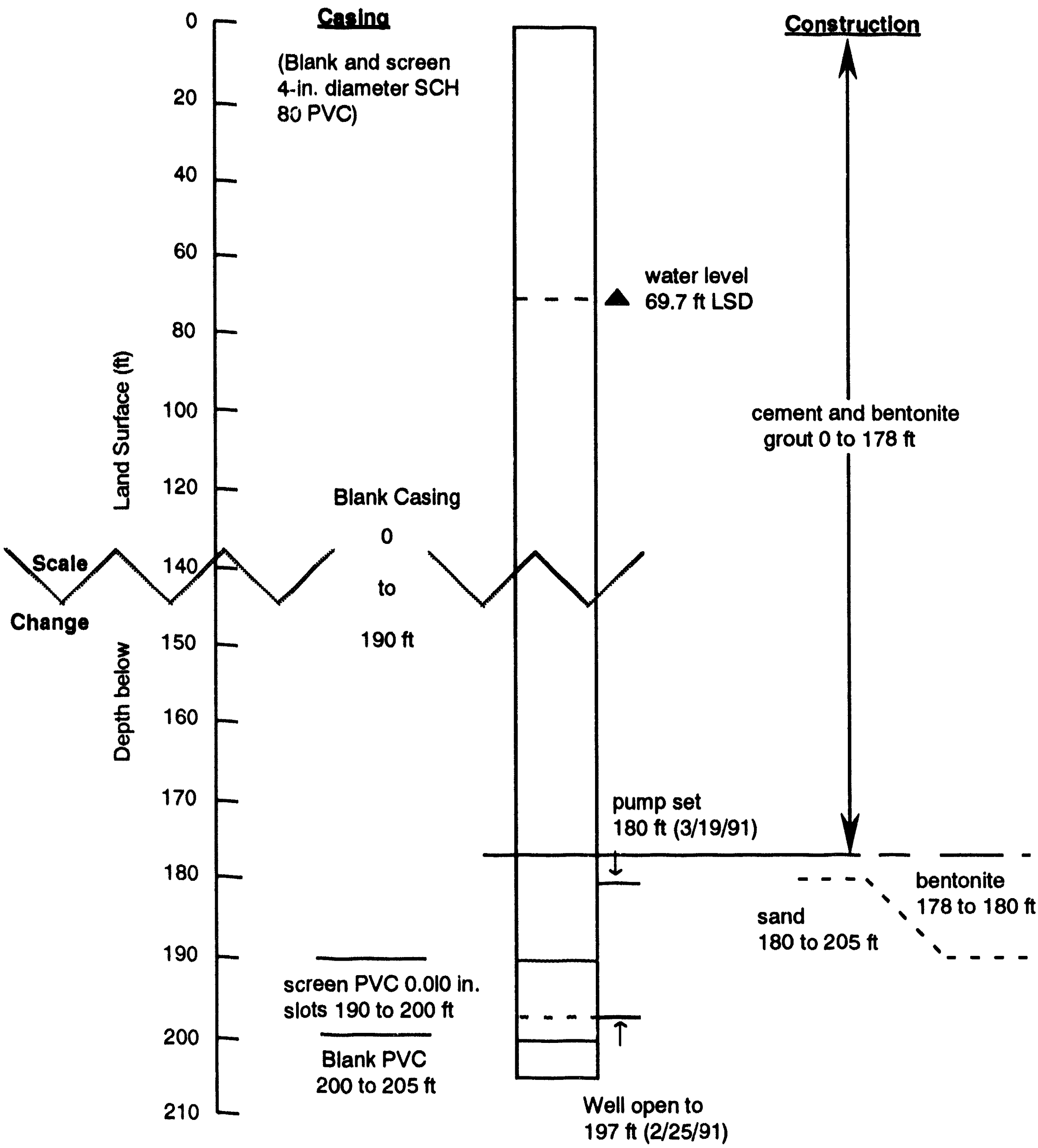

Figure 3. Well construction, water level (2/25/91), and pump setting on monitoring well Site 65.

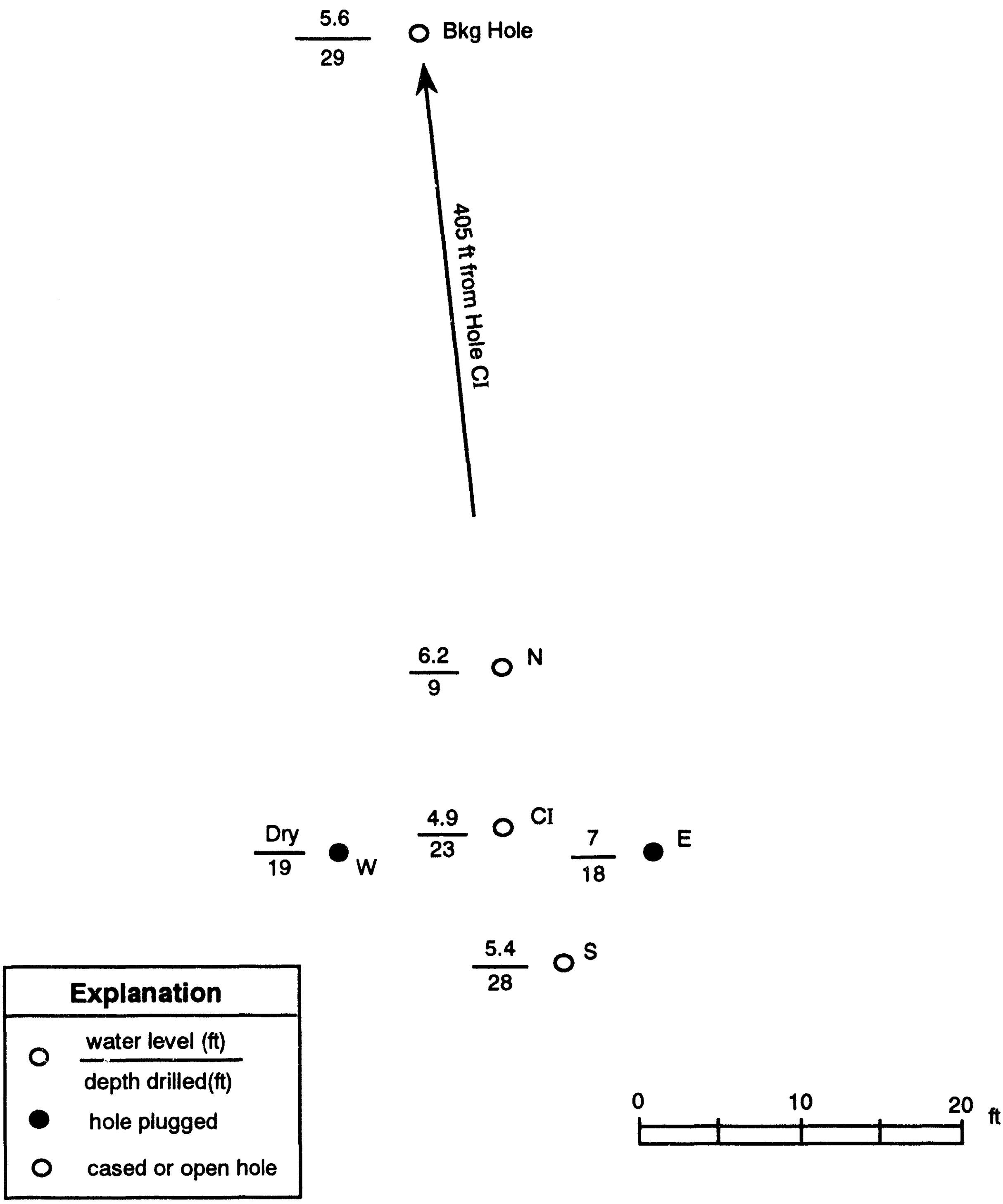

Figure 4. Location of test holes at Chess Site.

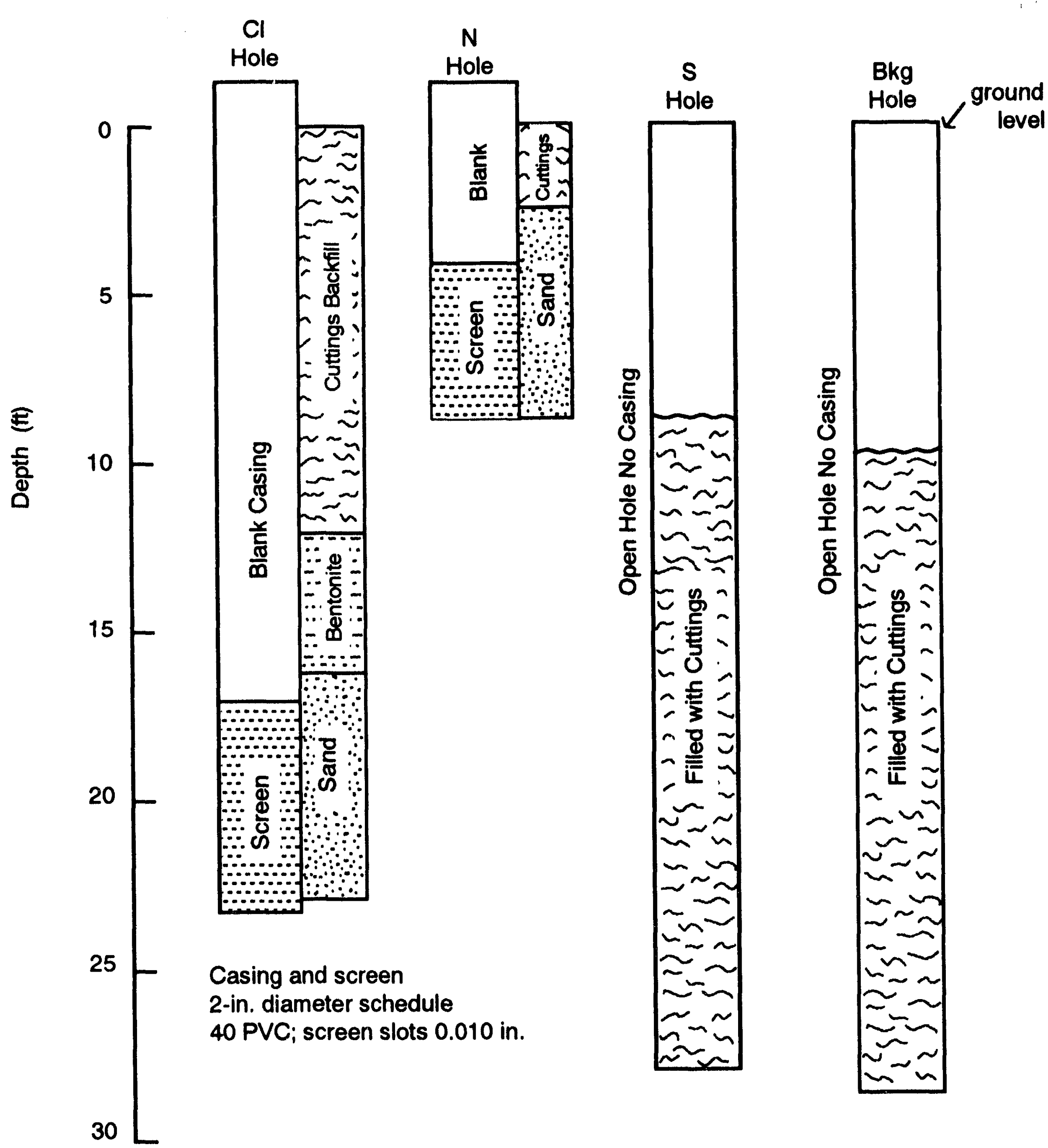

Figure 5. Casing schedule and open holes sampled at Chess Site.

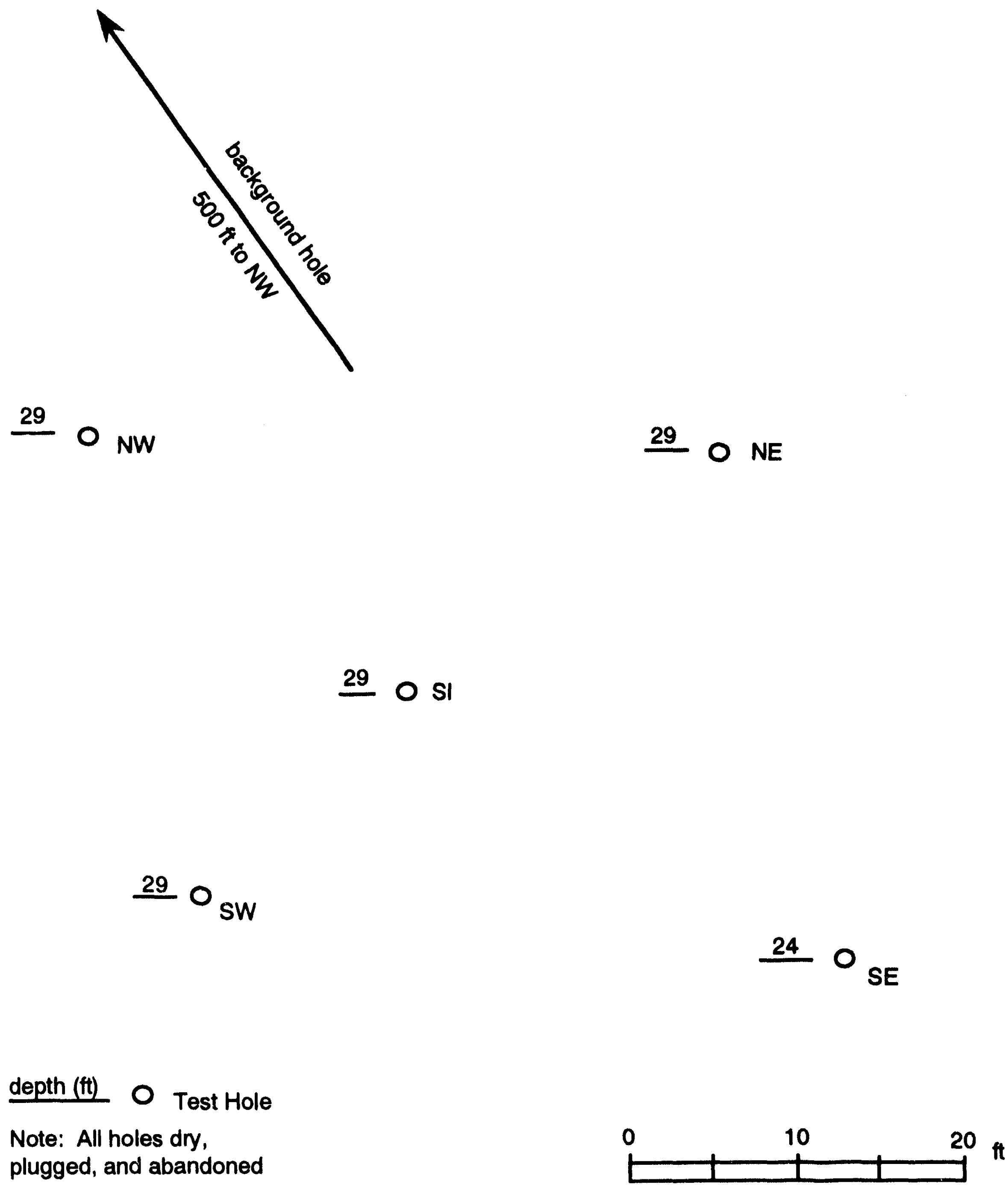

Figure 6. Location of test holes at Salt Site.

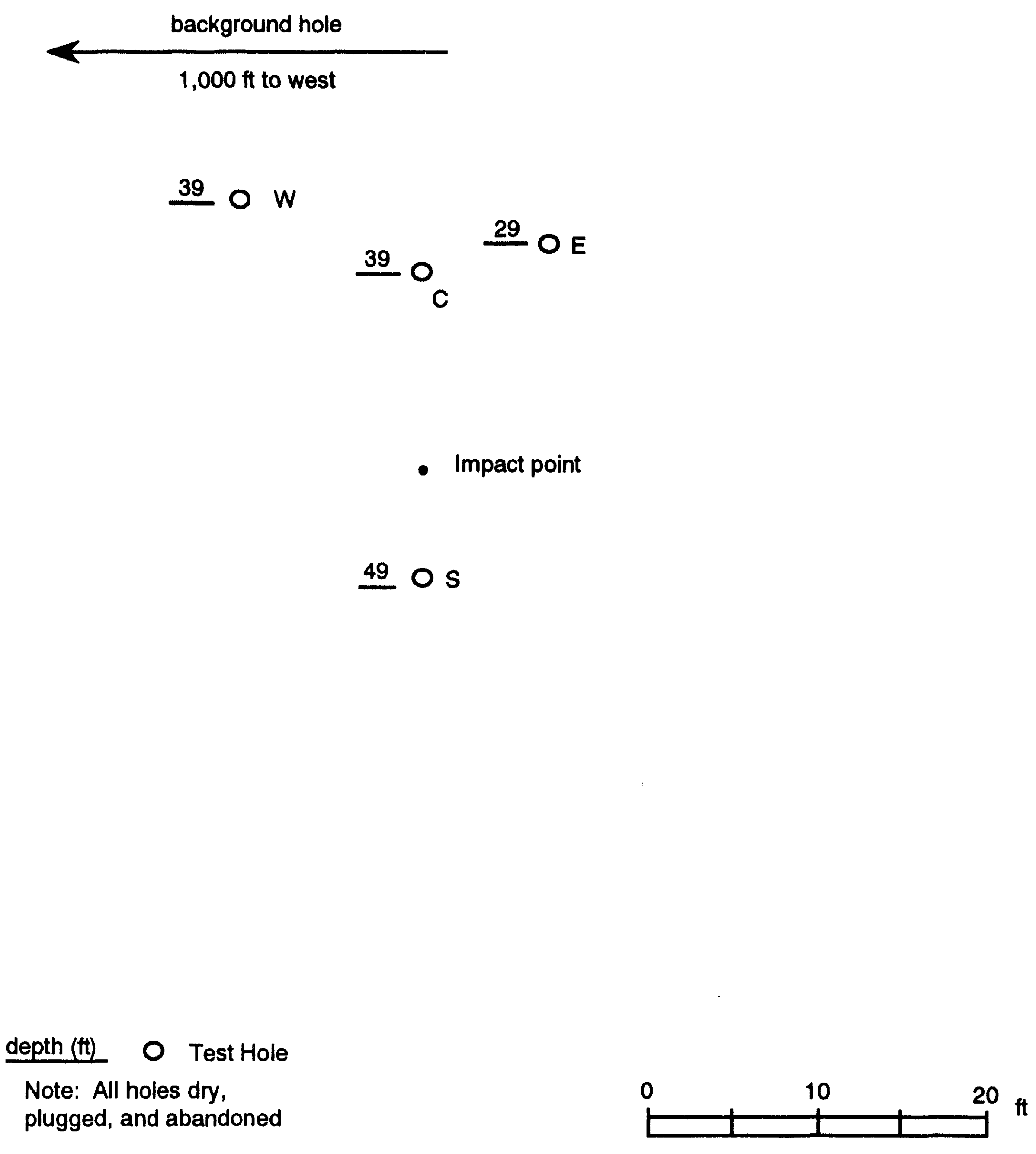

Figure 7. Location of test holes at Mine Site.

APPENDIX A

Geologic Logs of Core Holes

6-10-91

Setup on Chess II x 473 464
y 359 844
This x-y is a WSMR ~~grid~~ #

first hole is at stake point

Depth	Description
0-3	Recovery = 3'3" gypsum - [bottom 2' does not look disturb. Dark crystal stringer @ 1' (photo) below 2' Iron clumps @ 3' (½" dia); minor moisture Gypsum = lt grey to buff; distinct ½"-1" layers.
3-8	Recovery = 4'5"; some compaction due to coring gypsum, dark grey, moist to 3'6" top 1ft = lt. grey to buff color 1" yellowish grey layer @ 6' (is this sulphur?) } photos w/ tape measure
8-13	Apparent water contact at 8ft (photos - two) Recovery = 2'5" Core bit gypsum very dense - core barrel compacted gypsum, dark grey; top 1'5" is saturated bottom 1' is not saturated photos H_2S odor very distinct in upper saturated core
	microcrystalline gypsum thru-out (0-13) w/ many ⅛" and smaller distinct gypsum crystals (looks like fibrous glass chards) → Core barrel has yellowish (sulphur?) staining outside
13-18	Recovery = 5' gypsum - dark grey ⇒ looks like concrete Core looks wet in photo but water is from 8-13', making a wet rind around dryer gypsum inside No H_2S odor - water is perched at 8-13' Rind removed before sampling - core is relatively dense, ⅛" gypsum crystals apparent
18-23	Recovery = 5' barrel well expanded & drilled hard dk grey gypsum w/ many ⅛" frags of clear gypsum NO H_2S odor Core is saturated but is probably from the 8-13' zone since we stopped ≈ 45 min for lunch before getting this core run. Very hard gypsum in core bit (bagged sample)

Completed as monitor well.

Chess #1 completion 6-10-91 7

5 ft 0.010" factory slotted PVC at bottom

20 ft blank casing to surface (Schedule 40 PVC)

All threaded couplings w/ bottom end cap.

50 lbs. medium silica sand (10-20 mesh) "Colorado"

25 lbs "Environmental Plug" bentonite pellets

Cuttings backfill to surface

When 6 5/8" auger removed, a fine plug came out so hole was clean when sand added.

Screen below 8-13 ft perched layer; also bentonite plug should seal off perched layer.

6-10-91: Chess-West Hole ≅ 10 ft. West of Chess #1

Depth	Description
0-4	Recovery = 4 ft 0 in. Hard pan ≅ 6" below surface. Thickness ≅ 1 ft White to buff brown gypsum w/ microcrystalline matrix and v. many frags. of clear gypsum crystals ≤ 1/8" diameter very friable texture except for hard pan Some moisture.
4-9	Recovery = 2 ft 0" Hard gypsum in core bit White to buff brown micro cryst. gypsum w/ many frags of clear 1/8" dia gypsum The buff to yellowish brown gypsum has a distinct sulphur odor. Some moisture. The 2 ft of core is apparently from 4-6 ft below ground and 6-9 ft is saturated since core bit was plugged.
9-14	Recovery = 2 ft 9" Dark grey gypsum w/ sulphur odor on bottom 2 ft. More moisture than above but not 100% saturated. Core bit = hard gypsum but core barrel gyp. is friable. Suspect: 6-10 ft = saturated zone based on drilling sounds Auger is making "mud-balls" like it is in or near water but there is no water in hole.

Suspect: Disturbed area broke thru shallow hard pan and allowed (or created) perched zone.

Depth	Description
14-19	Auger is now yielding saturated cuttings Recovery = 1 ft 11 in. Banded white and dark grey gypsum Low moisture — standing water is leakage from above. Some H_2S odor but not as strong as above.

~~Completion as monitoring well~~ Abandoned

6-10-91

Chess - North ≈ 10ft North of Chess #1

Depth	Description
0-4	Recovery = 4 ft 1"
	Hard pan ≈ 6" below surface to ± 3'
	White to buff brown gypsum w/ microcrystalline matrix and frags of clear gypsum. Not friable
	No sulphur odor
4-9	Recovery = 2 ft 0"
	Bottom 1 ft = dark grey gypsum
	Top 1 ft = buff brown to lt. grey + white
	low moisture
	Water standing in borehole visible w/ sun on mirror.

Completed as monitor well.

5 ft 0.010 in factory slotted screen + end cap at bottom

5 ft casing at top - threaded joint

50 lbs. medium blasting sand - ≈ 1 ft above slots

½ bag bentonite pellets + cuttings at top.

6-11-91

GPS Reading 6:22

LAT 32° 52' 50.4 — 30' west of CHESS #1

Lon 106° 85' 11.3'

MSL 3960

6-N-91 Chess - East Hole = 10ft. E. of Chess #1

Depth	Description
0-4	Recovery = 4ft 1 in White to buff brown microcrystalline gypsum with occational clear crystals of 1/8" dia gypsum thru-out. very friable - low moisture 6" thick hard pan at 1ft. depth
4-9	Recovery = 1ft 8in White to buff brown microcry. gypsum NO sulphur odor - slightly moist texture friable. The recovered core is probably from above the water table as in Chess #1 and chest - North and chess - West
9-14	Recovery 2ft. 4in. Dark grey microcrystalline gypsum Fully saturated. Occational clear gypsum crystals throughout. Some H_2S odor noticable
14-18	14-15 ft. very hard drilling - wet cuttings (like concrete) at surface Recovery = 5 ft. fully saturated 11ft of standing water in hole Distinct H_2S odor dark grey micro crystalline gypsum lost drilling bit at 18'

Abondoned hole w/ fill (cuttings)

Chess north 0° from chess #1
Chess South 75°
chess west 260°
chess East 100°

6-11-91 Chess - South

Depth	Description
0 - 3	Recovery = 2 ft 9" White to buff brown microcrystalline gypsum with small clear frags (< 1/8" dia) gypsum throughout - low moisture & friable
3 - 8	Recovery = 4 ft 0 in. top 3 ft = as above lower 1 ft = dark grey gypsum 1 small (1/2 dia) yellow spot at 6 ft 9" below ground surface (i.e., 1 ft 3" from bot sampled separately NO Sulphur or H_2S odor yellow stain tested positive on meter as DU
8 - 13	Recovery = 1 ft 11 in. Piece of metal in core bit Dark grey gypsum - saturated in upper 10" metal may have plugged core barrel
13 - 18	Recovery = 2 ft 6 in. Dark grey gypsum - saturated top 1 ft 6 in. Bottom 1 ft. banded layers of alternating grey and white gypsum Strong H_2S odor in water and core sediments Bottom 1 ft. is moderately moist & apparently was not wetted by water from above
18 - 23	Recovery = 2 ft 5 in. Dark grey gypsum - saturated top 1 ft 5 in Bottom 1 ft. not saturated & layers as above NO H_2S odor in bottom 1 ft.
23 - 28	Recovery = 2 ft 6 in. Dark grey gypsum top 1 ft. saturated from above Bottom 1 ft. 6 in. lt. grey to buff banded layers of gypsum w/ some moisture. a two inch thick layer at 27.5 ft is yellowish and has H_2S odor. There is an adjacent 3 in dark grey layer at 27 ft. that may be

6-11-91 Chess - South con't

Depth Description

23-28 con't an old weathered horizon.
The gypsum seems to weather to dark grey if there is any water contact.

- ~~open hole~~ abandoned hole - bagged ~~on~~ top (not filled

---

Chess Bkg

≈ 135 yd North ≈ 355°

Lat — 32° 52' 56.0' N
Log — 106° 25' 12.1 W ~~39~~ 59'

Depth Description

Recovery = 4 ft 3 in
0-4 White to buff brown microcrystalline gypsum with many small clear gypsum crystals thru-out. Dry and friable
No distinct hard pan layer. No H_2S odor
From 0-1.5 ft the crystalline structure is more coarse than below (grain size ≈ 20 mesh)

4-9 Recovery = 2 ft 5 in
As above. Bottom 6" is banded white and black gypsum. No moisture or H_2S.
WL is probably 6-10 ft. as in other holes

9-14 Recovery = 3 ft 3 in
Dark grey gypsum - more moisture but not fully saturated. Top 6" is saturated & bit wet.
Bottom 1 ft is banded black + white gypsum
Core bit has hard (moderately) end plug.

14-19 Recovery = 2 ft 0"
Dark grey gypsum - saturated at top 6"
moist last 1.5 ft. H_2S odor (anerobic)

Dark grey color + H_2S ⇒ probably bacterial action in presence of moisture → H_2S

Observation from WSMR personnel ⇒ July - Aug normally have ponded water here (Chess site) from summer thundershowers.

Depth Description

Water level = 8 ft below land surface
measured by wet mark on core string

19-24 Recovery = 3ft 8in.
Dark grey gypsum - moist where not contaminated
by infiltration from above
Banded white-black gypsum at bottom 2ft.
1 in. band of yellowish white gypsum in bottom
6 in. Slight H_2S odor

24-29 Recovery = 2ft 0 in.
White to mostly buff brown microcrystalline
gypsum at bottom 1ft. grading into darker
grey gypsum in upper 1ft. Very hard gypsum
in core bit and moderately friable in core
barrel. Slight H_2S odor. Lots of water in upper
3ft of barrel.

Abandoned hole - no completion.
Filled hole with cuttings.

6-12-91 Salt Background

Depth	Description
0-4	Recovery = 3 ft 10 in. Lt. Brown soil, fine grain, dry 6 in. calache horizon at 6" from bottom
4-9	Recovery = 1 ft 9 in. Lt. Brown soil, fine grain, dry ≃ 65% clay 35% fine sand. 3" calache layer at bottom; bit plugged extended core barrel 2 in.
9-13	Recovery = 5 ft Core Barrel Set @ 60" Lt. to dark brown, clay rich soil (?) many fine grain crystals of mica, quartz, halite, calcite and gypsum (?) Is this a lacustrine deposit (?)
13-18	Recovery = 5 ft Dark reddish brown clay mica, qtz, and calcite (or halite) crystal frags (micro) Bottom 4" has a sand filled vertical fracture with 1/4" openning - photo
18-23	Recovery = 5 ft Dark brown clay - dry with halite + gypsum in small fractures Bottom 1 ft 9 in. = grey to buff brown clayey gypsum, dry Top 3 ft 3" = red clay w/ lenses of white to buff gypsum and ~~calcite~~ (?) halite.
23-28	Recovery = 5 ft. 4 ft 6 in. = Red clay ↓ 2 ft 6 in = Lt. Buff brown clay 1 ft 3 in = Red clay } all w/ 1/2" to 1" dia white spots and vertical vein filled fractures probably halite or gypsum. All dry, no H_2S odor. probably gypsum contact → { The Lt. buff ~~clay~~ looks like it has limonite staining and iron staining
28-33	⇐ Recovery = 5 ft. some moisture, very dense & sticky. Bit } red clay 6" ; 6"-1' Lt. brown clay ; 1-2' red ; 2-3'6" Lt brown clay ; 3'6"-5' red clay } all spotted w/ 1" to 2" circular & lenses of white halite / gypsum. Can not taste salt. Filled in hole

Salt Background

Lat 33 08' 08.5 +3940
Log 106 21 <17.4
1220 meters (map)

6-12-91 Salt SE

Depth	Description
0-4	Recovery = 3ft 0 in Brown clayey sand soil - looks disturbed friable, dry; several chunks of gypsum (?) ≤ 1/2" dia
4-9	Recovery = 5ft. Lt. Brown ~~clayey~~ soil with sand - lacustrian deposits Occational 1/2" dia rock frags of gypsum Microcrystalline grains of halite, qtz (?)
9-14	Recovery = 5ft Dense dark brown clay with microcrystalline halite stringers (< 1/4"); low to mod. moisture and sticky (sticks to core barrel) (14-12 ft) 12-9ft = sandy clay not as dense
14-19	Recovery = 5ft. Dense dark brown sticky clay many irregular small lenses of white crystalline gypsum thru out; very dense - making balls of cuttings
19-24	Recovery = 5ft. White to buff brown clay, dry, friable One dark, dense red clay layer @ 2.5ft. Distinct odor of manner of dead smell that is quite different than Salt Background.

filled in hole

6-13-91 Salt Lat 33° 07' 55.2" 4835' ELV
Long 106° 21' 46.3 ≈ 30 south

 6-12-91 Salt SW

Depth	Description
0-4	Recovery = 3 ft 0 in ~~Bottom~~-Up: 0-1 ft 5 in ⇒ dense red clay w/ white (0-1 in) balls of gypsum Bottom-Up: 1 ft 5 in to 3 ft ⇒ ~~sandy soil~~ cover Dry, friable clay
4-9	Recovery = 5 ft Dark red dense clay, occational fine stringers of grainy sand + gypsum ½" diagonal fracture running from 5 ft to 7 ft. filled with sand + gypsum
6-13-91	
9-14	Recovery = 5 ft Dark red dense clay, less moisture than yesterday - may have dried out over night ½" wide vertical fracture between 12-13 ft that is partially mineralized with gypsum or calcite.
14-19	Recovery = 5 ft. Dark red dense clay, moderate moisture marbled w/ white microcrystalline gypsum Approx. 15% vol. content of ≤⅛" dia clear gypsum crystals thru-out. Some corring induced fractures at lower 1 ft.
19-24	Recovery = 5 ft Distinct Color Change @ 19' White to buff brown fine grain gypsum with clay (?) NOTE this contact and compare to other holes at Salt Site. This contact was very distinct.
24-29	Recovery = 5 ft White to buff brown f.g. gypsum to 25.5 ft Gradational contact to buff brown clay w/ gypsum. Somewhat more moisture than above; bottom 1 ft was squeezing out some free water No H_2S odor.

Filled in hole.

18

6-13-91 Salt #1

Depth	Description
0-4	Recovery = 3ft 8in Lt. Brown clay-sand soil to 0-1ft Lt. Brown clay w/ ≈ 25% gypsum crystals Low moisture; occational ½" dia white gypsum frags
4-9	Recovery = 5ft. Lt. Brown (exterior) to dark brown (interior) Sandy clay w/ ≈ 25% gypsum crystals (micro) Low moisture. Very uniform core section.
9-14	Recovery = 5ft. Lt. Brown (exterior) to dark brown (interior) Sandy clay w/ ≈ 25% gypsum microcrystals Low moisture. Occational fractures filled w/ gypsum and ½" nuggets thru-out
14-19	Recovery = 5ft Dark red dense clay w/ marbeled white gypsum spots; clear ≤¼" dia gypsum crystals associated w/ fractures (small) and marbeled spots.
19-24	Recovery = 5ft 22.5-24 = white to buff gypsum ← mild earthy shit odor 22 - 22.5 = dark dense clay 22 - [redacted] = white to buff gypsum 19 -20 = dark dense clay
24 - 29	Recovery = 5ft. 2[redacted].5-24 = white to buff gypsum 24.5[redacted]29 = Buff clay w/ gypsum; occational nodules of white gypsum The nodules of gypsum seem to have an earthy shit odor

filled in hole

6-13-91 Salt NW

Depth	Description
0-4	Recovery = 3 ft 0 in 0-1.5ft = lt. brown clay - sand soil 1.5-4 = Lt. buff gypsum - clay bottom 2in = dark red clay w/ 1" fracture filled with lt. buff gypsum
4-9	Recovery = 5ft. Lt. Brown (exterior) to dark brown (interior) sandy clay w/ ≃ 25% gypsum microcrystals Low moisture. Very uniform The lt. buff gypsum fracture from above extends ≃ 2.5ft into top of this core; fracture has roots.
9-14	Recovery = 5ft Lt. Brown (exterior) to dark brown (interior Sandy clay w/ ≃ 25% gypsum microcrystals Low moisture. Very uniform
14-19	Recovery = 5ft 14 - 14.8ft = brown sandy clay as above 14.8-19 = dark red dense sticky clay w/ marbeled white microcrystalline gypsum spots and clear ≤ 1/4" dia gypsum frags (bladed crystals)
19-24	Recovery = 5ft top 2in = dense red clay of above 19.2 - 21.2 = white to buff gypsum 21.2 = 21.9 = dense red dark clay 21.9 - 24 = white to buff gypsum
24-29	Recovery = 5ft. 24.5 - 24 = white to buff gypsum 24.5 - 29 = buff clay w/ gypsum; occational nodules of white gypsum earthy shit odor filled w/ cuttings

20 6-13-91 Salt NE

Depth	Description
0-4	Recovery = 3.5ft 0-1.5 lt. brown sandy soil 1.5-4 lt. buff gypsum + clay
4-9	Recovery = 5ft lt. brown exterior to dark brown interior sandy clay w/ ≈ 25% gypsum microcrystals Low moisture - very uniform
9-14	Recovery = 5ft Lt. brown exterior to dark brown interior sandy clay w/ ≈ 25% gypsum microcrystals moderately low moisture - very uniform
14-19	Recovery = 5ft. 14-15 = as above lt to dark brown sandy clay 15-19 = dark red dense sticky clay w/ marbeled white gypsum spots; many ≤ 1/4" dia clear gypsum bladed crystals thru-out.
19-24	Recovery = 5ft 19-20.5 = dark red sticky clay as above 20.5-24 = white to buff gypsum with earthy smell odor
24-29	Recovery = 5ft. 24-26 = white to buff gypsum as above w/ earthy smell odor 26-29 = buff clay w/ gypsum ~~w/ g~~ ozing H_2O at core bit due to wedged core barrel - not fully saturated

filled hole w/ cuttings

6-18-91 Mine Site #1

Depth	Description [Abo Fm (?)] Check
0-4	Recovery = 2ft 9in. Dark brown to red sandy ~~clay~~ clayey w/ occational ½" frags of white crystalline gypsum(?). many microcrystalline frags of quartz thru-out. Friable, dry
4-9	Recovery = 4ft 10in. Dark brown to red clayey sandy ~~clay~~ w/ many microcrystalline quartz thru-out. Occational (< ½" dia) frags of calcedony (quartz pebbles) (dark brown) ~~&~~; friable, dry
9-14	Recovery = 4ft 10 in. 9 - 10 ft. 7 in = as above (red sandy clay) ~~… to 14 ft - buff brown~~ 10-11 ft ⇒ cobbles of limestone (dk brown + white) 11-14 ⇒ buff brown to white sandstone with calcite deposits thru-out (micro-crystalline white powery deposits)
14-19	Recovery = 3ft 5in. buff brown to white ~~sandy~~ sandstone with stringers of dark brown limestone 6" gravel LS @ 2ft. - many frags well rounded buff marl last 6 in.; dry. LS is very hard.
19-24	Recovery = 3ft 10 in. buff brown to white sandstone in a LS gravel matrix of dk brown frags - well rounded to angular. Last 6" is angular LS gravel, SS frags, and shale. LS is very dense and hard. dry. Core bit is damaged
24-29	Recovery = 3ft 10in. 0-2'4" } white to grey LS; large cobbles of black LS very dense, angular. 2'4" - 3'10" } buff brown gravel + sand ~~coarse~~ coarse grain with many LS gravel frags (angular). The coarse grain sand is well rounded

6-18-91 Mine Site #1 con't

Depth	Description
29-34	Recovery = 4ft 0in. LS conglomerate - frags of SS, LS, shale & pebbles in a fine grain sandy matrix. One yellow 1/2" dia rock (sulphur ?). Close-up photo. Bottom 3" ⇒ friable SS v.f.grain
34-39	Recovery = 5ft.
	0-9in = friable SS (v.f.grain) buff red
	9in-3ft = dense red clay (dry)
	3ft-5ft = friable SS (v.f.grain) buff red
	Occational white spots of calcite, v. minor amount of fibrous gypsum in SS
39-44	Recovery = 5ft
	0-3ft.4" = dense red clay w/ white gypsum spots.
	3ft-4in to 5ft = friable SS (v.f.grain)
	The red clay looks identical to that @ Salt Target
44-49	Recovery = 5ft. Dense red clay w/ occational microcrystalline gypsum spots (white). Looks like Salt Target red clay

filled hole w/ cuttings

6-18-91 Mine Site East

Depth	Description Approx. 20' NE of Mine #1
0-4	Recovery = 3ft 8in Dark brown to red clayey sand, v.f. grain w/ occational 1/4" frags of white microcrystalline gypsum. friable, dry.
4-9	Recovery = 5ft. Dark brown to red clayey sand, v.f. grain; from 7-8ft. the clayey sand has white microcrystalline gypsum banding; friable, dry.
9-14	Recovery = 5ft. 9-10'4" = red clayey sand v.f. grain as above 10'-4" to 14' = LS gravel w/ some sand large 1" frags of LS, angular
14-19	Recovery = 3ft 8in LS conglomerate w/ buff sand (v.f.g.) looks like Ready Mix concrete w/o water friable, dry
19-24	Recovery = 3ft 10in. 19-23 LS conglomerate as above 23-24 ⇒ red sandstone v.f.g. gradational contact w/ LS above; all very friable & dry 2" dia gypsum nodule at 22ft. - white microcrystalline gypsum on buff sandstone
24-29	Recovery = 4ft 5in. 24 - 27.5ft = buff SS (v.f.g.) w/ LS frags, (LS) angular to well rounded pea gravel 27.5-29 ft = clayey sandstone, v.f.g. w/ numerous 1/2" gypsum nodules

filled hole w/ cuttings

6-19-91 Mine Center

Depth	Description
0-4	Recovery = 3ft 6 in Dark brown to red clayey sand, v.f. grain w/ occational ≤1/4" frags of white microcrystalline gypsum; friable, dry
4-9	Recovery = 5ft Red clayed sand, v.f. grain; occational microcryptalline (<1/4" dia) gypsum spots; microcryptalline quartz thru-out friable, dry
9-14	Recovery = 4ft 4in 10'8"-14' = buff, white, red ss (vfg) w/ angular frags LS LS ≤1/2" dia, dk. brown to black 10'-8 - 11'8" = as above = red clayey sand v.f.g. microcrystalline gypsum or calcite thru out (?)
14-19	Recovery = 4ft 8in 17-19 ⇒ limey SS, red (vfg) w/ clay (buff) ball frags (≤1/4" dia); many angular to well rounded LS frags thru out 14-17 ⇒ red clayey sand, vfg w/ fewer LS frags and less clay than 17-19. See photo of core bit - a real garbage can conglomerate.
19-24	Recovery = 3ft 8in LS conglomerate w/ ± 25% red SS (vfg) LS + clay balls thru-out; LS gravel, pea size, angular to well rounded. Occational shale frags. All friable and dry. Contact between SS and LS is gradational between 17-19 SS content decreasing from 17 thru 24 while LS content increasing
24-29	Recovery = 3ft 10in 26-27 ⇒ sandy LS buff, dry, LS gravels 29-27 ⇒ limey, SS, v.f.g. reddish brown w/ clay, friable dry 24-26 ⇒ limey SS. vfg reddish brown w/ clay, friable dry

6-19-81 Mine Central Continued

Depth	Description
24-29	The 27-29' SS is more clayey than above more sticky to core bit.
29-34	Recovery = 3ft 8in LS Conglomerate - frags & pebbles of LS, SS, shale in a v.f.g. sandy matrix. One 1" dia yellow rock flag; calcite and quartz mineralization
34-39	Recovery = 5ft Sandy red clay w/ gypsum spots thru out. Looks like the top of our "Salt Target" clay.

filled hole w/ cuttings

6-19-91 Mine Site West

Depth	Description
0-4	Recovery = 3ft 5in Red clayed sand vf grain w/occational 1/4" frags of white micro crystalline gypsum friable, dry
4-9	Recovery = 5ft. Dark red SS, v. f. grain, friable occational microcrystalline gypsum, calcite, quartz in SS thru-out.
9-14	Recovery = 4ft 4in. 13-14 = dark red SS, v. f. g. somewhat friable & occational microcrystalline gypsum 13-8.5' ⇒ red to buff SS conglomerate v. f. grain matrix w/ large 1-2" frags hard dark brown SS, v. angular; smaller pea gravels of LS top 6" ⇒ dark red SS, v. f. grain friable as from 4-9
14-19	Recovery = 1 ft 6 in. Buff to red SS gravel v. f. grain w/ LS pea gravel frags; a large 2" dia frag of v. f. grain hard SS was in the core bit (may have been a coarse grain mudstone instead of SS) friable, dry
19-24	No recovery - dense LS (dark red to dk brown) boulder plugged bit - looks almost like chirty LS!
19-24	2nd try Recovery = 2ft 9in. Limey buff to red SS w/ many frags of SS, LS, clay balls, v. f. g. matrix friable, dry
24-29	Recovery = 3ft 6 in limey SS, v f. g reddish brown to buff bottom 1ft is more clayey, w/ LS, SS frags and buff clay balls friable, dry

 6-19-91 Mine West con't

Depth	Description
29-34	Recovery = 3ft 8in.
	32-34 => LS conglomerate, angular frags in a v.f.g. sandy LS matrix, white gypsum (microcrystalline); clay balls
	32-29 => v.f.g. SS, buff to red; small LS pea gravel in matrix.
34-39	Recovery = 5ft. top 4" = vfg SS matrix w/ LS gravels
	33⅔-39' = dark red clay, dense & sticky occasional gypsum spots. This looks like ~~salt target~~ clay!

filled hole w/ cuttings

6-20-91 Mine Background

Depth	Description
	Recovery = 3ft 6in
0-4	Red clayey sand v.f.g., friable, dry. 2-4 => Occational microcrystalline white gypsum 0-2 => many ½" dia angular LS frags (dk brown, microcrystalline, hard.
4-9	Recovery = 5ft. Red clayey sand (SS) v.f.g. friable, dry. Occational ¼" dia angular frags of dense mudstone or LS, lt. buff clay balls with gypsum outside; minor qtz, gypsum, calcite thru-out (v.f.g)
9-14	Recovery = 4ft 8in 9-13.5' = red clayey SS (vfg), friable, dry, w/ numerious ¼" frags LS + gypsum 13.5-14 => buff to lt. brown gravelly LS in a sandy matrix. Gravel = pea sized LS + gypsum power
14-19	Recovery = 3ft 6in. Buff to lt. brown LS conglomerate in a v.f.g. red sandy matrix. LS gravel from pea size to 2" dia. v. dense dk brown). Occational ½" clay balls; gypsum power thru out.
19-24	Recovery = 2ft. 4in. As above - drillings sounds like coarse gravel. Large LS cobbles up to 2" dia in core
24-29	Recovery = 3 ft 10 in LS conglomerate w/ angular (¼" to 3" dia) frags of LS + SS in a v.f.g. matrix of sand. Mudstone frags up to 3" dia w/ secondary mineralization of gypsum (microcrystalline, white) and some clay balls. Occational yellow to lt. brown nodules of gypsum or sulphur (?) = prob. gypsum
29-34	Recovery = 4 ft 0 in Buff red SS vfg, friable dry, w/ many ¼"-2" frags of LS; gypsum nodules and clay balls thru-out; secondary mineralization of gypsum in spots - generally around pebbles and angular frags Clean SS layer from 30-31

 6-20-91 Mine Background con't

Depth	Description
34-39	Recovery = 3ft 9in. Bottom 6" = sandy red clay [not real sticky here but firm Top = breccia w/ 1/4" to 2" dia angular frags of LS, SS, mudstone in a sandy gypsum matrix, Clay balls, yellow and white gypsum nodules (photo)
39-44	Recovery = 5ft. Dense red clay w/ occational gypsum nodules (< 1/2"); sandier at top and graditionally more dense at bottom
44-49	Recovery = 5ft. Dense red clay as above

filled in hole w/ cuttings

END

DATE
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3/9/94