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FINAL
HYDROGEOLOGIC INVESTIGATION REPORT AND GROUNDWATER MONITORING PLAN FOR THE SEWAGE TREATMENT LAGOONS HOLLOMAN AIR FORCE BASE, NEW MEXICO 88330

VOLUME 1

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EXECUTIVE SUMMARY

Radian Corporation, under contract No. DACA45-86-D-0052, with Omaha District, U.S. Army Corps of Engineers (USCOE), on behalf of U.S. Air Force Tactical Air Command's Environmental Office, performed a hydrogeologic investigation of the base sewage treatment lagoons and receiving waters at Holloman Air Force Base, New Mexico. The work was conducted in accordance with the Scope of Services and under Delivery Order No. 2.

The purpose of the hydrogeologic investigation was to gather hydrogeologic data in support of Holloman AFB and in accordance with EPA's compliance agreement with the base. The compliance agreement required that this investigation be conducted prior to initiation of groundwater monitoring per Title 40 Part 265 Subpart F (265.90-265.92) of the Code of Federal Regulations.

The hydrogeologic investigation was conducted from 29 July through 18 November 1987, and consisted of the following tasks:

- Task 1 - Subsurface interpretation of site geology: Geological data was obtained through soil boring, formation sampling, and analysis. Samples were collected at 5-foot intervals from 25 boreholes averaging 39 feet in depth.

- Task 2 - Determination of contaminant pathways: Hydraulic flow gradients and field water quality parameters were determined from 22 piezometers and 2 pump test wells. Wells averaged 27 feet in depth and were screened in the uppermost water bearing unit.

- Task 3 - Aquifer characterization and analysis: Slug tests were performed on nine piezometers; pump tests were performed using pumping wells and observation wells at two locations.

- Task 4 - Hydrogeologic conclusions and recommendations: Recommendations for groundwater monitoring were derived from Title 40 CFR Part 265 Subpart F of the regulations and TEGD. Detection monitoring schedules were in accordance with EPA's compliance agreement with the base.

Results

Geology

The subsurface geology below the sewage treatment lagoons consists of a thin layer (3-11 feet thick) of dry eolian sand and silt. Over most of the area, this shallow sand layer is underlain by a gypsiferous clay unit approximately 2 to 7 feet thick. Where clay is not present, the shallow sand is underlain by silt.

In cross-sectional view, the sediments vary in thickness and lateral extent. The highly stratified sediments are typical of alluvial deposition in Basin and Range provinces such as the Tularosa Basin. The hydrogeologic setting does not offer a definable lower aquifer boundary. The aquifer consists of several hundred feet of intertounging clay, evaporites composed almost entirely of gypsum evaporites, fluvial deposits, and dune sands, all of which are saturated with saline water.

Hydrology

Slug and pump test results indicate that the upper saturated zone transmits groundwater at a slow rate but more easily than deeper saturated zones. Aquifer characteristics of the saturated alluvium using the two test methods are presented in Table 1.

The average hydraulic conductivity in the uppermost saturated zone (zone most likely to transmit contaminants from the sewage lagoons) is

TABLE 1. HORIZONTAL GROUNDWATER VELOCITY RESULTS FROM NINE SLUG TESTS, HOLLOMAN AFB, NEW MEXICO

Well Number	Test Method	Hydraulic Conductivity (gpd/ft^2)	Hydraulic Conductivity (cm/sec)	Porosity[a] (%)	Velocity[b] (ft/day)	Velocity[b] (ft/year)
Upper Saturated Zone						
S-2	Recovery	7.1	1.2×10^{-4}	40	0.007	2.6
S-4	Slug	85.6	4.0×10^{-3}	30	0.13	47.5
S-5	Slug	61.8	2.9×10^{-3}	40	0.07	25.6
S-8	Slug	56.2	2.6×10^{-3}	40	0.06	20.5
S-11	Slug	80.2	3.8×10^{-3}	30	0.12	43.8
S-15	Slug	69.9	3.3×10^{-3}	30	0.11	40.2
S-16	Slug	45.8	2.2×10^{-3}	40	0.05	18.3
Average		58.0	2.7×10^{-3}		0.08	28.0
Deeper Saturated Zone						
D-2	Slug	2.8	1.3×10^{-4}	40	0.003	1.1
D-5	Slug	3.1	1.5×10^{-4}	30	0.004	1.5
D-3	Pump test	37.7	1.8×10^{-3}	40	0.03	11.0
D-4	Pump test	33.0	1.6×10^{-3}	30	0.04	16.0
P-1	Pump test	12.6	1.2×10^{-4}	40	0.01	4.6
P-2	Pump test	10.6	5.0×10^{-4}	30	0.014	5.0
Average		16.6	7.8×10^{-4}		0.016	6.0

[a] Based on the following values for porosity:

Sand = 30%, Silt = 40%, Clay = 50%

[b] Velocity (v) = $\frac{K(dh/dl)}{7.5a}$

dh/dl = Hydraulic gradient determined from piezometer elevation survey (.003).

58 gpd/ft^2 (2.7 X 10^{-3} cm/sec). The corresponding average horizontal velocity of groundwater through the uppermost zone is 28 feet per year. The deeper screened sand and silt units exhibit an average hydraulic conductivity of 16.6 gpd/ft^2 (7.8 X 10^{-4} cm/sec) and a corresponding horizontal velocity of 6.0 feet per year.

The results of the slug and pump tests are summarized below.

- The first affected aquifer is composed of saturated sands, silts, and clays hydraulically interconnected.

- There are discontinuous clays separating coarser-grained, shallow water-bearing sand and silt units from deeper units of equal or greater grain size.

- The term "aquifer" may be used to describe hundreds of feet of bolson fill sediments below Holloman AFB. The basal contact of the bolson is estimated to be the top of Permian bedrock (depth unknown).

- The bolson fill aquifer exists under water table conditions in the first saturated shallow zone. However, with increased depth, successive clay and silt units create semi-confining conditions beneath the sewage treatment lagoons. Artesian conditions do not exist at the depths investigated.

- Aquifer yield is based solely upon the porosity and permeability of the units screened. There are no secondary porosity factors to consider.

- A comparison of transmissivity hydraulic conductivity and storage coefficient calculations in the slug tests and two pump tests yielded values that would be expected in highly stratified inhomogeneous basin fill sediments. A comparison of

the two test methods indicates that the first saturated sand is more permeable than deeper saturated units. The upper sand is well drained sandy loam of the Holloman-Gypsum land-Yesum complex. With depth, the sediments generally become progressively finer grained.

There are no groundwater users in the vicinity of the sewage treatment lagoons. The nearest well is 3.5 miles west of the lagoons and used for livestock purposes. Groundwater would take approximately 389 years to reach this well if traveling at the maximum horizontal velocity determined during this investigation (47.5 ft./yr.).

Groundwater throughout the Holloman AFB area is naturally high in total dissolved solids (TDS). Field samples revealed TDS levels that exceeded 10,000 mg/L dissolved solids making the water saline (10,000 - 100,000 mg/L). Based on these results, the water is unfit for domestic or agricultural supply. Part 3-103 "Standards for Ground Water of 10,000 mg/L or less" adopted by the New Mexico Water Quality Control Commission (1984) do not apply to saline groundwater.

Recommendations

A total of 6 additional groundwater monitoring wells are proposed to be installed at the upgradient and downgradient boundaries of the seven sewage treatment lagoons. The addition of these wells combined with 2 existing piezometers will serve as the groundwater monitoring network. The locations of the groundwater monitoring wells and piezometers are shown in Plate 11.

Once the groundwater monitoring wells are installed, they will be sampled by the base for the parameters listed in Table 2 and at the frequency shown in Table 3. This groundwater monitoring schedule conforms to monitoring requirements outlined in EPA's compliance agreement with the base. The quality control procedures to be implemented during groundwater monitoring are discussed in Section 6.0 and Appendices H and I of this report.

TABLE 2. INDICATOR AND APPENDIX III PARAMETERS INCLUDING SAMPLING AND PRESERVATION PROCEDURES FOR GROUNDWATER MONITORING[a]

Parameter	Recommended Container[b]	Preservative	Maximum Holding Time	Minimum Volume Required for Analysis
		Indicator Parameters of Groundwater Contamination[c]		
pH	T, P, G	Field Determined	None	25 mL
Specific Conductance	T, P, G	Field Determined	None	100 mL
TOC	G, amber, T-lined cap[d]	Cool 4°C,[e] HCl to pH <2	28 days	4 x 15 mL
Chloroform	G, T-lined septa or caps	Cool 4°C	14 days	40 mL
		Groundwater Quality Characteristics		
Chloride	T, P, G	4°C	28 days	50 mL
Iron Manganese Sodium	T, P	Field Acidified to pH <2 with HNO_3	6 months	200 mL
Phenols	G	4°C/H_2SO_4 to pH 2	28 days	500 mL
Sulfate	T, P, G	Cool 4°C	28 days	50 mL
		EPA Interim Drinking Water Characteristics		
Arsenic Barium Cadmium	T, P	Total Metals Field Acidified to pH <2 with HNO_3	6 months	1,000 mL
Chromium			6 months	1,000 mL

(Continued)

TABLE 2. (Cont.)

Parameter	Recommended Container[b]	Preservative	Maximum Holding Time	Minimum Volume Required for Analysis
Lead Mercury Selenium Silver	Dark Bottle	Dissolved Metals Field Filtration (0.45 micron) Acidify to pH <2 with HNO_3		
Fluoride	T, P	Cool, 4°C	28 days	300 mL
Nitrate/Nitrite	T, P, G	4°C/H_2SO_4 to pH <2	14 days	1,000 mL
Endrin Lindane Methoxychlor Toxaphene 2, 4 D 2, 4, 5 TP Silvex	T, G	Cool, 4°C	7 days	2,000 mL
Coliform Bacteria	PP, G (sterilized)	Cool, 4°C	6 hours	200 mL

[a]References: Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, SW-846 (2nd Edition, 1982); Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020; and Standard Methods for the Examination of Water and Wastewater, 16th edition (1985).

[b]Container Types:
- P = Plastic (polyethylene)
- G = Glass
- T = Fluorocarbon resins (PTFE, Teflon, FEP, PFA, etc.)
- PP = Polypropylene

[c]Sufficient volume must be collected to allow for analysis of four separate replicates per sampling episode

[d]T-lined = Teflon-lined

[e]Do not allow any head space in the container.

TABLE 3. ANALYTICAL PLAN AND SCHEDULE FOR GROUNDWATER MONITORING, HOLLOMAN AFB, NM

Date	Analyses	Wells	Submittal Requirements
Month 1-4	4 monthly sampling episodes for Appendix III parameters plus 4 replicate analyses/ month of indicator parameters (pH, chloroform, TOC, specific conductance)	2 background wells; S-2, MW-1	Submission of laboratory results within 15 days of each sampling episode.
Month 2-5			Holloman AFB submits to EPA and NMEID groundwater asssessment monitoring outline pursuant to 40 CFR 265.92(b)(2).
Month 5	One sampling episode of Appendix III parameters plus indicator parameters (pH, chloroform, TOC, specific conductance)	8 groundwater monitoring wells including 2 background wells	Detection monitoring begins per 265.92(b)(2)
Month 6			Holloman AFB submits to EPA and NMEID report summarizing groundwater monitoring including statistical interpretation of the results as discussed in the proposed detection monitoring plan.
Semi-Annual sampling after month 6	Continued groundwater monitoring; one sampling episode for indicator parameters (pH, chloroform, TOC, specific conductance)	8 groundwater monitoring wells including 2 background wells	Report to EPA and NMEID summarizing analytical results; provided no statistically significant changes in contaminants are detected from previous sampling episodes; otherwise, begin assessment monitoring.
Annual sampling after month 6	Groundwater quality parameters (chloride, iron, manganese, phenols, sodium sulfate)	8 groundwater monitoring wells including 2 background wells	Annual report to EPA and NMEID provided sampling results do not trigger assessment monitoring.

1.0 INTRODUCTION

Radian Corporation, under the direction of the U.S. Army Corps of Engineers, performed a hydrogeologic investigation of the sewage treatment lagoons and receiving waters at Holloman AFB, New Mexico. The investigation was conducted under U.S. Army Contract No. DACA45-86-D-0052 Delivery Order No. 1, and intended to respond to alleged violation number 9 of EPA's Notice VI-502-H-"failing to install groundwater monitoring system." The hydrogeologic investigation was performed in accordance with Radian's approved Hydrogeologic Investigation Plan (HIP) submitted to EPA in April, 1987, and approved 15 July 1987. The investigation was structured in accordance with guidelines for hydrogeologic site characterization studies for owners or operators of interim status facilities (EPA Technical Enforcement Guidance Document, 1986).

The second purpose of this investigation was to fulfill items listed in Holloman's compliance agreement with EPA and the New Mexico Environmental Improvement Division (NMEID). The conclusions presented in this investigation are considered reasonable and technically adequate to warrant proceeding with groundwater monitoring as required by Title 40, Part 265, Subpart F (265.90-265.92) pending EPA and NMEID approval.

1.1 Purpose and Scope of Program

The primary objectives of this hydrogeologic investigation were to: 1) gain a more thorough understanding of the hydrogeologic characteristics of the first affected aquifer, 2) develop a revised groundwater monitoring plan for the emplacement of groundwater monitor wells to follow, and 3) respond to the EPA Region VI ruling requiring the acquisition of additional hydrogeologic documentation of the site prior to initiation of the groundwater monitoring. The methods chosen for the expansion of existing hydrogeologic data were based upon site-specific conditions and the objectives of the investigation as

stated above. The results of the Hydrogeologic Investigation are presented to Omaha COE for review and submittal to the Tactical Air Command (TAC) and EPA Region VI. Results of the Hydrogeologic Investigation are presented to the above agencies in order to proceed with the next phase of activities: design and installation of a groundwater monitoring network per 40 CFR 265 Subpart F requirements.

The following activities were conducted as part of the Hydrogeologic Investigation. The methods represent standard procedures recognized by EPA, ASTM, and state regulatory agencies for the conduct of hydrogeologic investigations. The activities included the following tasks:

- Task 1--Soil boring and formation sampling;
- Task 2--Piezometer installation;
- Task 3--Aquifer testing; and
- Task 4--Reporting, and recommendations for groundwater monitoring well network.

1.2 Duration of This and Previous Programs

Radian Corporation received formal authorization to proceed on the Holloman AFB Hydrogeologic Investigation on 15 July 1987. Field activities were conducted from 29 July to 18 November 1987. Previous investigations conducted at Holloman AFB that are relevant to this investigation are discussed in the following paragraphs.

In 1983, CH2M Hill conducted an Installation Restoration Program Records Search for Holloman AFB, New Mexico. The purpose of this report was to identify and evaluate suspected problems associated with past hazardous

material disposal and spill sites at Holloman AFB. As part of this records search, the grit burial site of the wastewater treatment plant was examined to determine potential for environmental impact. The sewage lagoon system was not examined. The results of the records search indicated that the potential for groundwater contamination was high, due to a shallow water table. However, the report further stated that the potential for adverse impacts was reduced since the groundwater was unusable as a potable water source due to high total dissolved solids (>10,000 mg/L).

The United States Geological Survey (USGS) conducted a geohydrologic study of the shallow bolson near the sewage treatment lagoons in 1985. The title of the study was "Hydrologic Data on the Shallow Bolson Fill Near the Sewage Lagoons and Lake Holloman," dated November 1985. The purpose of the study was to obtain stratigraphic data on the bolson deposits, collect water level data, and conduct a short-term pump test. A total of 12 monitor wells were drilled in the sewage treatment lagoon area. The findings of the USGS study, particularly the lithologic logs, were used to design the hydrogeologic investigation by Radian. In the USGS report, two rather distinct, water-bearing sand units were noted beneath the site at about 4.5-14 ft. and 31-39 ft. below land surface (bls). Radian incorporated this information into the development of the Hydrogeologic Investigation Plan (HIP) that focused on these stratigraphic units as the "first affected aquifer" (EPA, TEGD 1986).

Subsequent to the USGS report, Wilson and Company (1986), in a separate study, incorporated the existing USGS data into a report entitled "Evaluation of USGS Groundwater Data for Sewage Treatment Lagoon, Holloman Air Force Base New Mexico," dated April 1986. The purpose of the Wilson study was to use the hydrogeologic data presented by the USGS to present supporting documentation for Holloman AFB's petition for delisting of the sewage lagoons.

1.3 Installation Description and History

The following sections discuss Holloman AFB and its history. Most of the information is derived primarily from "Installation Restoration Program Records Search for Holloman AFB, New Mexico" prepared by CH2M Hill (CH2M Hill, 1983).

1.3.1 Location

Holloman AFB is located in Otero County in south-central New Mexico, approximately 75 miles north-northeast of El Paso, Texas (Figure 1-1). The nearest city is Alamogordo (population 31,000), which lies approximately seven miles east of the base.

1.3.2 History

Holloman AFB began as a temporary facility in 1942. The base was originally known as the Alamogordo Bombing and Gunnery Range. The base was briefly inactivated at the end of World War II and then transferred to the Air Material Command in 1947 in support of the Air Material Command Research and Development Program. In 1951, the base was placed under the guidance of the Air Force Missile Test Center at Patrick AFB, Florida; then, in 1952, the base became Holloman Air Development Center as it was named one of the development centers of the Air Research and Development Command. In 1961, the base was placed under the guidance of the Air Force Systems Command (AFSC) and designated as the Air Force Missile Development Center. The base was transferred to Tactical Air Command (TAC) in 1971, with the 49th Tactical Fighter Wing assuming host responsibilities.

TAC organizations currently at Holloman AFB include: the 49th Tactical Fighter Wing, the 479th Tactical Training Wing, and the 4449th Mobility Support Squadron.

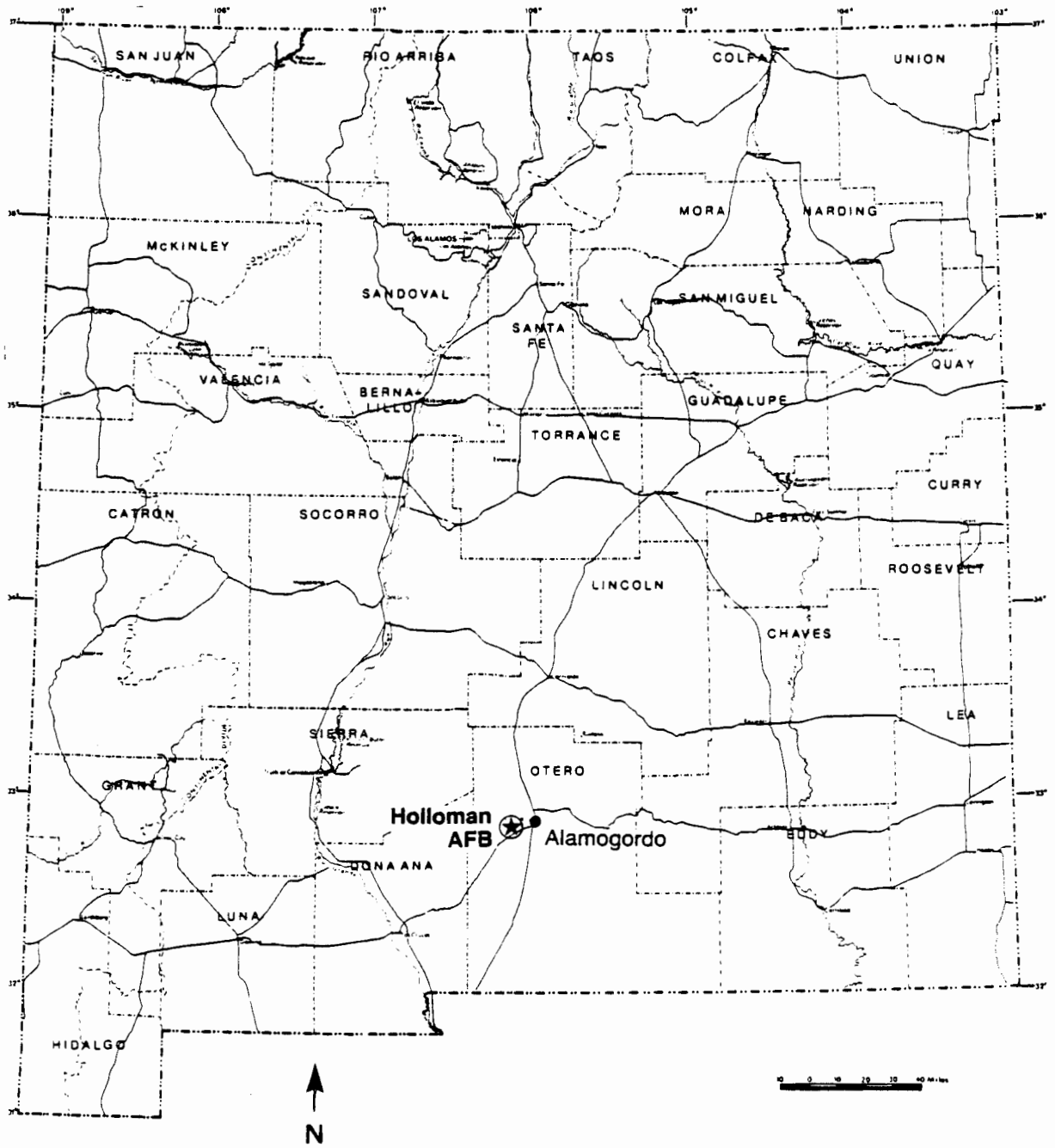


Figure 1-1. Location Map of Holloman AFB, New Mexico

1.4 Site Description

This section describes the current operation of the base sewage treatment lagoons and effluent waste streams at Holloman AFB. Site information is derived primarily from the delisting petition prepared by Computrac (1986), and is supplemented by Wilson and Company (1986).

The sewage treatment lagoons consist of two aerated lagoons operated in parallel and five nonaerated lagoons operated in series (Figure 1-2). These lagoons receive approximately 1.5 million gallons of residential and industrial wastewater per day. Residential domestic wastewater arises from family housing; the industrial wastewater arises from various sources including aircraft washing facilities, corrosion control facilities, hospital, analytical laboratories, machine shops, and maintenance shops. The discharge from the last lagoon in the series (Lagoon G) flows via an open ditch to Lake Holloman for eventual evaporation. Lake Holloman was formed by constructing a dam across a natural playa lake. This 166-acre lake was intended to be the final impoundment for evaporation of the treated wastewater but there have been conditions of overflow to a salina, identified as Lake Stinky, during winters; due to low evaporation, and in the summer during periods of unusually high rainfall. Lake Holloman and Lake Stinky currently hold approximately 379 million and 227 million gallons of water, respectively (Computrac, 1986). The location of Lake Holloman and Lake Stinky in relationship to the sewage lagoons is shown in Figure 1-3.

Raw sewage enters the base sewage treatment facility through a headworks where it is screened through bar racks, or ground with comminutors, and degritted in a horizontal flow grit chamber. Influent then enters a Parshall flume and wet well where it is pumped to a splitter box. The splitter box discharges to Lagoons A and B in parallel. Lagoons A and B are aerated facultative lagoons. Lagoons A and B have seven mechanical 3-hp floating propeller aerators evenly spaced throughout the lagoon. Lagoon C has two such aerators. Lagoons A and B are 10.1 and 11.2 acres, respectively, and both are approximately 5.2 feet deep. They hold approximately 17 and 19 million gallons, respectively.

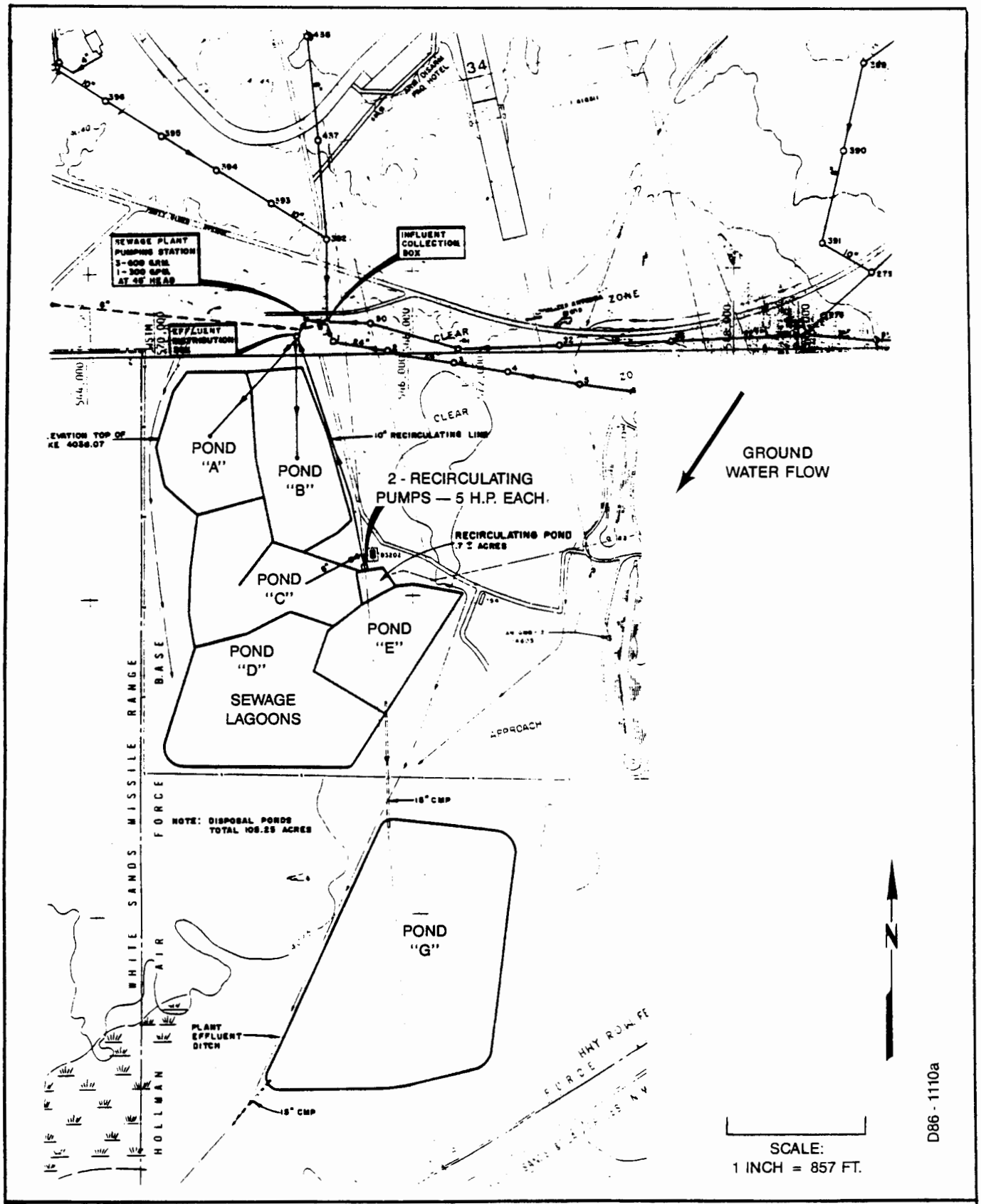


Figure 1-2. Sewage Treatment Lagoon Dimensions and Effluent Routes

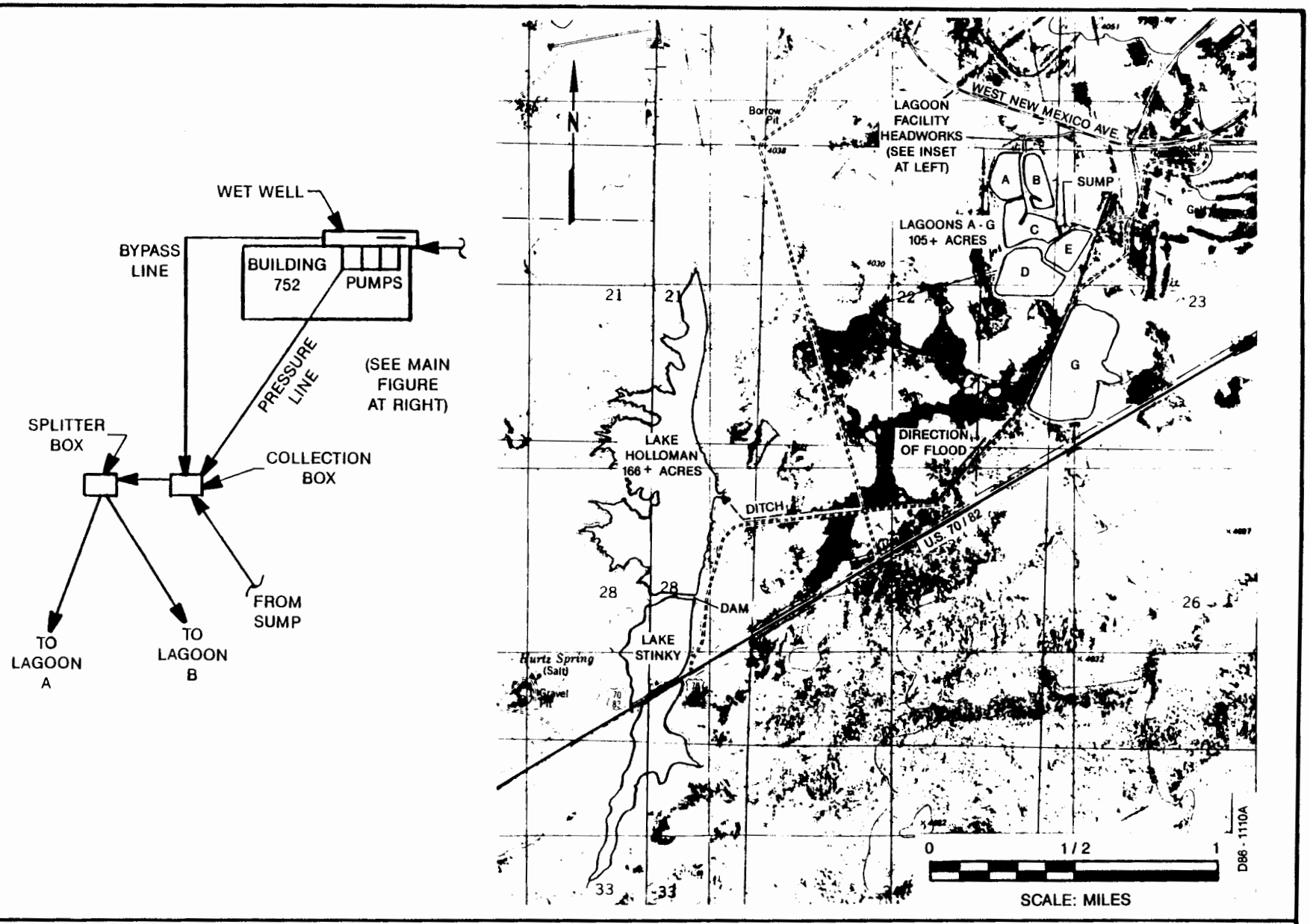


Figure 1-3. Location Map of Sewage Treatment Lagoons and Lakes Holloman and Stinky, Holloman AFB, NM

TABLE 1-1. DIMENSIONS OF LAGOONS AT HOLLOMAN AFB, NEW MEXICO

Lagoon Designation	Area (acres)	Depth (ft.)	Volume (Million Gallons)	Year Constructed
A	10.1	5.2	16.1	1943
B	11.2	5.2	16.1	1943
C	12.5	5.0	21.3	1955-1959
D	18.7	5.0	28.5	1955-1959
E	7.8	5.2	12.5	1955-1959
F	0.5	5.0	1.6	1955-1959
G	39.75	5.0	64.6	1970
Total	100.6	- -	160.7	- -

Wastewater flows from Lagoons A and B to a series of secondary lagoons (Lagoons C, D, E, F, and G) in series. Lagoon C has one 3-hp floating aerator at its influent point. Lagoon D was not in use during this investigation. The lagoon had been in and out of operation for several years due to bank leakage. Lagoon F is a small pond used to recirculate water from Lagoon E to the headworks. Lagoon G is the largest of the lagoons. From Lagoon G, treated effluent is discharged into a ditch which drains into Lake Holloman. The approximate size and volume of the lagoons is described in Table 1-1.

1.5 Project Team

Radian's project team for the Hydrogeologic Investigation was composed of a Program Manager, a Project Director, a Quality Assurance

Coordinator, a Task Leader, and field geologists. Mr. Nelson Lund, who served as Program Manager, had the overall responsibility, authority, and accountability for the project. The Project Director was Mr. Toby Walters. In this capacity, Mr. Walters was responsible for organizing and directing the technical activities of the project and for reporting the results of these activities. Ms. Wendy Rozacky served as supervisory geologist and soil boring/sampling Task Leader. She was responsible for all on-site activities, including drilling supervision, sample collection, field analyses, chain of custody, and reporting. Other key personnel included Mr. Gary Henderson, who served as a task leader for aquifer testing and field geologist for well installation, and Ms. Heidi Tomich, who served as a field geologist for well installation.

2.0 ENVIRONMENTAL SETTING

The following subsections describe the environmental setting of Holloman AFB, New Mexico. Included in this section are meteorologic, geographic, geologic, and hydrogeologic data as compiled from existing base records and previous reports. The base sewage lagoons, as well as associated historic groundwater problems, are also described in this section. Finally, the locations of wells on and off base are discussed.

2.1 Location

Holloman AFB is situated in south-central New Mexico in the northwest-central part of Otero County. The base occupies about 50,000 acres in the northeast quarter of T.17S., R.8E. Additional land extending northward from the base proper is occupied by testing facilities.

The base is located about 75 miles northeast of El Paso, Texas, and about seven miles west of Alamogordo, New Mexico. Alamogordo is the county seat of Otero County and the only town of appreciable size within 50 to 75 miles of the base. The population of Alamogordo was 23,535 in 1975. The population has grown appreciably since then, to about 31,000. The economy of Alamogordo is largely dependent upon Holloman AFB and other military installations in the area.

The base borders land that is either privately owned, public, or federal land. The major highway serving the base is Highway 70, which runs southwest from Alamogordo and forms the boundary between the base and public lands. Off-base installations of importance to this investigation include the Boles and San Andres water well fields, which supply potable water to the base. The well fields are located at the foot of the Sacramento Mountains, approximately 14 miles southeast of the base.

2.2 Meteorology

Holloman AFB is centered in the southern part of Tularosa Basin with mountain ranges to the east and west. The climate is arid with low annual rainfall and low relative humidity. The mountain ranges to the east and to the west have a dramatic influence on the local weather; they provide orographic lifting to produce summer thunderstorms and modify approaching weather systems.

Meteorologic data for Holloman AFB are presented in Table 2-1. Based upon 39 years of record, the average annual monthly mean temperature is 61°F. The mean daily high averages 75°F while the mean daily low averages 47°F. The average frost-free dates range from April 5 to November 10. The annual precipitation averages 7.9 inches, with annual extremes ranging from 2.5 inches to 13.5 inches (CH2M Hill, 1983). The greatest amount of precipitation usually occurs during July, August, and September.

The mean annual lake evaporation rate, commonly used to estimate the mean annual evapotranspiration, is estimated at 67 inches per year. The net precipitation (mean annual precipitation minus mean annual evapotranspiration) for the Holloman AFB area is approximately -59 inches per year.

In the Sacramento Mountains east of Alamogordo, precipitation amounts are significantly greater and temperatures lower than in the interior plain. During the duration of this investigation, high-intensity, but short-lived thunderstorms occurred at the front of the Sacramento Mountains in Alamogordo, while often, negligible precipitation amounts were recorded at the base.

2.3 Physical Geography

The location of Holloman AFB in relation to major geographic features in New Mexico is shown in Figure 2-1. The Tularosa Basin is an arcuate downfaulted closed intermontane basin that is part of a structural

TABLE 2-1. METEOROLOGICAL DATA FOR HOLLOMAN AFB[a]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average or Extreme
Temperature (°F)													
Monthly Mean	41	46	52	61	69	79	81	79	73	62	49	42	61
Mean Daily High	54	60	66	76	84	94	93	91	86	76	63	55	75
Mean Daily Low	28	31	37	45	54	64	68	66	60	48	35	26	47
Record High	78	80	90	94	103	109	108	106	102	92	82	75	109
Record Low	-11	0	9	23	26	44	52	54	38	26	3	2	-11
Precipitation (in)													
Monthly Mean	0.5	0.4	0.3	0.2	0.4	0.7	1.2	1.3	1.2	0.9	0.3	0.5	7.9
Record Maximum	1.9	1.4	3.0	0.8	2.9	3.6	3.7	4.4	3.9	4.2	2.5	2.4	4.4
Record Minimum	0	T[b]	0	0	0	T	T	0.2	T	0	0	0	0
Relative Humidity (%)													
4 a.m. Mean	66	61	52	40	42	42	60	66	68	61	61	63	57
1 p.m. Mean	42	35	27	19	20	19	31	35	38	34	34	37	31
Surface Wind													
Mean Velocity (Kt)	4	4	6	7	6	6	5	5	4	4	4	4	5
Prevailing Direction	N	N	S	S	S	S	S	S	S	S	S	S	S

[a] Source: AWS Climatic Brief, prepared by USAF Environmental Tactical Applications Center, Scott AFB, 1982.
Station: Holloman AFB, New Mexico
Period of Record: September 1942 to December 1981.

[b] T - trace.

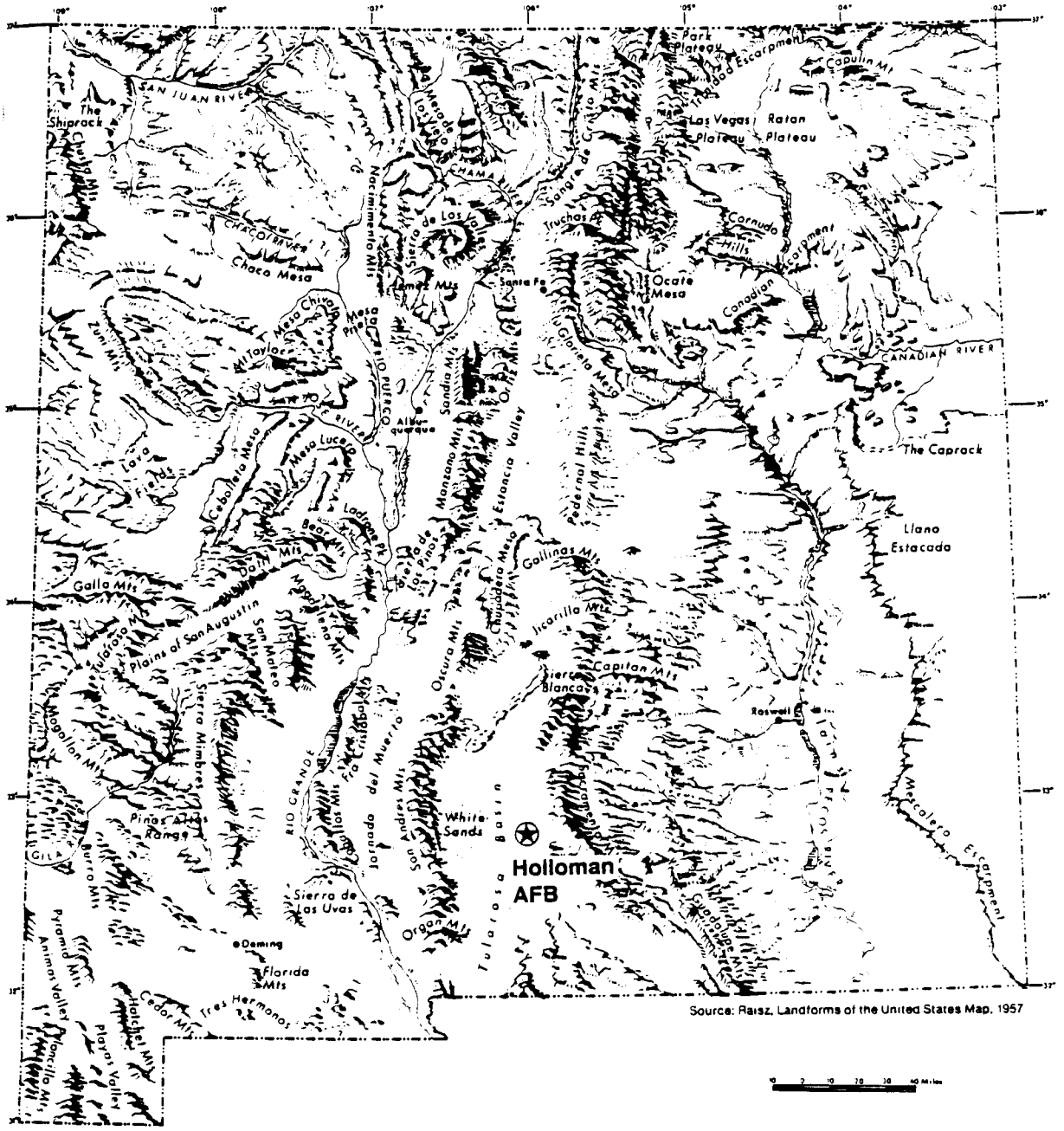


Figure 2-1. Relationship Between Holloman AFB and Major Geographic Features and Rivers in New Mexico

depression approximately 170 miles long, extending from the Chupadera Mesa in the north, southward to approximately the Texas-New Mexico state line.

The Tularosa Basin is bounded on the south by a low topographic divide near the state line; on the west by the uplifted Organ, San Andres, and Oscura Mountains; Chupadera Mesa on the north; and on the east by the uplifted Jicarilla, Sierra Blanca, and Sacramento Mountains. The interior plain has low relief with altitudes ranging from about 4000 feet in the southwest portion of the basin to about 4400 feet on the northeastern portion of the basin. The surrounding mountains rise abruptly to altitudes of 7,000 to 12,000 feet.

Surface runoff from the mountain fronts bordering the basin has deposited extensive alluvial fans. The size of each individual fan is somewhat proportional to the size of the watershed contributing alluvium to it. Out from the fans near the base, the surface of the plain is gently undulating, consisting of alternate small aeolian dunes and flat-bottomed playas (pan-shaped depressions carved by wind erosion). Further west of the base are gypsum sand dune fields belonging to White Sands National Monument.

The topography of Holloman AFB is a fairly flat plain. The highest surface elevations occur in the northeastern base area and gently slope toward Lake Holloman to the southwest at a rate of about 30 feet per mile. Lake Holloman is at an altitude of about 4,000 feet above mean sea level. West of Lake Holloman, the land elevation rises toward Hurtz Spring and a low bedrock outcrop that was once used as a rock quarry by the State Highway Department.

2.4 Regional Geology and Hydrogeology

2.4.1 Geology

Middle to late Cenozoic faulting formed the structural trough known as the Tularosa Basin. Geologically, the Tularosa Basin is a graben

structure, bounded on the east and west by mountains which are actually tilted fault blocks. During the Paleozoic era (270 million years ago), the basin and southern New Mexico were covered by a shallow sea. During this period, lime stone and sandstone were deposited, forming thick sedimentary units. The deposits are locally referred to as the Permian red-beds. Bedded Permian strata may be seen along the west face of the Sacramento Mountains east of the base. Hueco limestone (Permian) may also be seen west of the base as a low outcrop feature near Hurtz Spring.

Toward the end of the Mesozoic era (70 million years ago), the major mountain building activities that formed the Rocky Mountains took place. New Mexico literally emerged from the oceans as the earth's crust gently unwarped.

During the Cenozoic era (beginning 70 million years ago), basin and range formation occurred in the west. Large scale north-south trending faulting caused the center of the arched portion to collapse between the fault scarps. Mountains such as the San Andres and Sacramento Mountains are actually tilted fault blocks. The Tularosa Basin is the central area which collapsed between the fault scarps on either side of the valley. At the same time, many valleys were formed by down-faulting, including the Rio Grande Rift now occupied by the Rio Grande west of the Tularosa Basin. Alluvial filling of the Tularosa Basin began during the Pliocene era (10 million years ago).

Further basin adjustment occurred as buried fault blocks shifted within the Tularosa Basin. A geologic map of the present-day Tularosa basin is presented in Figure 2-2. Consolidated rocks (Permian Hueco and Yeso Limestone) are exposed in a north-south bedrock high beginning south of Holloman AFB in the Jarilla Mountains trending north through Tres Hermanos and Twin Buttes. The bedrock high extends through a small bedrock outcrop near Hurtz Spring west of the base and through a bedrock knob north of the base test track (Figure 2-2). A schematic east-west cross-sectional view of the southern basin is shown in Figure 2-3. The line of bedrock outcrops represents a large, buried down-faulted block. The fault block is en-echelon to the main

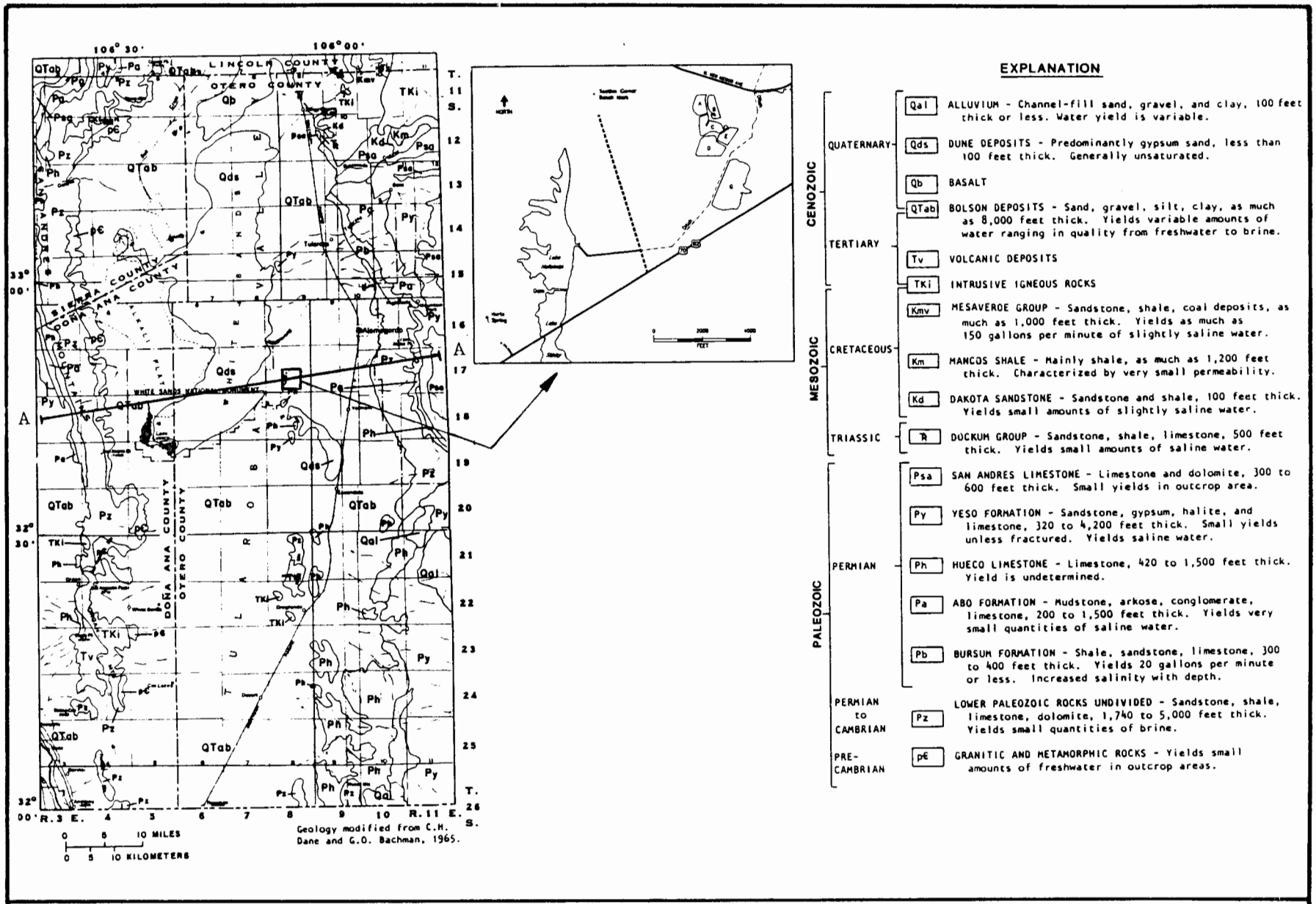


Figure 2-2. Geologic Map of the Tularosa Basin Relative Locations of Lake Holloman and Sewage Treatment Lagoons, Holloman AFB, New Mexico

Source: Orr, 1986

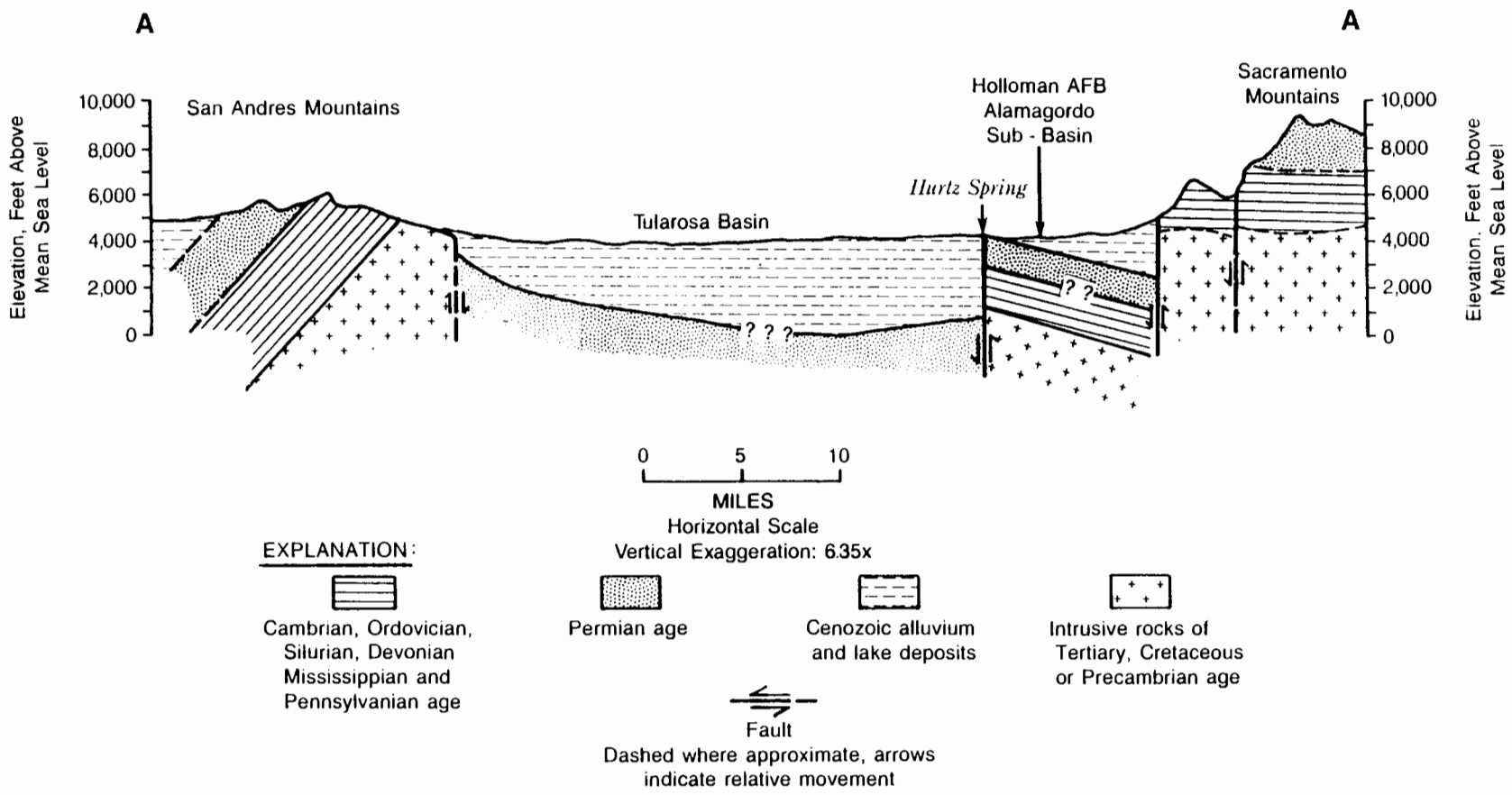


Figure 2-3. Geologic Cross-Section (looking north) Along Line A-A' of the Tularosa Basin, Holloman AFB, New Mexico

basin-forming fault scarp at the base of the Sacramento Mountains. The fault block is tilted to the east slightly and plunges to the north (Orr, 1987). The fault scarp is buried by bolson fill deposits in the Holloman area, but the fault is suspected to trend north-south in line with the bedrock outcrops described. This tilted fault block divides the larger Tularosa Basin/White Sands area from the Alamogordo sub-basin. The schematic cross-section, shown in Figure 2-3, depicts the relationship between the Tularosa Basin and Alamogordo sub-basin. West of Holloman AFB (near Hurtz Spring), the main Tularosa Basin begins. The Tularosa Basin is bounded on the east by the near-vertical fault scarp evidenced by the alignment springs and faulted outcrops described earlier, and on the west by the San Andres Mountains (Figure 2-3). The source of groundwater eminating from these springs is from shallow Permian-age rocks, including the Yeso and Hueco Formations. The Yeso Formation outcrops several hundred feet south of Hurtz Spring.

Bolson fill deposits are thin from Alamogordo toward Holloman AFB on the western edge of the sub-basin. Bolson sediments range in thickness from 4,000 feet near Alamogordo to less than 100 feet near Hurtz Spring (USGS, 1986). Bolson fill deposits in the central portion of the Tularosa Basin are 8,000 feet thick or more.

The lithology changes abruptly at the surface and with depth basin-ward from Alamogordo to Holloman AFB. Test wells have revealed abrupt lithologic changes both horizontally and vertically in the vicinity of Holloman AFB (USGS, 1986).

Recently (10 million years ago or less), lava flows erupted along existing fault planes created earlier during active basin development. The Carrizozo lava flow north of the base is an example of an eruption that took place during this time.

2.4.2 Soils

The U.S.D.A. Soil Conservation Service has identified two soil associations in the vicinity of Holloman AFB: the Holloman-Gypsum land-Yesum complex and the Mead silty clay loam. Most of the information provided in the following discussion of surficial soils at Holloman AFB was obtained from the U.S.D.A. Soil Conservation Service Soil Survey of Otero Area, New Mexico (U.S.D.A., 1981). Figure 2-4 shows the extent of the soil types in the vicinity of Holloman AFB.

Most of the surficial soils at the base are shallow, well drained sandy loam and deep, well drained sandy loam and gypsum of the Holloman-Gypsum land-Yesum complex. The soils of this association formed in alluvial and aeolian gypsiferous sediments. The Holloman soil is a light brown to pink, very fine sandy loam that is high in gypsum. The soil is moderately permeable, calcareous, and mildly to moderately alkaline. The Holloman unit makes up about 35% of the complex. It reaches depths of about 60 inches. The Gypsum land unit which makes up about 30% of the complex is soft to hard white gypsum, typically overlain by less than one inch of very fine sandy loam. The Yesum unit is light brown to pinkish-white to pink very fine sandy loam that is high in gypsum. It is moderately permeable, calcareous throughout, and mildly alkaline. The Yesum unit makes up about 20% of the complex. This unit extends to a depth of more than 60 inches.

The Mead silty clay loam soil occurs over a small area of the base. This soil consists of reddish-brown silty clay loam, clay loam, and clay. The soil has low permeability and available water capacity is low. It is mod erately calcareous throughout and is moderately to strongly alkaline. The soil has a layer of salt that is more soluble than gypsum. The surface layer of silty clay and clay loam is about 5 inches thick. The substratum of clay extends to a depth of 48 inches. Below that, lacustrine material of variable texture and color extends to a depth of more than 60 inches.

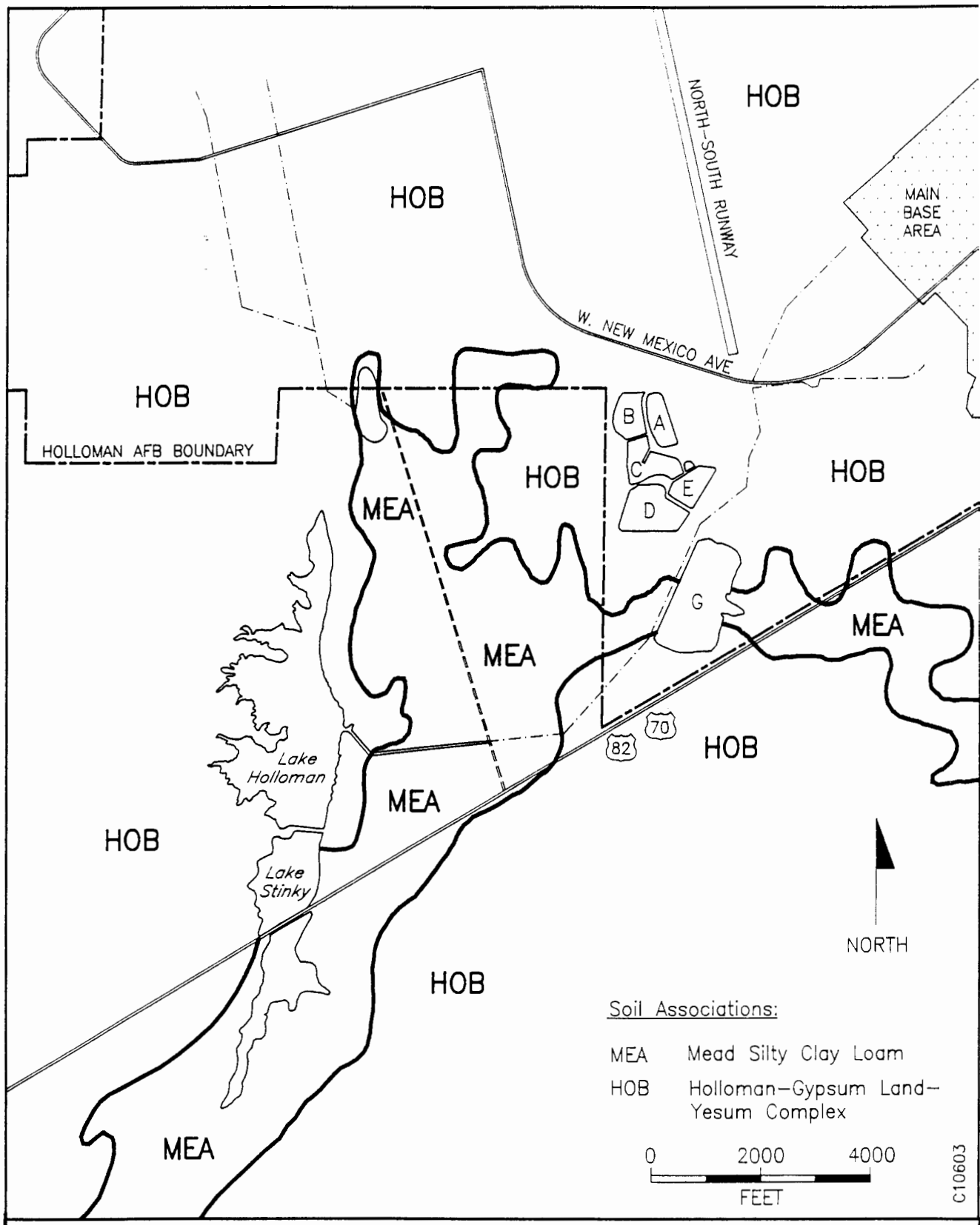


Figure 2-4. Soil Types at Holloman AFB, New Mexico

2.4.3 Surface Water

The Tularosa Basin is a closed basin; no surface water drainage leaves the basin. Surface water is either lost to evaporation and infiltra tion or collects in the lowest point in the basin at or near Lake Lucero. This lake is located approximately 20 miles southwest of Holloman AFB.

The base is crossed by several southwest trending arroyos (inter mittent streams). One of these drainages (Lost River) is fed by shallow (less than 10 feet below land surface) groundwater seeps or springs. Lost River runs from the northwest corner of base property to the southwest. The river appears and disappears along its course as springs add water and evapo transpiration and infiltration recapture it. Surface drainage within the undeveloped parts of the base is controlled by the major arroyos including Lost River and Dillard Draw and their tributaries. Surface flows are to the southwest toward the White Sands National Monument.

Drainage within the developed portion of the base flows by way of ditches and culverts to the southwest corner of the base, into the wastewater treatment lagoons. The wastewater treatment system at Holloman AFB consists of six aeration/evaporation lagoons located in the southwest corner of the base. Just southwest of these lagoons, a natural playa lake known as Lake Holloman receives runoff from the base as well as effluent from the sewage lagoons. A dam/dike has been constructed across the southern quarter of Lake Holloman. Seepage through the dam and overflow has created a small playa lake known as Lake Stinky.

2.4.4 Groundwater

Groundwater occurs within the unconsolidated bolson deposits at shallow depths beneath Holloman AFB. The water table is very near the surface (less than 10 feet) over most of the base. Figure 2-5 is an illustration of the relationship between the Sacramento Mountains and the bolson fill relative to groundwater occurrence. At the base of the mountains, the hydraulic

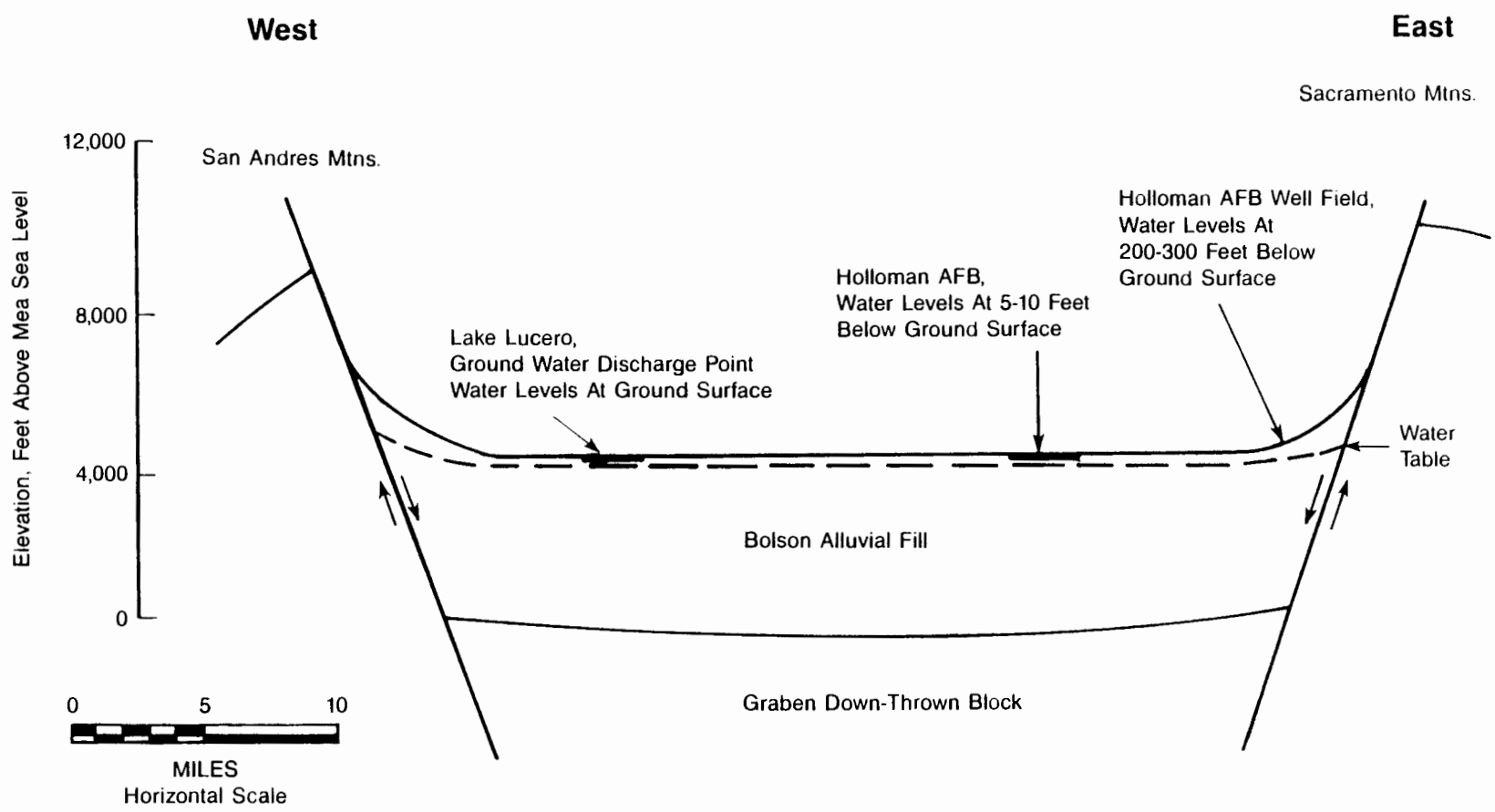


Figure 2-5. Schematic Cross-Section (looking north) of Groundwater Occurrences and Discharge Areas Beneath the Tularosa Basin, Holloman AFB, New Mexico

gradient is quite steep but then flattens out quickly. In the vicinity of Holloman AFB, the ground surface slopes to the southwest at a very low gradient but at a slightly steeper grade than the hydraulic gradient of the water table. As a result, the depth to water decreases from 270 feet (or more) near the mountains to less than 10 feet at Holloman AFB.

The majority of the groundwater recharge to the bolson aquifer occurs through the coarse, unconsolidated alluvial fan deposits along the western flank of the Sacramento Mountains. Water percolates downward into the bolson fill aquifer in this area and migrates downgradient (westward) through progressively finer grained sediments into the basin. Groundwater discharge occurs either through evapotranspiration, springs or seeps along steep-sided arroyos or into closed playa lakes such as Lake Lucero, the regional groundwater discharge area.

Groundwater of good quality occurs near recharge areas, but becomes progressively more mineralized downgradient toward the interior of the Tularosa Basin. This is due to the slow migration rate of groundwater from recharge to discharge areas and the presence of readily soluble minerals in the bolson sediments. The primary dissolved ions in the groundwater are sulfate and chloride. Because groundwater below Holloman AFB contains high total dissolved solids (TDS) (in excess of 10,00 mg/L), the groundwater is designated as unfit for human consumption based upon New Mexico Water Quality Control Commission Regulations (NMWQR Part 3-100 through 3-103) dated September, 1987.

2.4.5 Historical Water Use at the Base

Holloman Air Force Base obtained all of its water supply from the town of Alamogordo during the operation of the base as an Army Air Field during World War II and until the summer of 1947. In 1947, Mr. L. C. Boles drilled a proposed irrigation well on his property, part of the present well field, and found that the water was potable. Subsequently, the Air Force

leased the property and much of the surrounding property in secs. 24 and 25, T. 17 S., R. 9 E., and secs. 18 and 19, T. 17 S., R. 10 E. During an 8-year period from 1947 to 1955, at least 35 wells and test holes were drilled in the well field area. Of the 35 wells and test holes, only 14 wells have been used or equipped at one time or another to produce water. In 1955 there were 12 wells equipped for use, but only 10 wells were used to any extent.

Water requirements at the base were essentially stable during World War II. The amount of water used ranged from 0.4 to 0.5 million gallons per day (mgd). After the war, as activities at the base were curtailed, the use of water dwindled to about 0.1 mgd. When the base was reactivated as a research establishment, the demand for water began to increase again, reaching the wartime level in about 1950.

The continued increase in use of water at Holloman Air Force Base reflects the increase of the population of the base and the enlargement of the physical plant. The research facilities, on-base housing facilities, and landscaping have been expanded more or less continually. The continued increase in research and landscaping has resulted in a rising average use of water per capita. The use of water per capita fluctuates seasonally and is related in part to the seasonal or monthly temperature. Generally, during cold weather individual consumption of water is reduced. During the colder weather, the amount of irrigation of lawns and trees is small. As the temperature rises, these uses of water increase rapidly.

2.4.6 Current Water Use

Presently, Holloman Air Force Base, White Sands Missile Range Headquarters, and the community of Alamogordo are the chief users of the freshwater in the Tularosa Basin. The city of Alamogordo reportedly used 6.4 mgd in 1984. Although water from some sources contained more than 1,000 mg/L dissolved solids, the water delivered to the consumers usually contained less than 1,000 mg/L. About 1.6 mgd in 1984 were obtained by pipeline from Bonito Lake, 60 miles northeast of the basin. An additional 4.3 mgd were obtained

from developed springs in La Luz, Alamo and Fresnal Canyons in the Sacramento Mountains, and the remaining 0.5 mgd were obtained from wells drilled in alluvial fan deposits at the base of the Sacramento Mountains between Alamogordo and La Luz.

Holloman Air Force Base used 2.6 mgd during 1984, of which 1 mgd was obtained from the city of Alamogordo (Computrac, 1986). The water obtained from Alamogordo represents a mixture of water from other sources at the base of the Sacramento Mountains, plus water from the Bonito Lake pipeline. The remaining 1.7 mgd in 1984 were withdrawn from wells in the Boles, San Andres, and Douglas well fields. At present, the city of Alamogordo is discontinuing use of the Bonito pipeline due to continued breaks and vandalism along the system.

White Sands Missile Range 25 miles southwest of HAFB obtains its fresh water supply from alluvial deposits in the reentrant between the Organ and San Andres Mountains and along the mountain front on the west side of the basin. The hydrologic implications of White Sands' water use is insignificant to this investigation.

2.5 Historic Groundwater Problems

The base sewage treatment facility has been in continuous operation since the late 1940's. The sewage lagoons have, in the past, received unknown quantities of hazardous waste. The probable source of this waste was industrial wastewater which arose from various sources: aircraft washing facilities, corrosion control facilities, hospital, analytical laboratories, machine shops, and maintenance shops. In order to eliminate the discharge of hazardous waste into the lagoons, waste discharges into the lagoons have been rigidly controlled since October 1984 (Wilson & Company, 1986).

Water samples collected from 12 monitor wells installed by the USGS near the sewage treatment lagoons indicate that overall water quality of the shallow aquifer near the sewage lagoons is poor with conductivities ranging

from 14,400 to 50,800 micromhos per square centimeter (μmhos/cm^2). High concentrations of sodium ranging from 2940 milligrams per liter (mg/L) to 9600 mg/L and chloride from 3700 to 21,000 mg/L are naturally present in the groundwater in this area. Elevated levels of sulfate ranging in concentration from 1040 mg/L to 5590 mg/L are present (Wilson, 1986).

Total organic halogens (TOX) were detected in all groundwater samples collected from USGS monitor wells near the sewage treatment lagoons. However, the report (Wilson, 1986) did not discuss the methodology used to obtain TOX concentrations or if a QA/QC check was run on the samples. The standard method for TOX, Method 9020 (SW846), requires duplicate analyses. Based upon the Wilson report, none were completed.

Method 9020 for TOX analyses uses carbon adsorption with a microcoulometric-titration detector. Method 9020 detects all organic halides containing chlorine, bromine and iodine that are adsorbed by granular activated charcoal under the conditions of this method. The limitations of this method are that it is not applicable to samples (groundwater) in which the inorganic-halide concentration exceeds the organic halide concentration by more than 20,000 times. For this reason, the method should not be applied in saline conditions such that occur at Holloman AFB. The interference of the naturally high inorganic halide concentrations in these waters most likely is the cause for the false-positive organic TOX values recorded in the previous study performed by Wilson and Associates (1986). The TOX values reported should not be assumed to indicate sewage lagoon leakage, and the method should not be used in future studies as an indicator of groundwater contamination at Holloman AFB. A possible alternative is SW846 Method 9021--purgeable organic halides (POX). This method does not use activated charcoal to sorb the halides. Instead, the volatile organic halides are purged into a pyrolysis furnace using a stream of CO_2 and the hydrogen halide (HX) pyrolysis product is trapped and titrated electrolytically using a microcoulometric detector.

The base performs periodic analyses of the wastewater treatment system influent, effluent, and Lake Holloman samples. The base has also collected and analyzed sludge from the bottom of the sewage lagoons. Heavy

metals, pesticides, phenols, cyanide, and oil and grease were the parameters analyzed. Past results show that these parameters are either absent or present at very low concentrations (Computrac, 1986).

2.6 Locations of Wells On and Off Base

No water supply wells are located on base because of the poor quality of groundwater. Base potable water supplies are obtained from surface water from Bonita Lake, and from 21 wells in three separate well fields located on the western slope of the Sacramento Mountains.

The nearest production well found downgradient of the sewage treat ment lagoons is a livestock well located 3.5 miles west of the lagoons (Computrac, Inc., 1986). No other downgradient or near-base potable or irrigation wells exist.

Previous investigations on base included the installation of monitor wells. The most relevant study was an investigation performed by the USGS in 1985 during which twelve monitor wells were installed around the sewage lagoon area. One of these wells is located upgradient of sewage lagoon E. Ten wells were placed on the berm and southwest of Lagoon D; one well was placed near Lake Holloman. The locations of these wells are shown in Plate 9. There are no ongoing groundwater monitoring programs involving these or any other monitor wells on-base.

2.7 Land Ownership

Real Property records indicate land used for the operation of the sewage lagoons is owned by Holloman AFB. Land adjacent to the lagoons is public land maintained by the Bureau of Land Management. West of the sewage treatment lagoons, the runoff ditch crosses public land to Lake Holloman. Lakes Holloman and Stinky border lands that are federally, privately and state-owned. Public lands in this portion of New Mexico are administered by the Bureau of Land Management (Las Cruces District).

2.8 Permits

Prior to beginning the investigation and during the course of the study, Radian, Holloman AFB, TAC, and USACE (Albuquerque District) worked together to secure right-of-entry permits onto the lands described above. Right-of-entry permits are presented in Appendix A. Table 2-2 is a list of the property owners, date of entry agreement, and number of wells installed on each property.

TABLE 2-2. PROPERTY OWNERS INVOLVED IN RIGHT-OF-ENTRY PERMITTING

Land Owner	Right-of-Entry Date	No. Wells/Boreholes
Wes Walker	17 September 1987	1
Bureau of Land Management	14 September 1987	7
Holloman AFB	30 May 1987	17

Only one borehole was installed on private property (Wes Walker's). The borehole was for exploration purposes only and was not completed as a piezometer well. The borehole was grouted up to land surface with cement after completion. No groundwater was encountered at the final depth (30 feet below land surface).

The terms of the right-of-way onto lands administered by the BLM allow the USACE access to the seven piezometer wells for a term of 25 years from the date of execution (14 September 1987). This long-term right-of-entry could be useful if periodic sampling and analysis of the wells is required. Right-of-entry permits are presented in Appendix A.

3.0 FIELD PROGRAM

3.1 Field Program Development

The precursor to the Hydrogeologic Investigation Plan for Holloman AFB was a proposed groundwater monitoring plan submitted in November 1986 by Radian Corporation and entitled, "Proposed Groundwater Monitoring Plan, Holloman Air Force Base, New Mexico." The groundwater monitoring plan was reviewed by representatives of EPA Region VI. It was ruled by EPA that a thorough hydrogeologic investigation be conducted prior to initiating the groundwater monitoring plan. Based upon this ruling, Radian Corporation prepared and submitted a Draft Proposed Hydrogeologic Investigation Plan on 9 April 1987, to Omaha District Corps of Engineers for distribution to TAC, Holloman AFB, and EPA.

A meeting was held 12 May 1987 at Holloman AFB to discuss the Draft Proposed Hydrogeologic Investigation Plan. In attendance at the meeting were representatives of Holloman AFB, EPA (and their consultant), Omaha District COE, HQ TAC, and Radian Corporation. Written comments restating the comments and discussions of the 12 May meeting were received from EPA on 4 June 1987.

In response to EPA review comments received 4 June 1987, Radian Corporation, in cooperation with the Omaha District COE, resubmitted the Hydrogeologic Investigation Plan for the sewage treatment lagoons and Lakes Holloman and Stinky at Holloman AFB, New Mexico. The Hydrogeologic Investigation Plan was approved on 15 July 1987.

3.2 Field Program Implementation

The field program at Holloman AFB consisted of the following activities: 1) installation of 22 piezometer wells, two pump-test wells, and one soil boring; 2) soil sampling and analysis; and 3) aquifer testing. Field activities began on 29 July 1987 and ended on 18 November 1987.

3.2.1 Well Numbering System

A total of 22 piezometers, two pump-test wells, and one borehole were installed at Holloman AFB during the hydrogeologic investigation. They are identified by an alpha-numeric label as shown in Plate 9. Piezometers completed in the shallow aquifer are labeled with the letter S followed by a number. Wells S-1 through S-16 are shallow piezometers. (Note: Piezometer S-14 was completed in the clay zone underlying the shallow aquifer.) Piezometers completed in the second, or deep, aquifer are labeled with the letter D followed by a number. Piezometers D-1 through D-6 were installed in deeper saturated zones. The two pump wells are labeled P-1 and P-2 and are completed in the deep aquifer.

3.2.2 Piezometer Locations

The hydrogeologic setting of the study area is large and diverse; it represents specific hydraulic conditions (i.e., wastewater impoundments, effluent ditches, and natural playa lakes) that influence and could be influenced by base operations. For instance, the sewage lagoon "system" comprises about 100 acres. Lakes Holloman and Stinky comprise over 166 acres. Approximately 1.5 miles separate the sewage treatment lagoons and Lakes Holloman and Stinky. However, little hydrogeologic data existed prior to this study.

As a means of gathering adequate data and describing these "systems," the study area was divided into a series of four zones as shown in Plate 9. They are defined as follows:

- Zone 1--Area east (upgradient) from sewage lagoons;
- Zone 2--Area west (immediately downgradient) and north of sewage lagoons;

- Zone 3--Central area between sewage lagoons and Lake Holloman; and

- Zone 4--Area immediately west (downgradient) from Lake Holloman.

Each zone represents a specific physical area of interest and is representative of the unique data needs for that particular area. Zone descriptions and piezometers for each zone are discussed below.

Zone 1 includes the upgradient or background area northeast and east of the sewage treatment plant and lagoon area. Hydrologic influences include the runoff ditch and the north-south runway area. Three shallow piezometers, S-1, S-2, and S-12, and one deep piezometer, D-3, were installed in this area (Plate 9). Piezometers S-1 and S-2 are situated between the runoff ditch and golf course. Pathways of contamination in Zone 1 include irrigation waters from the golf course and seepage from the runoff ditch or lagoons.

Zone 2 encompasses the area north and immediately downgradient (west) of the sewage treatment lagoons (Plate 9). Hydrologic influences include potential groundwater contamination caused by downward percolation of wastewaters below the unlined sewage lagoons. A total of six shallow piezometer wells (S-3, S-4, S-5, S-13, S-14, and S-15) and two deep piezometer wells (D-4 and D-5) were installed in this area. Potential sources and pathways of contamination include the six sewage lagoons and effluent ditch leading from Lagoon G to Lake Holloman.

Zone 3 consists primarily of off-base public land (BLM) extending from half-way between the sewage treatment lagoons and Lakes Holloman and Stinky through the eastern part of the two lakes (Plate 9). Four shallow piezometers, S-6, S-8, S-10, and S-11, and two deep piezometers, D-1 and D-2, were installed in this area to maintain geologic and hydrologic control between the sewage lagoons and Lakes Holloman and Stinky. Potential pathways for contaminant migration beyond this zone are primarily Lakes Holloman and Stinky and to a lessor extent the effuent ditch.

Zone 4 is the most remote of the four zones; it encompasses the western edge of Lakes Holloman and Stinky and the bedrock outcrop/Hurtz Spring area (Plate 9). Data needs of this area were primarily geologic in nature. Information from Zone 4 was used to extend geologic cross-sections and to view the hydraulic gradient, including mounding effects, if any, caused by Lakes Holloman and Stinky. Three shallow piezometers (S-7, S-9, and S-10), one deep piezometer (D-6), and one deep boring (B-1) were installed in this area. The borehole west of Hurtz Spring was used to determine the depth to bedrock and to define the boundary effects on the water table caused by a bedrock high on the west side of Lake Holloman.

3.2.3 Piezometer Data Requirements

A total of 16 shallow and 6 deep piezometers were installed. The shallow piezometers were completed in the first water-bearing sand and ranged in depth from 9 to 19 feet below land surface (bls). The deep piezometers were installed to depths ranging from 58 to 77 feet bls. At least one deeper piezometer was placed in each of the four zones to compare water quality characteristics and variability between the two saturated units. In the pump-test area (Zone 2), a piezometer (S-14) was installed in a clay unit separating the shallow and deeper saturated sand units. A list of the piezometer depths, screened intervals, and elevations is presented in Table 3-1.

For the purpose of the Hydrogeologic Investigation, 22 piezometers were considered adequate to describe both the horizontal and vertical flow path and gradient in the four zones. The piezometers were installed after the borehole data were reviewed in the field to insure proper screen placement. Piezometers were installed at all but one borehole location (B-1) located near Hurtz Spring (Plate 9). This borehole was installed for geologic control purposes and to assess the change (if any) in the occurrence of the water table west of a bedrock high that intersects Hurtz Spring. The information obtained from the piezometers provided a variety of hydrogeologic data including:

TABLE 3-1. SUMMARY OF SPECIFICATIONS FOR ALL PIEZOMETER AND PRODUCTION WELLS

I.D.	Measuring Point Elevation (ft., MSL*)	Ground Level Elevation (ft., MSL*)	Screened Interval (ft. below surface)	Screened Interval Elevation (ft., MSL*)	Total Depth (ft. below surface)	Bottom of Borehole Elevation (ft., MSL*)
S-1	4041.72	4038.99	7.00-12.00	4031.99-4026.99	17.00	4021.99
S-2	4040.56	4037.99	7.00-17.00	4030.99-4020.99	24.75	4013.24
S-3	4042.66	4040.93	4.00-9.00	4036.93-4031.93	12.00	4028.93
S-4	4034.46	4031.49	6.00-11.00	4025.49-4020.49	20.00	4011.49
S-5	4033.47	4031.32	5.00-10.00	4026.32-4021.32	17.00	4014.32
S-6	4031.52	4029.44	10.00-15.00	4019.44-4014.44	47.00	3982.44
S-7	4030.24	4028.22	12.50-17.50	4015.72-4010.72	22.00	4006.22
S-8	4033.15	4031.02	14.00-19.00	4017.02-4012.02	22.00	4009.02
S-9	4020.67	4018.42	9.00-14.00	4009.42-4004.42	26.00	3992.42
S-10	4030.00	4027.85	9.00-14.00	4018.85-4013.85	34.00	3993.85
S-11	4027.23	4025.17	9.50-14.50	4015.67-4010.67	19.00	4006.17
S-12	4048.31	4046.01	4.00-9.00	4042.01-4037.01	12.00	4034.01
S-13	4032.34	4030.05	5.00-10.00	4025.05-4020.05	20.00	4010.05
S-14	4032.43	4030.20	29.00-34.00	4001.20-3996.20	35.00	3995.20
S-15	4037.71	4034.86	4.00-9.00	4030.86-4025.86	15.00	4019.86
S-16	4029.46	4027.46	7.80-12.80	4019.66-4014.66	34.00	3993.46
D-1	4030.66	4028.34	25.00-35.00	4003.34-3993.34	75.00	3953.34
D-2	4023.30	4021.37	53.30-63.30	3968.07-3958.07	77.00	3944.37
D-3	4047.41	4045.48	58.00-68.00	3987.48-3977.48	75.00	3970.48
D-4	4031.86	4030.19	39.00-49.00	3991.19-3081.19	58.00	3972.19
D-5	4039.34	4036.86	49.00-59.00	3987.86-3977.86	64.70	3972.16
D-6	4030.20	4027.98	24.00-39.00	4003.98-3988.98	68.30	3959.68
P-1	4047.51	4045.09	57.00-67.00	3988.09-3978.09	77.00	4045.09
P-2	4032.11	4030.25	42.00-52.00	3988.25-3978.25	62.00	4030.25

*MSL = Mean Sea Level.

- Water levels and seasonal fluctuations thereof;
- Groundwater flow gradients;
- Gross indicators of water quality (pH, temperature, conductivity); and
- Whether there exists vertical communication between shallow and deeper water-bearing units.

Seasonal fluctuations could not be determined due to the short period of observation; however, short-term water table fluctuations were monitored. Water levels were taken from a marked "point" on the well casing to insure correct and consistent water level data were obtained each time. This point was also used by the surveyor in determining the elevation of the well above mean sea level. Based upon surveyed elevations of piezometers and subsequent water table measurements, hydraulic gradients and flow paths were determined. Groundwater flow gradients are discussed in Section 4.3.5.

Field indicators of groundwater quality (pH, temperature, and conductivity) were measured after the piezometer was adequately purged to remove stagnant water in the well casing. Field water quality results are discussed in Section 4.2.3.

Paired shallow and deep piezometers were monitored during the pump test to quantify potential vertical communication between shallow and deeper water-bearing units. Results of the aquifer tests are presented in Section 4.3.

3.3 Drilling Techniques

Drilling operations at Holloman AFB consisted of installing boreholes for soils characterization, piezometers for measurements of water levels and indicators of water quality, and pump-test wells for aquifer characterization. A hollow stem auger drill rig (Mobil B-50) was used to install the

boreholes and wells. This method proved satisfactory because the rig operated without the use of potentially contaminating drilling fluids (water or foam). The drill rig was also easy to maneuver during the project, even during rainy days.

During drilling operations, a Radian geologist collected and described split-spoon samples at approximately 5-foot intervals. Soils were collected for analysis by driving a split-spoon sampler through the end of the hollow-stem auger into the undisturbed underlying formation. Drilling methods and sample collection techniques are discussed below:

- Boreholes were drilled using a Mobil B-50 hollow-stem auger rig. Each auger flight was 5 feet in length. Auger dimensions were 8-inch outside diameter (O.D.) and 3 3/8-inch inside diameter (I.D.). Two wells, P-1 and P-2, were installed by larger augers measuring 12-inch O.D. and 6 5/8-inch I.D. in size.

- Twenty-four-inch long, 3-inch I.D. split spoons were used to collect formation samples at 5-foot intervals. Soil core samples were collected using a 140-lb. hammer to drive the split spoon into the formation according to ASTM methods D-1586 and D-1587. The number of blow-counts per 6 inches of penetration was recorded on the drilling log. The split spoons were thoroughly cleaned (ALCONOX soap and water wash, and potable rinse) between samples. Samples were described and photographed in the field. Selected samples were transferred to labeled, one-quart plastic jars for laboratory characterization.

- Soil cuttings produced during the drilling activities were left on site after well completion. After close visual inspection and from readings from the OVA, none of the cuttings produced were suspected to be contaminated. All sites were raked and

smoothed to a pre-disturbance condition as required by Base Environmental Engineer and as specified in the right-of-entry agreements with off-base land owners.

- When the borehole reached total depth, as determined by the supervising geologist, it was completed as a piezometer well, as described in the following sections.

3.3.1 Piezometer Installation Methods

Piezometer wells ranged between 9 and 68 feet in depth depending upon geologic conditions, and were designed and constructed in compliance with monitoring well construction guidelines (RCRA TEGD, 1986). For this reason, the piezometers are suitable for future water quality monitoring. A typical piezometer construction schematic is shown in Figure 3-1. As-built diagrams of each piezometer are presented in Appendix B. The piezometers were installed using the following procedures:

- After reaching total depth (TD) as determined by the supervising Radian geologist, the screen and casing were assembled and inserted through the augers. If the borehole lithologies were stable (i.e., allowing the borehole to stand open), the augers were withdrawn before the casing and screen were installed.

- Wells were completed with 2-inch diameter, flush-threaded, Schedule 40 PVC with 0.020-inch mill slot screens in 5 or 10 foot sections (depending upon saturated thickness). All well casing and screens were steam cleaned and kept covered in plastic sheeting before use.

- Well casings were 2-inch diameter, Schedule 40 PVC, with flush-threaded joints. No glues or other additives were used to assemble the casings.

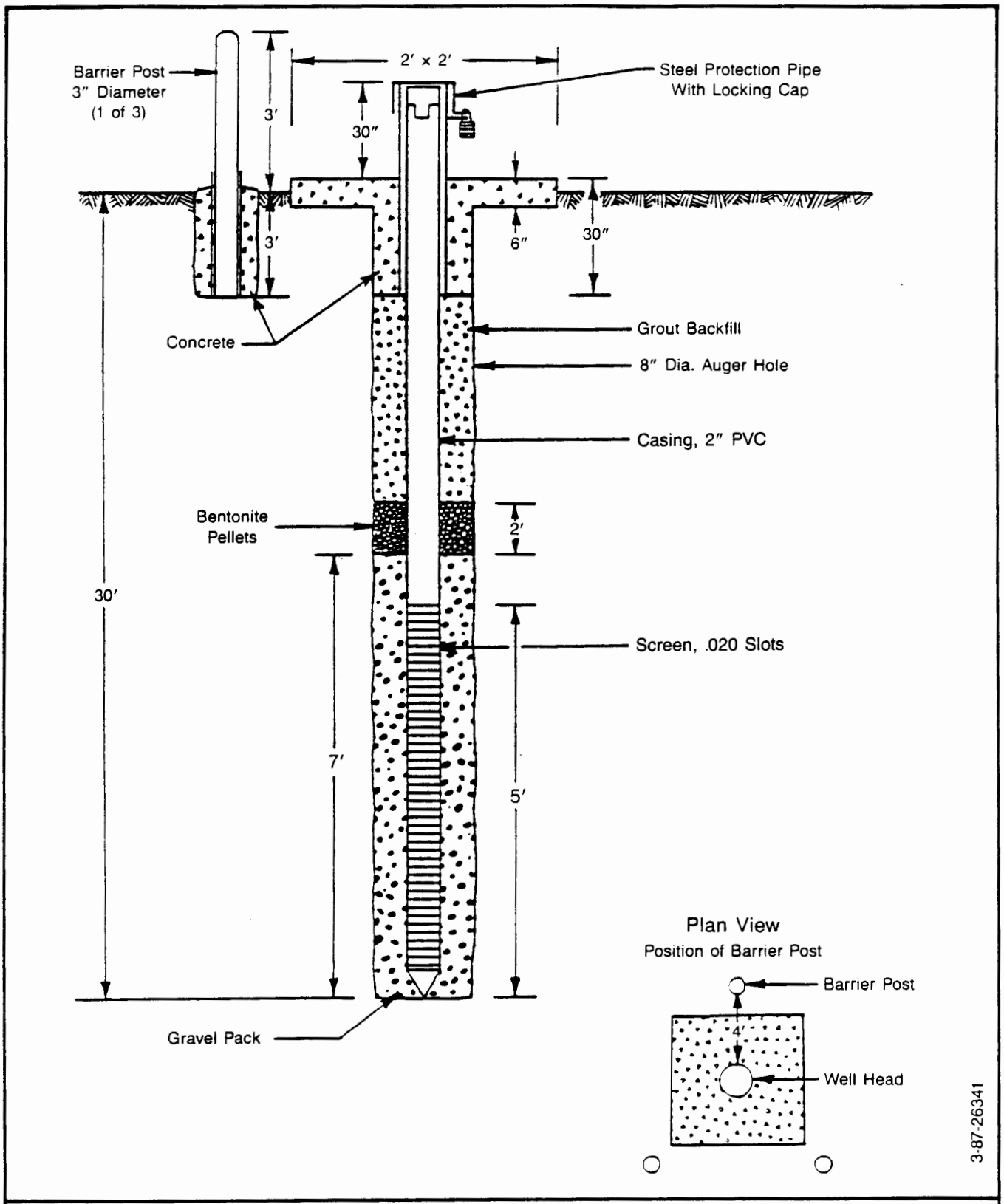


Figure 3-1. Piezometer Well Construction Schematic, Holloman AFB, New Mexico

- The annulus was completed with a clean sand pack through the screened interval to 2 feet above the screen. A bentonite seal was hand-fed from land surface onto the sand pack, forming a 2-foot seal above the sand pack. The bentonite seal was allowed to hydrate for a minimum of 8 hours before grouting. Neat cement grout (Type I-II Portland cement) was placed from the top of the bentonite seal to the land surface. The cement seal was emplaced by mixing the grout and then pouring the cement from land surface, sealing the annulus from the bottom to the top.

- The PVC casing was cut off to provide a 2- to 3-foot "stick-up," and a coupling with a vented hole was drilled into the top of the end-cap.

- A 6-inch steel protective surface casing, with locking cap and a weep hole near the bottom, was emplaced over the PVC casing and seated in the cement. The weep hole was drilled into the base of the steel surface casing to allow for drainage.

- After the well was completed, it was developed to sand-free conditions by air-lift techniques or by bailing according to EPA water-well construction specifications (EPA, 1975). If sand-free conditions could not be achieved per EPA specifications as discussed in Article 52.000-001-000 "Sand Content Testing," then development continued until pH, conductivity, and temperature stabilized (TEGD, 1986). Any excess water which may have been introduced from upper saturated zones was evacuated during this process. Development proceeded no less than 48 hours after grouting.

- Three guard posts were installed radially 4 feet from each wellhead. The guard posts consisted of 3-inch diameter steel pipes, 6 feet in length, of which 2 feet was below ground

level. The guard posts were secured in cement; the annulus of each guard post was also filled with grout.

- All augers were steam cleaned, washed (ALCONOX), and rinsed following completion of the well at an area designated for decontamination activities.

3.3.2 Pump Well Installation Methods

Two 4-inch diameter (I.D.) pump wells (P-1 and P-2) were installed at the locations shown in Plate 9. Each pump well was drilled by hollow- stem auger methods using 12-inch O.D. augers. The pump wells were large diameter to accommodate a 3 3/4-inch submersible pump. Well construction methods for the pump wells were identical to the piezometer well construction methods as discussed in Section 3.3.1. The pump wells were used solely for aquifer testing of the shallow and deeper saturated sand units.

3.4 Formation Sampling

As part of this investigation, formation samples were collected using recognized ASTM sampling procedures as described below.

During drilling, soil samples were collected at approximately 5-foot intervals using split-spoon samplers (ASTM D-1586). Soil samples were described in the field on the basis of mineralogy, particle size, sorting, color, visible salt accumulation, trace minerals, and moisture content.

Two core samples (24-inch) from each borehole were sent to the laboratory for physical characterization. For the purpose of this investigation, one core sample from the saturated water-bearing zone intended to be screened was analyzed. A second core sample was retained for physical characterization analysis from the clay unit immediately below the saturated

water-bearing zone that was intended for monitoring. In each borehole, the auger extended at least 2 feet into the "confining unit" below the water-bearing sand to define the lower boundary of sand and to ensure that the clay was of sufficient thickness to warrant terminating the borehole. The soil samples were characterized with respect to grain size distribution, Atterberg limits, and moisture content.

A total of 41 soil samples were submitted for physical analysis. (Note: Three samples were analyzed from boring D-3. At D-5, the second sand unit encountered was at least 22 feet thick. One soil sample was collected from this unit. However, after drilling to a depth of 65 feet, no confining clay unit was encountered; therefore, only one soil sample was submitted for analysis from this location.)

The results from all soil sample analyses are discussed in Section 4.1 and presented in Appendix C.

3.5 Groundwater Sampling

Because the intent of this investigation was to determine the physical hydrogeologic setting of the lagoon area only, laboratory analyses of groundwater were not conducted. However, field measurements were made as described in the following paragraphs.

Temperature, pH, and specific conductance measurements were made in the field after the piezometers were installed and developed. The following methods were followed to determine pH, temperature, and specific conductivity in the field:

- After purging the well of three well volumes, lower a 1-liter capacity pre-cleaned Teflon bailer into the well, avoid agitation of the water column; pour sample into a clean wide-mouth container.

- Immediately determine the ambient groundwater temperature using a factory-calibrated, mercury-in-glass thermometer. Record the temperature in the sampling log.

- Measure the pH and conductivity of a grab sample from the well using a Myron conductivity meter, or comparable device.

  -- Calibrate the pH meter daily using pH buffer solutions of 4, 7, and 10 (consult the user's manual for details of the calibration procedure);

  -- Calibrate the conductivity meter daily using a standard solution (i.e.,1413 umhos/cm @ 25°C) (consult the user's manual for details of the calibration procedure);

  -- Rinse the sample cup thoroughly with distilled water before adding sample or standard;

  -- Fill and pre-rinse the sample cup with well water three times before measuring pH and conductivity;

  -- Determine the pH and conductivity of the sample; (be sure to select and note the appropriate range scale) and record the values in the sampling log; and

  -- Clean the pH/conductivity meter electrodes by triple-rinsing with distilled water.

Results of these measurements are presented and discussed in Section 4.2.3 of this report.

3.5.1 Static Water Level Measurement

Two rounds of static water level measurements were conducted during this investigation. The information was used to prepare potentiometric

surface maps, which were in turn used to determine the hydraulic gradient beneath the site. Each round of measurements provided valuable information on the configuration of the potentiometric surface and direction of groundwater flow at the time of sampling. Furthermore, compilation and comparison of these data with rainfall events was particularly useful in identifying any changes in the water table due to surface water infiltration.

An Olympic brand electric line was used to determine the depth to water in each well. A steel tape was also used to calibrate the E-line and to check the accuracy of the results. The Olympic brand E-line utilizes an indicator probe attached by an insulated wire line to an electric meter. When the probe contacts water, an electric circuit is completed, and either a light illuminates or a buzzer sounds. The stepwise procedures used at Holloman AFB are outlined below:

1. Calibrate the insulated wire line of the E-line against a steel tape before each trip to verify that the actual length corresponds to the marked length. If they do not correspond, determine the correction factor and record it in the sampling log. Test the battery.

2. Decontaminate the probe and line of the E-line between wells. Do not immerse the spool. Do not allow the clean line to contact the ground or other potentially contaminated surface prior to use.

3. Remove the locking and protective cap from the piezometer. Locate the surveyed markpoint on the top of the well casing. If measuring water levels in boreholes, take measurement from land surface.

4. Slowly lower the E-line probe into the well casing or open borehole until the probe contacts the water surface. Contact will be indicated either by a visual or audible signal, depending on the instrument setting.

5. Measure the depth to water from the markpoint on the wire line to the nearest 0.01 foot using a steel tape. Record the depth in the project logbook.

6. Raise the probe above the water level and repeat steps 4 and 5 to verify the water level measurement. Exercise care when raising and lowering the probe to avoid entangling the electric line.

Water level maps and groundwater flow gradients based upon static water levels are discussed in Section 4.2.2 of this report.

3.6 Aquifer Testing

After the piezometers were installed, two types of aquifer tests were performed: a single-well slug-recovery test and a multiple-well pump test. A total of 10 single-well slug-recovery tests were performed. Two pump tests were also performed. The aquifer test methods are described below.

3.6.1 Slug-Recovery Tests

After the 22 piezometers were installed and developed, single-well slug-recovery tests of 10 piezometers were performed. However, results were obtained from only nine wells. Piezometer S-10 was used as a slug-test well, but did not respond due to a shallow saturated zone. The slug immediately dissipated into the unsaturated sandpack above the water table. All other slug tests (nine) were successful. The slug-recovery test was used to determine the hydraulic conductivity (K) and transmissivity (T) of the aquifer according to the methods outlined by Ferris and Knowles (Methods for Determining Permeability, Transmissivity and Drawdown, USGS Water Supply Paper 1536-I, 1963). The results were used for comparison purposes with more elaborate pump tests described below. The slug-recovery procedures and results are presented in Sections 4.3.1 through 4.3.4.

3.6.2 Pump Tests

The purpose of the pump test was to define the upper and lower aquifer limits of two fairly distinct saturated sand units identified by this and previous investigations (Wilson, 1986), and to determine whether a semi-continuous clay unit separating the two saturated sand units is confining, that is, of low enough permeability to minimize the passage of contaminants to stratigraphically lower saturated units (RCRA TEGD, 1986).

The resultant transmissivity and hydraulic conductivity of the deep and shallow sand units were then determined. The data derived from the pump tests and slug-recovery tests were compared to each other and to existing hydraulic data from Wilson (1986) and the USGS (1985). The results of the pump tests were used to determine the aquifer characteristics and to predict horizontal and vertical migration of groundwater beneath the areas adjacent to the lagoons. Pump test procedures and results are presented in Section 4.4.

3.6.3 Surveying

At the conclusion of well installation activities, the piezometers were surveyed by Daniel Engineering, a New Mexico licensed and registered surveyor from Alamogordo, New Mexico. The elevations of the piezometers were referenced to the 1929 National Geodetic Vertical Datum and to the UTMS coordinate system. The results of the survey are presented in Appendix D of this report.

As required in the scope of services contract, all elevation and distance measurements were maintained as follows:

- The top of ground elevation to the nearest 0.01 foot;
- The top of the well casing elevation to the nearest 0.01 foot;

- Survey points taken from the top of the well casing were permanently marked for future reference; and

- Horizontal coordinates were within 1.0 foot from section corners on base.

4.0 DISCUSSION OF RESULTS AND SIGNIFICANCE OF FINDINGS

This section discusses geologic and hydrogeologic results and significance of findings in the vicinity of the base sewage lagoons. Geologic conditions are described by zone and by site. Results of soils analyses for physical characteristics are discussed. Hydrogeologic interpretations are made on the basis of observed water-level elevations, shallow slug-recovery tests, and deeper zone pump tests and physical characteristics of the geologic formations.

4.1 Geologic Data

In this subsection, geologic conditions observed during drilling operations are discussed and results of soils analyses are presented. Results of previous geologic investigations are incorporated where possible. Lithologic logs of all wells installed as part of this investigation are presented in Appendix E and as a series of cross-sections shown as eight plates. A location map showing eight geologic cross-sections is shown in Figure 4-1. The corresponding plates of geologic cross-sections are presented at the end of this report.

4.1.1 Zone 1

Zone 1 encompasses the area upgradient of the sewage lagoon area. Soil borings S-1, S-2, S-12, and D-3 were drilled in this zone. USGS well SH-1 was installed in this zone during the USGS investigation conducted in 1985. Cross-section H-H'(Plate 8), runs north to south across Zone 1 and incorporates S-1, S-2, S-12, and D-3.

Subsurface soils in this area consist of very fine-grained sand, silt, and clay. In the northern part of the zone (at S-12 and D-3), a tan sandy silt was encountered during the first 3 feet of drilling. At S-1 and S-2, in the southern part of Zone 1, silt occurs from ground surface to a

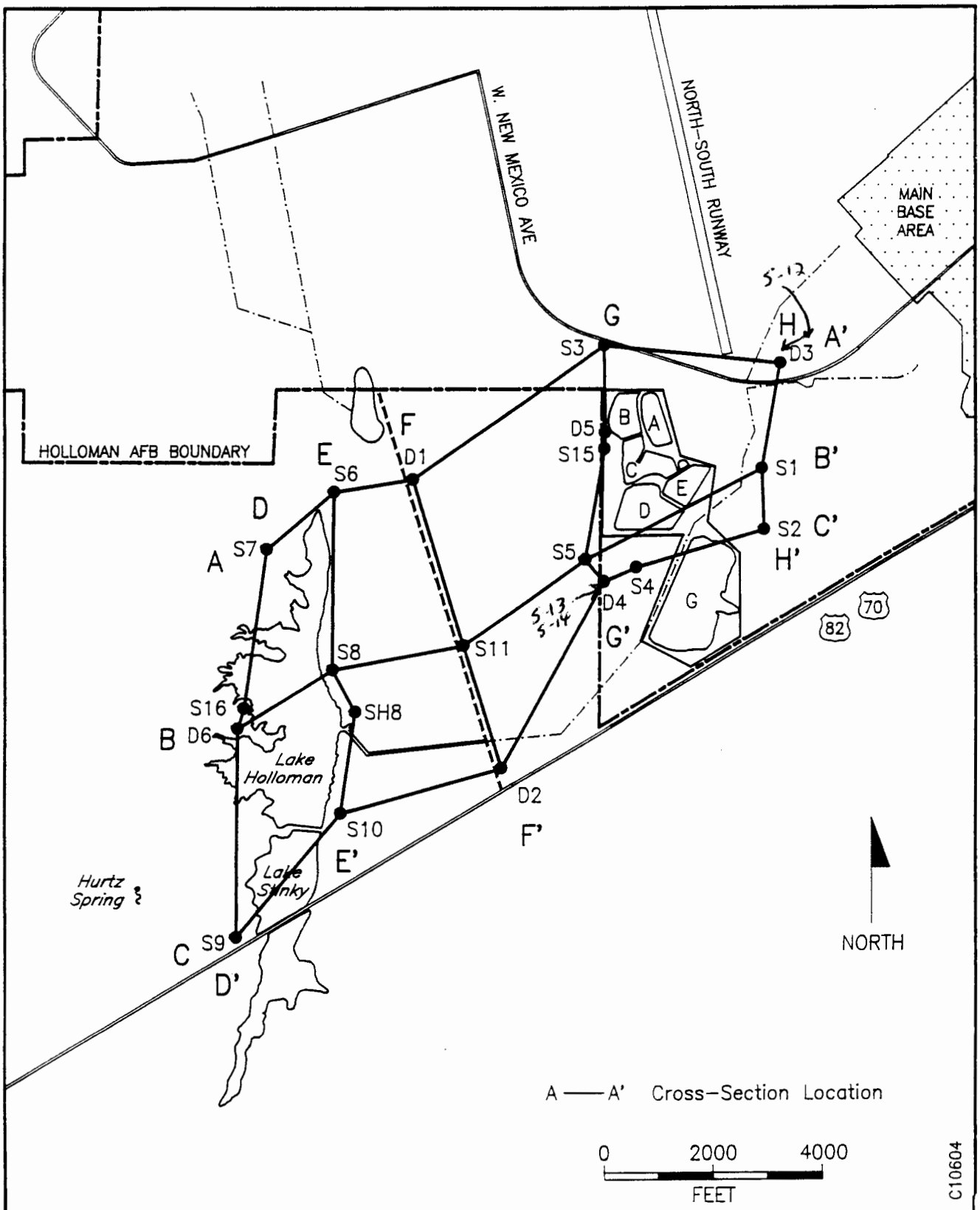


Figure 4-1. Location Map Showing Eight Geologic Cross-Sections (A-H), Holloman AFB, New Mexico

depth of approximately 7 to 10 feet. Here the silt is brown, tan, and light reddish-brown and is also slightly sandy. Sand was encountered below the silt in all Zone 1 borings. The thickness of the sand ranges from about 3 feet at S-1 to about 10 feet at S-2 (including a 2-foot thick layer of sandy silt). The sand is quartzose, very fine-grained, clayey, and generally saturated. This sand was the first saturated zone encountered in Zone 1.

Beneath the sand, clay was encountered at S-2, S-12, and D-3. The field description of the lithology encountered in S-1 at 13 feet was clay. However, grain size distribution results of the soil sample collected at this depth show the soil to be a clayey sand and not a clay. Although clay was not encountered at S-1, correlation with other borings in the area suggests that clay is likely to be present at S-1 at depths of about 18 feet, 3 feet below the total depth sampled. The clay layer of Zone 1 consists of a reddish-brown to greenish-tan clay of low plasticity. Gypsum crystals are abundant in places. The clay is generally dry to moist. Although S-2 and S-12 penetrate only about the upper 2 feet of the clay layer, boring D-3 penetrates the entire thickness of the clay. This dominantly clay layer at D-3 is approximately 45 feet thick, including a 5-foot thick layer of clayey silt. Beneath the clay, a 15-foot thick layer of silt and sand is present. This layer is composed of a greenish-gray to reddish-brown silt with interlayered greenish-gray, very fine-grained sand. The silt and sand are moist to saturated and are underlain by a grayish-green silty clay.

4.1.2 Zone 2

Zone 2 includes the area immediately north and west of the sewage treatment lagoons. Borings S-3, S-4, S-5, S-13, S-14, S-15, D-4, and D-5 were drilled in this zone. USGS wells SH-2 A and B, SH-3 A and B, SH-4 A and B, SH-5, SH-6 A and B, and SH-7 were installed in this zone during the previous USGS investigation. Cross-section G-G', running from the northern end of the zone to the south, is shown in Plate 7. This cross-section includes borings S-3, D-5, S-15, SH-7, S-5, and D-4.

Subsurface soils found in Zone 2 are consistent with those present in Zone 1. The soil profile in Zone 2 consists of silt, sand, and clay. The uppermost lithology is a brown to tan silt. The silt ranges in thickness from approximately 2 feet to 7 feet. At S-15, directly downgradient of sewage lagoon D, the uppermost silt layer is light tan to whitish in color and saturated, with black discoloration at approximately 13 inches bls. At all locations in Zone 2, the silt grades into a very fine-grained sand. This sand ranges in thickness from about 3 feet at S-15 to 14 feet at D-4. The sand is light tan to brown in color, quartzose, clayey in places, and commonly silty. Gypsum grains are present in trace amounts. The sand is wet to saturated.

Beneath the sand is a clay layer. The thickness of clay encountered ranges from 5 feet at S-3 to 13 feet at SH-7. The clay was completely penetrated only at boring D-5, where it is about 20 feet thick. Here, the overlying sand layer graded to a clayey sand, then into clay. The clay is reddish-brown to light green, silty, and contains gypsum crystals in scattered "pockets" throughout the unit. The clay is slightly moist to moist. The clay encountered at S-3, S-5, S-14, and S-15 was similar but slightly sandy. At deep well D-4, the clay was very heterogeneous, consisting of interbedded sand and clay layers from 18 feet to 58 feet bls.

Lithologic logs from the previous USGS investigation reveal similar lithologies to those described above. SH-2, -3, -4, -5, -6, and -7 were drilled downgradient of Lagoon D, just south of borings D-5 and S-15. The uppermost layer encountered at most of these locations was a fine-grained white sand (with a sewage odor at SH-2, -3, and -4). At SH-6 and -7, the uppermost layer is a dark brown or white silt 5 to 7 feet thick underlain by fine-grained wet sand approximately 10 feet thick. Clay was encountered below the sand at all USGS well locations. The clay is described as varying in color from brown to red-brown to red-yellow to white; silty, with abundant gypsum crystals. The thickness of the clay at SH-5 (where it was completely penetrated) is about 40 feet. At SH-5, a second sand unit (8 feet thick) occurs below the clay, followed by a second clay unit approximately 42 feet

thick. This second clay unit is underlain by sand from 111 to 121 feet and interbedded sand and clay from 121 to 188 feet.

4.1.3 Zone 3

Zone 3 consists of the area from a north-south line half-way between the sewage treatment lagoons and Lakes Holloman and Stinky to the eastern sides of the two lakes. Borings D-1, S-11, D-2, S-6, S-8, and S-10 were drilled in this zone. Boring SH-8 was drilled during the previous USGS investigation. Two cross-sections were constructed for this zone, both running from north to south. Cross-section E-E' includes boring S-6, S-8, SH-8, and S-10. Cross-section F-F' includes borings D-1, S-11, and D-2. These cross-sections are shown in Plates 5 and 6.

Soils present in Zone 3 include sand, silt, and clay. Silt was the first unit encountered while drilling at S-6, S-8, S-10, and S-11. This silt layer ranges in thickness from approximately 3 feet at S-6 to about 7 feet at S-8. The silt is light tan to brown in color, slightly sandy, with minor gypsum and organic material in some locations. It is loose to slightly cohesive and dry to slightly moist. Underlying the silt in these four borings is a sand layer 4 to 10 feet thick. At S-6, the sand is underlain by 2 feet of silt. At S-10, the sand is underlain by 7 feet of silt followed by 5 more feet of sand. The first sand layer at S-8 and S-11, and the sand and silt layers at S-6 and S-10, were the first saturated zones encountered in borings S-6, S-8, S-10, and S-11.

At borings SH-8, D-1, and D-2, sand was the first unit encountered while drilling. The sand ranges in thickness from 2 feet at D-2 to about 11 feet at SH-8. At D-1 and D-2, the sand is underlain by 4 to 7 feet of silt followed by a second sand layer. At D-1 and D-2, this second sand layer (at a depth of 7 to 8 feet below ground level) was the first saturated zone encountered.

These upper layers of saturated sand and silt vary in color from light tan to light brown to light tannish-gray to light reddish-brown. The sand is quartzose in composition with minor gypsum and minor dark accessory minerals. It is very fine-grained and slightly silty and/or clayey in places. The silt is commonly sandy and clayey.

The first saturated zone is underlain by clay at S-6, S-8, S-11, D-1, and D-2. This clay varies in thickness from approximately 3 feet at S-11 and D-1, to 5 feet at S-6, S-8, and D-2. At S-10, the first saturated zone is underlain by approximately 5 feet of interlayered sand, silt, and clay which grades into a clay layer at least 8.5 feet thick. The clay layer underlying the shallow saturated zone is generally reddish-brown to grayish-green in color, silty, with some gypsum crystals and trace amounts of very fine-grained sand. It is stiff, has low plasticity, and is moist.

Lithologic units underlying the uppermost clay vary greatly from boring to boring. All borings except S-10 penetrated the first clay completely. At S-6, the clay is underlain by a thick layer of sand (about 24 feet thick). This sand is in turn underlain by clayey silt and sand followed by another clay layer at least 3 feet thick. At S-8 and S-11, about one foot of silt was encountered under the clay, followed at S-11 by at least 3 feet of sand. At D-1, the clay is underlain by 15 feet of sand, 2 feet of silt, 13 feet of clay, another layer of silt 20 feet thick, with a layer of clay at the bottom of the borehole at least 4 feet thick. The first clay layer at D-2 is underlain by about 13 feet of alternating sand and silt, followed by a 16-foot thick layer of clay, an 8-foot thick layer of sand and clay, and, at the bottom of the borehole, by at least 14 feet of clay. The sand and silt layers encountered under the clay are moist to wet; the clay layers are very slightly moist to moist.

4.1.4 Zone 4

Zone 4 consists of the western edge of Lakes Holloman and Stinky. Borings S-7, S-16, D-6, S-9, and B-1 were drilled in this zone. Cross-section

D-D′ was constructed from the lithologic logs of S-7, S-16, D-6, and S-9 and is shown in Plate 4.

Sand, silt, and clay were the lithologies encountered while drilling at Zone 4. The uppermost unit at all boring locations is a brown, sandy silt, ranging in thickness from 4 feet (at D-6) to 16 feet (at S-9). At S-9, the silt becomes saturated at about 12 feet bls. At S-7, S-16, and D-6, a very fine-grained sand was encountered below the silt and the sand is the first saturated zone. The sand is light tan to brown and quartzose in composition. The thickness of the sand ranges from 5 feet at S-7 and S-16 to 6 feet at D-6. Sandstone and sand were encountered under the silt while drilling at B-1. No saturated zones were found in this boring.

Lithologies underlying the first silt and sand units of Zone 4 vary greatly from boring to boring. At boring S-7, the shallow sand is directly underlain by a clay layer 3 feet thick. At S-16, the sand is underlain by silt and sand followed by a layer of interbedded sand and clay. At S-9, the uppermost silt and sand unit is underlain by about 5 feet of clay. At D-6, the first sand layer is underlain by 6 feet of interlayered sand and silt followed by another 6 feet of sand. This unit of sand and silt is underlain by a clay layer 6 feet thick. The clay layer is grayish-green to reddish-brown in color, soft to firm, moist, and contains scattered gypsum crystals. The sandstone and sand encountered at boring B-1 are underlain by 8 feet of sand and silt followed by 10 feet of sandstone and sand.

The clay layer (underlying the first saturated zone) was fully penetrated at S-7 and D-6. At S-7, alternating layers of sand and clay underlie the first clay unit. At D-6, the clay is underlain by a layer of sand at least 40 feet thick.

4.1.5 Interpretation of Site Geology

The general geology of the site is shown in part by three cross-sections which cover all four zones. Cross-sections A-A′, B-B′, and C-C′ (as

shown on Plates 1 through 3) run from east to west across the entire study area. The lithologies present appear to be generally consistent site-wide. The subsurface consists of a thin layer (3 to 11 feet thick) of dry silt and/or sand underlain by a saturated sand or sand and silt layer. Over most of the area, this shallow sand layer is underlain by a thin (approximately 2 to 7 feet thick) layer of clay. This clay layer is reddish-brown in color with abundant gypsum crystals. The clay is commonly sandy and/or silty. Where the clay layer is not present, the shallow sand is underlain by interbedded sand and clay or sand, silt, and clay.

Lithologic logs from deep borings show a second saturated zone of interbedded sand, silt, and clay underlying the clay layer. This layer is very heterogeneous and ranges in thickness from 34 feet at D-4 to about 50 feet at D-1.

The second saturated zone is underlain at three of the six deep boring locations by a green stiff, plastic clay. The clay was encountered at various depths in borings D-2, D-3, and D-4. This green clay may be present at locations D-1, D-5, and D-6 at elevations below the total depth drilled; however, cross-sections indicate that if present, the green clay should have been encountered during drilling.

A buried north-south trending vertical fault appears to cross the western edge of the site. The fault runs between Hurtz Spring and White Sands National Monument. Both surficial and subsurface evidence of the fault was found. On the ground surface, fault gouge was observed in a limestone outcrop (partially excavated) east of B-1. Results of field measurements taken at the outcrop show vertical joints and small scale north-south trending faults. It is possible that the outcrop and Hurtz Spring area represent the edge of the fault scarp and that the spring emerges at the surface along the fault plane. At S-9, D-6, and S-16, unconsolidated sands, silts, and clays were encountered. At B-1, consolidated sandstone and rock gouge were encountered at a depth of 7 feet. The sandstone is completely dissimilar to the Hueco

limestone outcrop located about 600 feet east. The sandstone is presumed to be recent in age, and is consolidated by calcite cement.

4.2 Hydrology

Section 4.2 describes the field results of surface water and groundwater field measurements made at Holloman AFB. Section 4.3 discusses the results of the slug testing. Pump-test results are presented in Section 4.4. Regulatory implications of the water quality results and aquifer tests are presented in Sections 5.5 and 5.6.

4.2.1 Surface Water

Surface water bodies in the study area consist of sewage lagoons and Lakes Holloman and Stinky. All are artificially recharged by base effluent and shallow groundwater. No natural water bodies exist in the base area.

Several random pH and conductivity measurements of the lagoons and impoundments were taken for comparison with groundwater measurements collected from the newly installed piezometers. The surface water measurements are listed below.

TABLE 4-1. RESULTS OF SURFACE WATER MEASUREMENTS

Impoundment	Date	pH	Conductivity (μmhos/cm^2)	Total Dissolved Solids (mg/L)
Lagoon A	11/18/87	NA*	4,250	2,975
Lagoon G	11/17/87	9.0	5,000	3,500
Running Water Draw	11/18/87	9.6	6,000	4,200
Lake Holloman	11/17/87	8.8	9,400	6,580

* Not analyzed

The pH of the surface water is slightly basic, likely attributable to the large amount of carbonate, bicarbonate, and other soluble ions in the water.

Specific conductance or conductivity of water is the ability of the water to transmit an electric current. Since conductivity is a function of the total dissolved solids (TDS) in the water, TDS may sometimes be indirectly estimated from conductivity. If the conductivity value is multiplied by 0.7, it is roughly equal to the dissolved solids content in milligrams per liter. However, this method only gives approximate values for total dissolved solids in water. This method was used to calculate TDS levels in surface water and groundwater.

The conductivity values and estimated TDS content indicate that the water quality of the lagoons is brackish (between 1,000 and 10,000 mg/L total dissolved solids). The water quality degrades (increases in total dissolved solids) downstream from Lagoon A as seen in the corresponding increase in total dissolved solids in Lagoon G and Lake Holloman. The total dissolved solids content of samples from Lake Holloman is more than twice that of Lagoon A. The observed increase is probably due to stagnation of surface water in the lake, and evaporation of surface water resulting in enrichment of ponded water with dissolved solids. As discussed in Section 1.2, groundwater is naturally high in dissolved solids (greater than 10,000 mg/L) as evidenced by groundwater samples collected during the course of this investigation. Also, the water table immediately upgradient from Lake Holloman is approximately at the same elevation as the surface of the lake suggesting hydraulic connection. An alternative suggestion is that mixing of poorer-quality (high TDS) groundwater and low TDS surface water from Lake Holloman is taking place.

4.2.2 Groundwater

Groundwater occurs under water table conditions at Holloman AFB. Depth to water ranges from 2 to 13 feet below land surface, increasing in depth from the sewage lagoons toward Lake Holloman (Table 4-2).

TABLE 4-2. WATER LEVELS AND FIELD MEASURED DATA HOLLOMAN AFB 16-18 NOVEMBER 1987

Well I.D.	Date	Depth to Water Below MP (ft.)	MP (ft.)	Depth to Water Below Surface (ft.)	Water Table Elevation (ft. msl)	pH	Conductivity (umhos/cm^2)	Remarks
S-1	11/17/87	6.80	2.73	4.07	4034.92	7.0	10,000*	--
S-2	11/17/87	9.19	2.57	6.62	4031.37	7.4	6,000	Clear, gassy
S-3	11/17/87	8.06	1.73	6.33	4034.60	7.3	10,000*	Gassy, clear, no odor or sediment
S-4	11/17/87	9.45	3.03	6.42	4025.01	6.7	10,000*	Clear, slightly yellow, no sediment
S-4	11/21/87	Lab Conductivity		--	--	--	56,400	Lab rerun for conductivity
S-5	11/17/87	9.81	2.15	7.66	4023.66	6.8	10,000*	Cloudy, silty
S-5	11/21/87	Lab Conductivity		--	--	--	51,700	Lab rerun for conductivity
S-6	11/16/87	12.21	2.08	10.13	4019.31	7.5	10,000*	Silty, cloudy
S-7	11/16/87	12.46	2.02	10.34	4017.78	7.9	10,000*	Cloudy, no odor, no sentiment
S-8	11/16/87	15.18	2.13	13.05	4017.97	8.3	10,000*	Gassy, no odor or sentiment
S-9	10/21/87	10.21	2.25	7.96	4010.48	--	--	--
S-10	11/16/87	13.99	2.15	11.84	4016.01	7.7	10,000*	11/17/87 Cloudy, slightly yellow
S-11	11/17/87	10.92	2.06	8.86	4016.31	6.9	10,000*	--
S-12	11/17/87	7.56	2.30	5.36	4040.75	7.2	10,000*	Cloudy, yellow
S-13	11/17/87	8.93	2.29	6.64	4023.41	6.8	10,000*	Gassy, fairly clear
S-14	11/17/87	8.77	2.20	6.57	4023.66	7.8	10,000*	Clear
S-15	11/18/87	4.75	2.85	1.9	4032.96	8.0	10,000*	Poss. malfunction; slightly silty, cloudy, gassy
S-16	11/16/87	11.13	2.0	9.13	4018.33	7.2	10,000*	Gassy, clear, no sediment

(Continued)

TABLE 4-2. (Cont.)

Well I.D.	Date	Depth to Water Below MP (ft.)	MP (ft.)	Depth to Water Below Surface (ft.)	Water Table Elevation (ft. msl)	pH	Conductivity (umhos/cm^2)	Remarks
D-1	11/17/87	8.94	2.32	6.62	4021.72	7.4	10,000*	Clear, no sediment
D-2	11/17/87	5.99	1.93	4.06	4017.31	7.7	10,000*	Clear, gassy
D-3	11/17/87	5.94	1.98	3.96	4041.47	8.2	10,000*	Clear
D-4	11/17/87	7.47	1.67	5.8	4024.39	7.2	10,000*	Clear
D-5	11/18/87	7.17	2.48	4.79	4032.07	NA	10,000*	Clear, gassy, very strong sewage odor
D-6	11/16/87	11.75	2.22	9.53	4018.45	7.6	10,000*	Gassy, clear, no odor
Lagoon A	11/18/87	--	--	--	--	NA	4,250	No pH recorded, instrument malfunction
Lagoon G	11/17/87	--	--	--	--	9.0	5,000	Collected on bank nearest S-2
Lake Holloman	11/17/87	--	--	--	--	8.8	9,400	West of S-10, green algae color, sewage odor
Running Water Draw	11/17/87	--	--	--	--	9.6	6,000	Collected from dam

*Sample conductivity greater than instrument detection limit (10,000 μmhos/cm^2).

NA = Not analyzed.

MP = Measuring point.

Hydraulic Gradient

Plate P-10 depicts the hydraulic gradient beneath the area of the investigation measured 17-18 November 1987. Water table elevations of each well are shown in Table 4-2. The hydraulic gradient, dh/dl, was derived from the contour map and incorporated into the equation for groundwater flow discussed in 4.3.5. The contour lines are shown at 2-foot intervals; they connect points of equal head. The movement of groundwater is perpendicular to these lines and in the direction of decreasing head. The water level contour map from the 17-18 November sampling episode was drawn using a gridding package (CPS-1), and was checked against hand plotted water level data for accuracy. The algorithm uses tangential projections from higher heads to lower heads to predict groundwater flow. Water levels fluctuated very little during the field investigation. USGS well elevations were measured; elevations were consistent with previous studies (Wilson, 1986). The average hydraulic gradient during the sampling episode was 0.3 percent, which is consistent with previous reported gradients (Wilson, 1986).

The horizontal hydraulic gradient is fairly consistent (equally spaced contour lines) from northeast to southwest as shown in Plate P-10. The water table elevation is highest near the upgradient well cluster (S-12, D-3, and P-1). A slight flexure is evident in the contour lines as they pass underneath the sewage treatment lagoons. This flexure is likely representative of groundwater mounding beneath the lagoons. The hydraulic gradient flattens out between the sewage lagoons and Lake Holloman as evidenced by the distance between contour lines 4018 and 4020.

A shift in the horizontal hydraulic gradient occurs east of Lake Holloman based upon water levels in piezometers S-8, S-10, S-11, and D-2. Groundwater flow is redirected from Lake Holloman to the south-southeast toward D-2. Mounding may be caused by either the topographic high near Hurtz Spring (and bedrock outcrop area), or Lake Holloman and the backed-up portion of the runoff ditch.

West of Lake Holloman, the horizontal hydraulic gradient is redirected toward the southwest, based upon water table data from S-9. The downgradient flow west of the lakes assumes the regional southwestern gradient toward Lake Lucero.

In summary, a groundwater divide occurs between the sewage lagoons and Lake Holloman. The divide is the result of either a topographic high west of Lake Holloman which causes groundwater to flow toward the south, and/or mounding underneath Lake Holloman, which has redirected groundwater originally moving southwest from the sewage lagoons toward Lake Holloman to the south toward D-2. West of Lake Holloman, groundwater resumes a southwesterly flow.

West of Hurtz Spring, the water table is believed to be at least 30 feet below land surface. A shallow soil boring (B-1) drilled west of Hurtz Spring did not encounter groundwater at the completion depth (30 feet). The auger encountered sandstone and could not penetrate the rock beyond that depth. However, by extrapolating water table contours, it is likely that the borehole was completed above the water table in this area (about the same elevation as Lake Holloman), since the borehole was installed on a high rise approximately 30 feet higher than the lake.

4.2.3 Groundwater Quality Results

Field pH and conductivity measurements were taken from 20 piezometers between 16 - 18 November 1987. The results are presented in Table 4-2. Generally, pH values ranged between 7.0 and 8.0 pH units. The lowest pH value was 6.8, taken at S-13; the highest pH was 8.3 in S-8. Results indicate that groundwater beneath the base appears to be neutral to slightly alkaline. From a water quality aspect, the neutral to slightly alkaline groundwater would tend to reduce the solubility and mobility of metals. The silty, clayey sands tend to absorb dissolved metals, also reducing their mobility. In comparing the pH of groundwater and surface water, the groundwater is less alkaline.

Groundwater conductivities exceeded 10,000 μmhos/cm^2 (the maximum instrument detection limit) in all but one piezometer (S-2). Since the instrument could not record conductivities in excess of 10,000 μmhos/cm^2, water samples from three piezometers, S-4, S-5, and D-2, were returned to Austin for laboratory determination of conductivity. Groundwater in S-4 had a conductivity value of 56,400 μmhos/cm^2; samples from piezometers S-5 and D-2 were lower, with values of 51,700 μmhos/cm^2 and 25,300 μmhos/cm^2, respectively. The conductivity readings from these three samples indicate that groundwater is high in total dissolved solids, ranging from approximately 17,700 mg/L (D-2) to 39,480 mg/L (S-4) or greater in this area. Based upon these high values, the water is classified as saline (10,000 - 100,000 mg/L).

Groundwater in piezometer S-2 had the lowest groundwater conductivity reading, 6,000 μmhos/cm^2. Referring back to surface water conductivities, particularly Lagoon G (5,000 μmhos/cm^2), it is likely that groundwater in the vicinity of S-2 is "improved" through mixing of "fresher" (lower TDS) water from Lagoon G. Lagoon G is approximately 39.75 acres in size and is located about 700 feet south of S-2. Lagoon G is subject to leakage since the lagoon is in a sandy soil and is unlined. These factors could result in surface water/groundwater mixing in this particular area. This may also indicate mounding of groundwater.

Groundwater conductivity values in all other piezometers are greater than 10,000 μmhos/cm^2, which indicates that TDS values are equally high.

Field Water Quality Observations

Piezometers were developed to sand-free conditions as possible. However, some silt-size particles were still present after development, but only in three piezometers. Because of a high carbonate-bicarbonate content, the groundwater is very gassy. Groundwater was generally clear and ranged between 17 and 23 degrees Celsius.

Only one piezometer installed during this investigation (D-5) contained water suspected to be contaminated as evidenced by a strong sewage odor in the water. The piezometer was installed 63 feet west of a ditch paralleling Lagoon A and 216 feet west of the bank of Lagoon A. The ditch empties into a broad open plain in Zone 3. No strong sewage odors were evident in the ditch. The ditch appears to intercept road runoff from the main taxiway and west New Mexico Avenue. No other water samples from Radian-installed piezometers revealed abnormal discoloration or noticeable odors when sampled.

Interestingly, S-15, the shallow piezometer 300 feet south of D-5 and 350 feet west of Lagoon C, did not reveal sewage odors when sampled. The well is screened from 4 to 9 feet below land surface. The significance of the presence of contaminants in D-5 will be discussed in Section 5.2.3.

USGS Wells

A total of twelve USGS wells were installed around the sewage lagoons in 1985 to determine the hydrogeologic characteristics of the bolson fill near the sewage treatment lagoon area. These wells were later sampled for organic and inorganic contaminants (Wilson, 1986). At present, the wells are unusable as monitoring wells because they have been left uncapped for an indeterminate length of time. Two of the wells, SH-2B and SH-5, located near Lagoon D, exhibited extremely offensive sewage odors when examined (refer to Figure 2-6). Either animal (rodent) feces or a carcass of a rodent-sized animal was observed floating in USGS well, SH-2B. The odor in the other USGS well (SH-5) was attributed to either a dead animal in the well or from leakage of Lagoon D. Based upon the USGS report (1985), the wells are suspect in construction and completion integrity as well. Recommendations for abandonment of USGS wells are presented in Section 6.1.

The pH of groundwater in the USGS wells adjacent to Lagoon D averaged 6.3 pH units. As in the other piezometers, conductivities were off-scale (greater than 10,000 μmhos/cm^2). Conductivity and pH values in Lagoon D were previously reported as 4,480 μmhos/cm^2 and 8.3, respectively

(Wilson, 1986). Field water quality measurements from Lagoon D were not obtained during this investigation. However, the water conductivity reading of Lagoon D, reported previously, closely resembled the conductivity reading taken in Lagoon A during this investigation (4,250 μmhos/cm^2). It is likely that surface water within Lagoons A through D varies very little in pH and conductivity.

4.3 Aquifer Testing

This section describes the purpose, procedures, and results of aquifer testing activities conducted during the hydrogeologic investigation at Holloman AFB. Two types of aquifer tests were performed at the base: slug tests and pump tests.

The purpose of aquifer testing is to determine aquifer characteristics such as:

- Transmissivity: Amount of water transmitted horizontally through aquifer under a hydraulic gradient of 1;

- Storage coefficient: Volume of water absorbed or expelled from storage per unit surface area, per unit change in hydraulic head; and

- Hydraulic conductivity: Coefficient of proportionality describing rate at which water moves through a medium.

From these data, groundwater flow velocity can be calculated. Pump tests can also be used to establish whether vertical hydraulic communication exists between aquifers.

4.3.1 Slug Tests

The slug test is an aquifer test made by either pouring a small, instantaneous charge of water into a well or by withdrawing a slug of water from the well (Fetter, 1980). Slug tests are best suited for low permeability materials or where conditions prohibit a pump test. Wells with low hydraulic conductivity or shallow wells with short screen lengths that would not transmit enough water for pump testing are candidates for slug tests.

4.3.2 Slug Test Procedures

Slug-injection tests were conducted on nine piezometers during November 1987 (Table 4-3). Slug injection was preferred over slug withdrawal because of the relatively straightforward procedures involved and because of possible greater filter pack effects on data analysis with slug withdrawal. A slug recovery test was performed on one piezometer and compared against the slug data.

Before the slug test was conducted, the static water level in the piezometer was established with an electrical conductance-type measuring device (Olympic Well Probe). After the water level was measured, one to two gallons of formation water were hand-bailed (PVC bailer) and placed into a clean, plastic bucket. The bailed formation water was later used as the slug of water injected into that piezometer. This procedure maintained the chemical integrity of water around the piezometer. After bailing, the water level was allowed to recover before the slug test was conducted. The water levels in the piezometers recovered quickly. Generally, the time between bailing and slug testing was two hours or more.

When the water level had completely recovered in the piezometer, the slug test was conducted. A pressure transducer, connected to a battery-operated data recording device (Hermit SE 1000 B Environmental Data Logger), was used to measure water levels in the piezometers during the slug tests.

TABLE 4-3. SLUG TEST WELLS AND CONDITIONS INCLUDING LENGTH OF TEST, VOLUME OF SLUG, AND INITIAL WATER LEVELS, HOLLOMAN AFB, NEW MEXICO

Location	Type	Duration (min.)	Volume Injected (gal.)	Transducer Depth (ft.)	Date
S-16	Slug	88	1.0	4.0	11/18/87
D-2	Slug	60	1.0	5.05	11/18/87
*S-10	Slug	18	1.3	--	11/17/87
S-5	Slug	18	1.0	3.81	11/18/87
D-5	Slug	60	1.25	5.05	11/18/87
S-4	Slug	32	1.4	3.96	11/17/87
S-8	Slug	86	1.0	5.03	11/17/87
S-15	Slug	46	1.0	7.00	11/18/87
S-11	Slug	50	1.0	5.00	11/17/87
S-2	Recovery	20	--	24.00	11/04/87

*No data recovered; slug instantly dissipated into unsaturated sandpack.

The pressure transducer was lowered into the piezometer and secured with tape around the protective casing to ensure limited transducer movement. The transducer was generally set from 3 to 7 feet below water level in the piezometer. The data logging unit was programmed to record water levels on a logarithmic cycle as follows:

Time Elapsed	Reading Intervals
0 - 2 sec.	0.2 sec.
2 - 20 sec.	1 sec.
20 - 120 sec.	5 sec.
2 - 10 min.	30 sec.
10 - 100 min.	2 min.

The data logger was activated to begin collecting data at the time of slug injection. This allowed the arrival of the injected slug to be timed. Between 1.0 and 1.4 gallons was injected during the slug tests (Table 4-3). The water was poured from the plastic bucket into a modified, plastic funnel that enhanced the arrival time of the slug. Care was taken to ensure that all water was injected into the piezometer.

After injecting the slug, field personnel left the site to start another test using another transducer and data logger. Slug tests lasted from 18 to 88 minutes (Table 4-3), depending primarily on how fast field personnel could get back to the site. Since the test was conducted using automatic recording devices, it was not critical for personnel to be on site at the time of recovery to initial water levels. It was critical, however, to continue the tests to at least 95% of total initial head recovery.

Before each slug test ended, the data in the logging unit were output to a hard copy using a field printer. This allowed field personnel to not only have a hard copy of the data but also to evaluate whether recovery was complete. If recovery was complete, the test was ended and the transducer was pulled from the piezometer.

4.3.3 Slug-Injection Data Analysis Methods and Limitations

Analysis of slug-injection tests consists of observing water level recovery after slug injection and the time elapsed since slug injection. When a comparatively small volume of water is instantaneously injected into a well, the well is considered to be an instantaneous vertical line source (Ferris and Knowles, 1963). The rate at which the water level falls back to static conditions is primarily controlled by formation characteristics, although unsaturated formation or filter packs can affect the rate by absorbing some of the slug before the formation does.

The method of analysis of the Holloman AFB slug tests is that of Ferris and Knowles (1954). The transmissivity of the material in the immediate vicinity of the piezometer can be estimated by the formula:

$$T = \frac{114.6\ q\ (1/tm)}{s} \qquad (4\text{-}1)$$

where, T = transmissivity (gallons per day per foot, gpd/ft),
q = volume of the slug (gallons),
tm = time in minutes since slug was injected, and
s = residual head after injection of slug (feet).

The equation is solved graphically from a plot of residual head(s) versus the reciprocal of time in minutes (1/tm) since the slug injection. The residual head(s) at any instant is the difference between the observed water level and the initial, pre-slug water level.

The method of Ferris and Knowles (1954) is best suited for wells that are under artesian conditions and are screened through the saturated thickness of the aquifer. It can be used for wells in water conditions if care is used and if it is understood that not all assumptions used in the solution will be met.

4.3.4 Results of Slug Tests

Data Reduction

Slug test data are presented in Appendix F. This includes the strip chart print-out of water level changes recorded by the data logger. Also presented in Appendix E are the tables generated from the field print-out and the graphical plots of residual head(s) versus the reciprocal of time (1/tm).

Figure 4-2 is the graphical plot of the data from the slug test at D-2. It shows the data (time, reciprocal of time, and residual head) from the slug test used in constructing the graphical plot. Not all data were used to construct the plot since there were more data than actually needed.

The plot of the slug test data for D-2 shows a curvilinear relationship (Figure 4-2). The data used to calculate aquifer characteristics are on the left side of the plot. The initial one minute (right side tail) or so of the slug test does not yield data concerning formation characteristics since: (1) the injected slug causes turbulence in the casing; (2) the slug forces water into the sand pack and formation due strictly to the weight (force); and (3) back-wash effects are induced as water tries to come back into the casing after being forced out of the casing. In short, approximately the first one minute of the slug test represents extremely perturbed hydraulic conditions in and around the well bore. To solve for transmissivity (T), a straight line is drawn from the origin through those data points that define a straight line from a reciprocal of time values 0.8 to 1.0 (Figure 4-2).

In some instances, the field print-out did not initialize at a water level of 0.00. This number has to be subtracted from the next value to get residual head(s). Since it is the relative change in water level that is needed, the initial non-zero value is not critical or significant to the succeeding calculations.

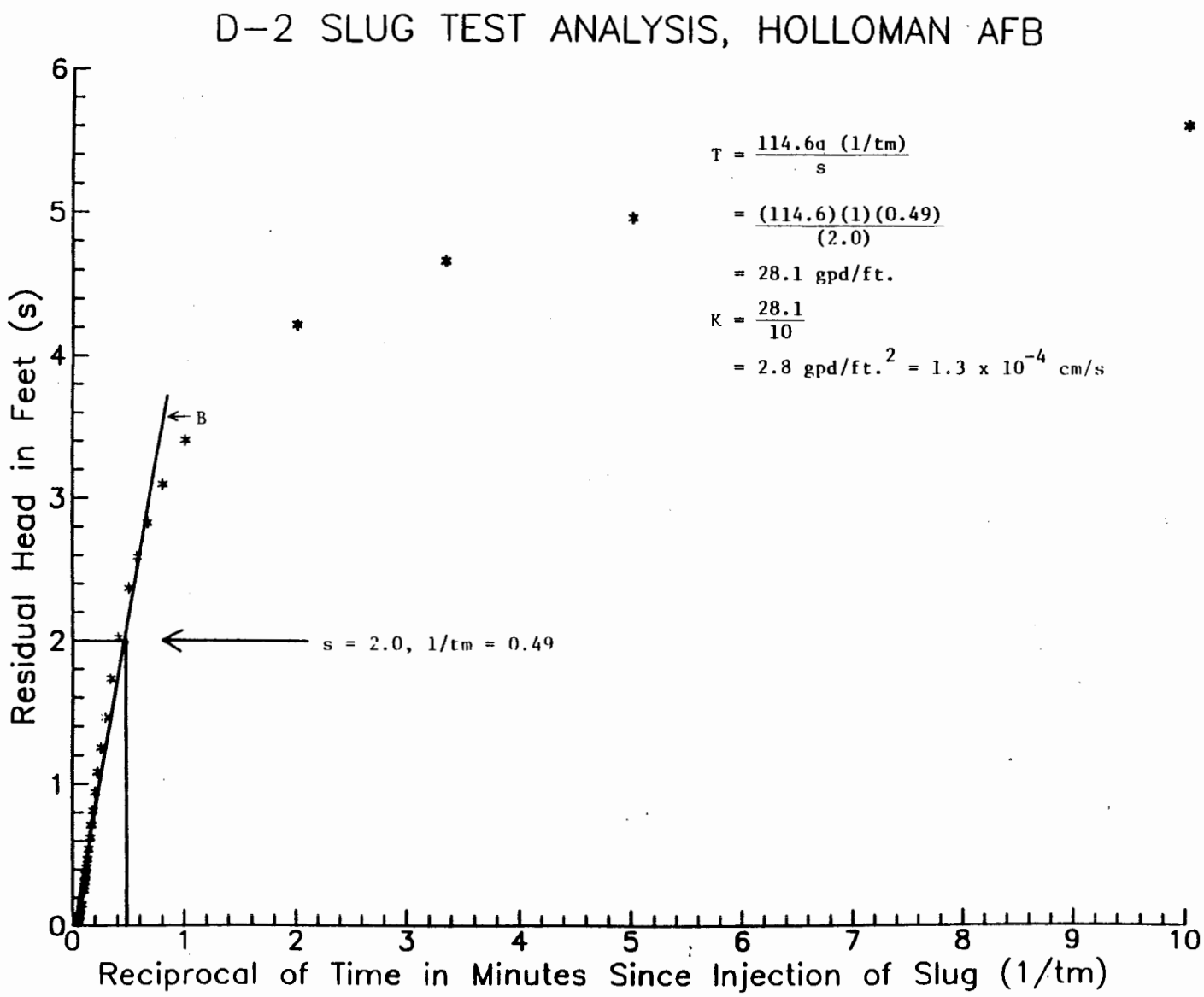


Figure 4-2. Graphical Determination of Transmissivity and Hydraulic Conductivity Using Slug Test Data, Holloman AFB, New Mexico

The slope(B) line is used for calculating transmissivity (T) as in equation 4-1. A point, generally about midway along the line, is used as the value for s and 1/tm in the equation. For example, Figure 4-2 shows the point along the line used in the calculation of transmissivity. The calculation of transmissivity is also shown on Figure 4-2. Hydraulic conductivity (K) is the transmissivity divided by the saturated screen length. Figure 4-2 shows this calculation in American practical units (gallons per day per square foot).

Table 4-4 presents the results of the slug tests conducted at Holloman AFB. Graphical methods of determining T and K are shown in Appendix E. The range of values for transmissivity is between 28.1 and 427.8 gpd/ft. The range of hydraulic conductivities is from 3.1 to 85.6 gpd/ft^2 (1.5×10^{-4} to 4.0×10^{-3} cm/sec). The average hydraulic conductivity of all nine piezometers tested was 46 gpd/ft^2 (2.2×10^{-3} cm/sec). The average transmissivity value, based upon the slug test results, was 219 gpd/ft. for the nine piezometers.

4.3.5 Groundwater Velocity Based Upon Slug Tests

As discussed earlier, groundwater flow is toward the southwest. The hydraulic gradient dh/dl was determined to be 0.003 based upon a head difference of 20 feet over a length of 5,775 feet (from Plate P-10). The equation for horizontal velocity (V) is derived from Darcy's flux velocity and the continuity equation and presented below:

$$\text{Velocity (v)} = \frac{K\ (dh/dl)}{7.5\ a} \qquad (4\text{-}2)$$

where, K = hydraulic conductivity (gpd/ft^2),

dh/dl = hydraulic gradient,

7.5 = conversion factor to English system (7.5 gallons/ft^3), and

a = porosity (decimal).

This equation was used to determine the horizontal velocity of groundwater beneath the site. Table 4-4 presents groundwater velocity calculations based upon the results of the hydrogeologic investigation. Porosity values were assigned based upon soils characterization results and published information. Variables and algebraic solutions of equation 4-2 are presented in Appendix F.

TABLE 4-4. HORIZONTAL GROUNDWATER VELOCITY RESULTS FROM NINE SLUG TESTS, HOLLOMAN AFB, NEW MEXICO

Well Number	Hydraulic Conductivity (gpd/ft^2)	Hydraulic Conductivity (cm/sec)	Porosity[a] (%)	Velocity[b] (ft/day)	Velocity[b] (ft/year)
S-2	7.1	3.3×10^{-5}	40	0.007	2.6
S-4	85.6	4.0×10^{-3}	30	0.13	47.5
S-5	61.8	2.9×10^{-3}	40	0.07	25.6
S-8	56.2	2.6×10^{-3}	40	0.06	20.5
S-11	80.2	3.8×10^{-3}	30	0.12	43.8
S-15	69.9	3.3×10^{-3}	30	0.11	40.2
S-16	45.8	2.2×10^{-3}	40	0.05	18.3
D-2	2.8	1.3×10^{-4}	40	0.003	1.1
D-5	3.1	1.5×10^{-4}	30	0.004	1.5
Average	45.8	2.2×10^{-3}	36.7	0.06	21.0

[a]Based on the following values for porosity: Sand = 30%, Silt = 40%, Clay = 50%

[b]Velocity (v) = $\frac{K(dh/dl)}{7.5a}$

The following conclusions are presented based upon the results of the slug tests. The results are dependent upon many variables. Since the clays and sands possess differing physical characteristics and the curve matching technique an average value, the velocities given in this section are considered estimates limited by the method and inhomogeneity of the media tested. Actual velocities may vary by an order of magnitude more than those reported.

The horizontal velocity of groundwater in the vicinity of the sewage treatment lagoons ranged from 0.003 to 0.13 ft/day (1.1 to 47.5 ft/yr). The average horizontal velocity was calculated as 0.06 ft/day (21 ft/yr). The deeper piezometers (D-2 and D-5) had lower hydraulic conductivities and resultant horizontal velocities in comparison with the shallow piezometers. The shallow screened portion of the saturated soils appears to be more permeable, generally, than deeper alluvial materials. This was verified by sieve analysis characterization in the laboratory. Sieve analytical results are presented in Appendix C.

Additional characterization of the shallow and deeper saturated zones was determined by two pump tests, as described in the following sections.

4.4 Pump Test Results

The following sections describe the design, procedures, and results of the pump tests conducted at Holloman AFB. Two aquifer pump tests were conducted at Holloman AFB to gain a clearer understanding of the hydrologic complexity of the bolson fill deposits. From the geologic data gathered, it was determined that the bolson sands, silts, and clays were interconnected hydraulically. Therefore, a simple definition of the lower boundaries of the "first affected aquifer" could not be made with any degree of certainty. However, the pump tests did yield aquifer test data which supported the geologic findings of this investigation.

4.4.1 Pump Test Design

The primary purpose of the pump tests was to provide data from which principal aquifer characteristics, transmissivity and storage coefficient, could be calculated. Two locations upgradient and downgradient from the sewage lagoons were selected for separate pump tests. They are shown in Figures 4-3 and 4-4.

Table 4-5 is a summary of the wells incorporated into the pump tests at Holloman AFB. At the upgradient location, two piezometers (S-12 and D-3), were used as observation wells. Wells S-12 and D-3 were installed 29.5 feet apart and completed in fairly distinct sand zones: between 4-9 feet and 58-68 feet, respectively. Aquifer characteristics of these zones were estimated through laboratory analysis of core samples, field observations, and published sources. Using this information, a simple model was utilized (Walton, 1986) to predict the aquifer yield and drawdown from a 4-inch pumping well placed at varying distances from the observation wells. The theoretical yield of the aquifer was obtained based upon grain size analyses of the screened portion and published hydraulic conductivity of typical silty clays. The information indicated that the optimum distance for the pumping well was between 75 and 100 feet from the two observation wells. The expected yield would be 2 gpm. Any greater yield would produce nearly instantaneous drawdown in the production well. If the distance from the pump-well to the observation wells was greater than 100 feet, the observed drawdown effects would be negligible. For any distance closer than 50 feet, interference from the production well would occur. The pumping well was placed about 77 feet from observation wells S-12 and D-3 (Figure 4-3).

The downgradient pump-test location consisted of a line of three observation wells, S-13, S-14, and D-4. Wells were spaced approximately 15 feet apart. Wells S-13, S-14, and D-4 were screened from 5-10 feet, 29-34 feet, and 39-49 feet bls., respectively. Using information derived from core samples and length of the screened portion of D-4, theoretical hydraulic

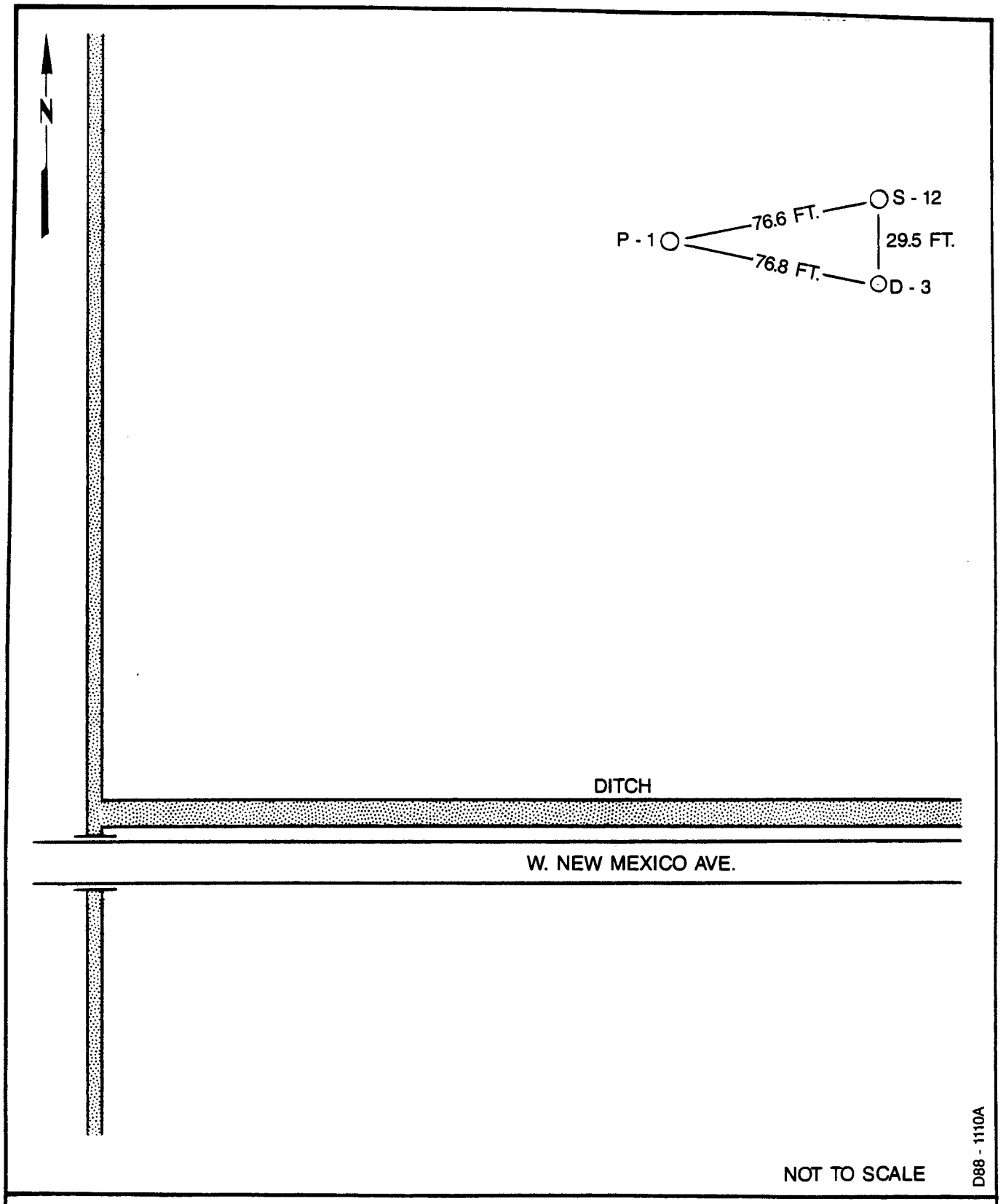


Figure 4-3. Plan View of Upgradient Wells Used in Zone 1 Pump Test, Holloman AFB, New Mexico

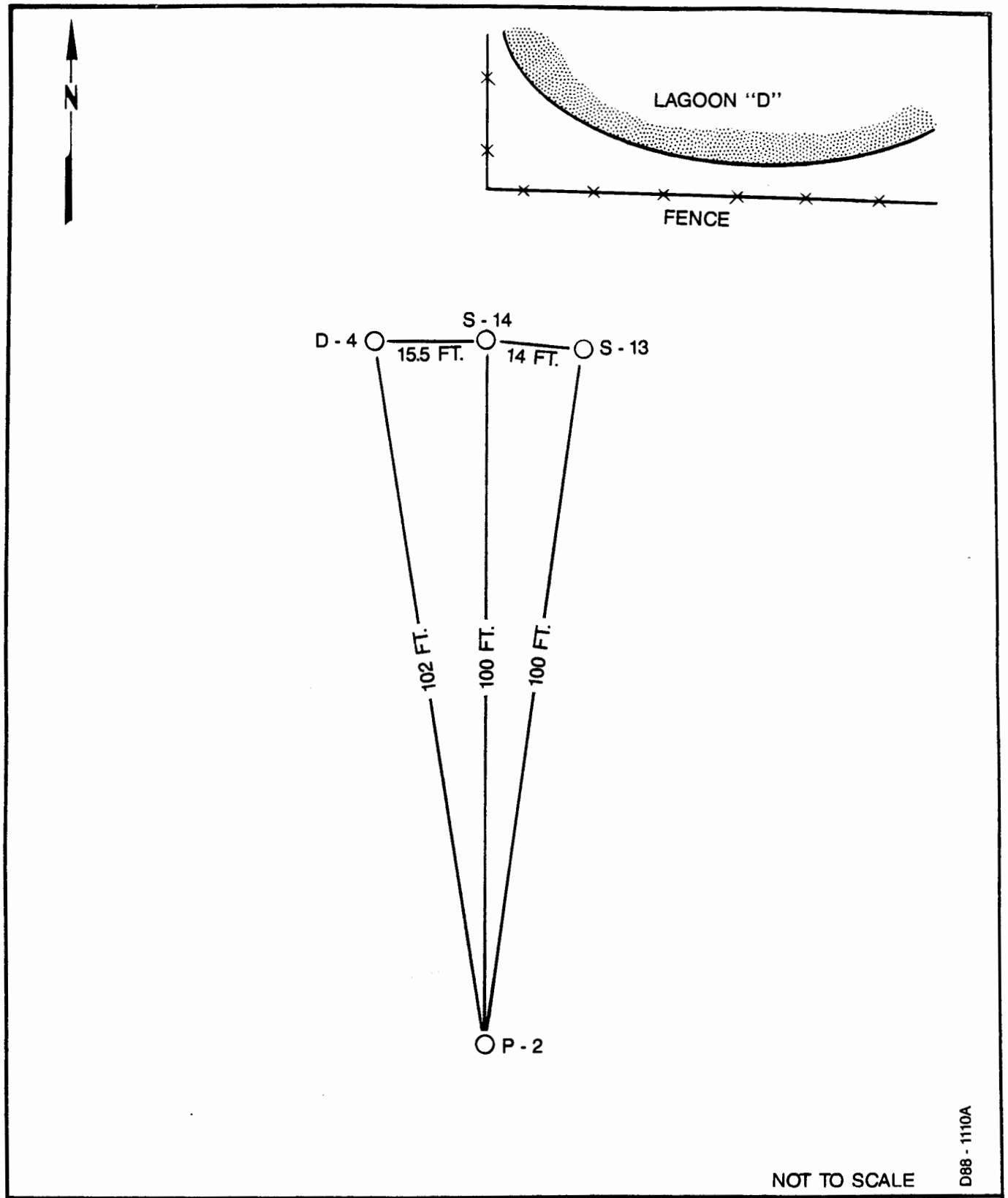


Figure 4-4. Plan View of Downgradient Wells Used in Zone 2 Pump Test, Holloman AFB, New Mexico

TABLE 4-5. DESIGN SPECIFICATION OF THE TWO AQUIFER PUMP TESTS

Well I.D.	Function	Aquifer (Upper/ Lower)	Top-Bottom of Aquifer (bls.)	Aquifer Thickness	Screened Interval	Distance from Pump Well	Maximum Observed Drawdown (ft.)
UPGRADIENT WELL CLUSTER							
P-1	Pump-well	Lower	55-68	13	57-67	---	10.6
D-3	Obs. well	Lower	49-65	16	58-68	76.8	1.67
S-12	Obs. well	Upper	3.5-12	8.5	4-9	76.6	0.55
(Discharge rate, 2 gpm, Pump test duration, 130 minutes).							
DOWNGRADIENT WELL CLUSTER							
P-2	Pump-well	Lower	41-54	13	42-52	--	37.0
D-4	Obs. well	Lower	38-51	13	39-49	102	4.6
S-13	Obs. well	Upper	4-13	9	5-10	100	0.0
S-14	Obs. well	Middle-clay*	28-35	7	29-34	100	0.35
(Discharge rate, 5 gpm, Pump test duration, 420 minutes).							

*Clay unit screened between both aquifers, not considered an aquifer.

conductivity and transmissivity of the deeper sand zone were determined. Again, the optimum location for the pumping well was chosen by modeling (Walton, 1986). Since the saturated portion of D-4 was fine-medium silty sand, it was predicted that the aquifer would yield up to 5 gal/min. Using this constant rate and incorporating the results of the model, the pumping well was placed about 100 feet away, perpendicular to the row of three observation wells. The configuration of the downgradient pump test well cluster is shown in Figure 4-4.

Originally, the pump-test program was designed as two separate tests, for the upper and lower aquifers. However, due to internal and vertical discontinuities in lithologies across the area, an exact determination of the upper and lower aquifer boundaries could not be made. Therefore, it was decided to pump the lower saturated sand and observe the overall drawdown response in the shallow and deep sands. This data was considered more useful from an environmental consequences approach. Also, the shallow piezometer slug-test data gave fairly reliable results which were considered useful in describing the aquifer characteristics of the upper saturated sand. For these reasons, a shallow pump test of the first saturated zone was considered unnecessary. Shallow observation wells were included in the deep pump-tests, however.

4.4.2 Pump Test Equipment

Certain preliminary steps were taken to insure that data were recorded accurately and carefully. Static water level measurements were collected periodically before the pump tests to determine if barometric pressure affected the static water level during the day. Twenty-four hours before the actual pump-test was started, the generator was tested and the pump assembled and lowered into the well. Since simultaneous water levels needed to be taken from the pump well and observation wells at rapid intervals, a pressure transducer (Hermit 2000 Data Logger) was used. The instrument's pressure transducers, which are linked to a control box, measure changes in the water table (through pressure change) to an accuracy of 0.01 foot. Data

from the control box were linked to a field printer and periodically inspected. Raw field printouts from the Hermit Data Logger for both pump-tests are presented in Appendix G. Data from the data logger were transferred to field sheets for hand plotting drawdown curves. Field sheets and drawdown curves are also presented in Appendix G.

The pump utilized during the pump-test was a 1/2 hp, 3 3/4-inch diameter Red Jacket brand submersible pump. It is rated at 5.5 amps with a current of 240 volts. The maximum yield from the pump was obtained at P-1. The pump yielded approximately 9 gpm when submerged 60 feet in P-1. The discharge hose was a one-inch plastic hose which extended 33 feet downslope from the upgradient pump well (P-1) and 40 feet downslope from the downgradient pump well (P-2). Attached to the end of the discharge hose was a one-inch galvanized spigot with a control valve to adjust the discharge rate.

A gasoline powered generator was used to supply electricity (240 volts) to the pump. To determine the optimum discharge rate, the generator and pump were test-operated 24 hours before the pump test. Discharge rates were measured using a 5-gallon bucket and stop watch. The pump and transducers were left in the well overnight after test-operated to allow the aquifer to achieve equilibrium. The Hermit was left on to record the water-level recovery prior to beginning the actual test the next day.

The same procedures were used in preparing for the downgradient pump test. However, the discharge rate was adjusted to 5 gallons per minute as discussed in the following subsection.

4.4.3 Pump Test Duration

The objectives of the two pump tests were to obtain long-term and reliable drawdown data within a reasonable period of time (i.e. 1 hour after the pump test began). For this reason, the upgradient pumping well P-1 was tested 24 hours before actually beginning the pump test to obtain an optimum

discharge rate. During the "mini pump test", P-1 was test pumped at 5 gpm. After 5 minutes, the well dewatered. The valve on the discharge hose was adjusted back to 2 gpm. The pump well was restarted and run for 15 minutes. At 2 gpm the well showed appreciable drawdown (10 feet), but did not dewater. The pump was shut-off, and the well allowed to recover for the actual pump test to begin the following day. It was concluded that the theoretical (optimum) rate of 2 gpm predicted through modeling (Walton, 1986) and actual yield of P-1 appeared to coincide.

The first pump test, in Zone 1, began on 3 November 1987 at the upgradient location and continued for three hours and 14 minutes. The pump test was cut short 130 minutes into the test because the pump over-heated. The low discharge caused the pump to heat up, thus increasing the resistance which eventually tripped a thermocouple on the generator. This interrupted current to the pump until the thermocouple cooled down. The pump automatically restarted after a delay of approximately three minutes. During the pump test, distance-drawdown data were plotted in the field. The pump test results were determined to be reliable until the pump shut-off 130 minutes into the test. To avoid risking incorrect interpretation of drawdown data, the recovery test was started after the temporary pump interruption occurred.

The downgradient pump-test location was set-up on 4 November, 1987, with transducers, submersible pump and generator 24 hours before the pump-test. During this time, a "mini pump test" was run to determine the maximum discharge rate that the aquifer could sustain. Earlier, through grain size characterization from D-4, it was determined that the second water bearing zone was fairly permeable with mostly silty sands as opposed to more clayey sands found in the upgradient pump test area. For this reason, pump well P-2 was placed about 100 feet away from the observation wells. The theoretical yield from the aquifer was predicted through modeling. A yield of 5-9 gpm was considered the maximum sustained yield from an aquifer of the given grain size fractions. During the mini pump test, P-2 was pumped at 9 gpm for 10 minutes. After 10 minutes, the pumping well dewatered. The discharge valve was cut back to 5 gpm. The pump was restarted. The well did

not dewater but showed appreciable drawdown. The test was halted after 10 more minutes to avoid over-stressing the aquifer. Water levels were measured before the mini pump test and prior to starting the actual pump test the next day to insure that the aquifer had regained equilibrium.

The second pump test, in Zone 2, began on 5 November 1987 and continued for seven hours without incident. The discharge rate was held constant at 5 gallons per minute. Since the discharge rate was higher (greater aquifer yield), the pump remained cool and did not overheat. After seven hours, the drawdown curve began to exhibit steady-state conditions. After data were reviewed in the field, the generator was shut down to begin the step-recovery test. The recovery test lasted 17 hours. Field results of the two pump tests are presented in Appendix G.

4.4.4 Pump Test Sensitivity and Accuracy

The field measurements taken before and during both pump tests were checked for accuracy by the field staff before they were incorporated in the report. With respect to those observations, the following list presents data and accuracy requirements for each observation.

- Production well discharge (0.1 gpm);
- Depth to water in production wells and observation wells below measuring point (0.01 ft.);
- Synchronous time (0.1 second);
- Description of measuring points;
- Elevation of measuring points (0.01 ft);

- Vertical distance between measuring point and land surface (0.1 ft);
- Total depths of wells (0.1 ft);
- Depths and lengths of screened intervals (0.1 ft);
- Diameter, screen type, and method of well construction including annular dimensions of borehole;
- Distances from pumping well to observation wells (1.0 ft); and
- Barometric pressure.

Barometric pressure effects were measured by collecting water level data from piezometer S-13 every hour during the upgradient pump test. No noticeable change in the water table was noted; therefore, the net effect of barometric pressure on the water table was assumed to be negligible. If either pump test had been conducted for a longer period of time (24 hours or more), barometric pressure adjustments for drawdown would have been factored in. Barometric pressure readings were made available through the meteorological office on-base.

4.4.5 Drawdown and Recovery Data Accuracy

Upgradient Pump Test

The locations of piezometers and pumping wells relative to each other, screened intervals, and drawdown amounts are shown in Table 4-5.

As discussed earlier, the pumping well P-1 shut down due to overheating 130 minutes into the test, then restarted three minutes, forty seconds later. Overall, the drawdown rate "tailed off" (began to reach steady-state conditions) twenty minutes into the pump test. However, the

results of the drawdown curve were not used to calculate transmissivity (T) and coefficient of storage (S). The definition of these parameters is given in Section 4-3. The recovery results from P-1 were much more reliable and consistent (Figure 4-5) for the calculation of T and S. As seen in the recovery curve of pump-well P-1, a fairly consistent recovery rate was achieved during the first ten minutes of the test (Figure 4-5). The curve then "flattens out" as the well approaches equilibrium. The recovery test was halted after 200 minutes. The maximum recovery in P-1 was 10.6 feet during the course of the test.

Observation well D-3, screened at the same depth as P-1 and 77 feet away, exhibited drawdown approximately 19 minutes into the pump test (Figure 4-6). The slope of the points was fairly consistent through the end of the test.

The recovery plot of D-3 was fairly consistent during the period of observation. Drawdown and recovery graphs of D-3 correlate well. The maximum recovery in D-3 was 1.67 feet (Figure 4-6). The drawdown and recovery curves shown in Figure 4-6 were used to calculate T and S for the deeper aquifer.

The drawdown response in the shallow piezometer S-12, 77 feet from P-1, was very small, and could not be plotted due to the extremely low fluctuations in the water level over time. The recovery plot of S-12 was too erratic to correlate with any degree of accuracy. The maximum drawdown observed in S-12 was 0.55 feet, which accounts for the low resolution of the recovery curve over time. Raw drawdown and recovery data for the upgradient wells are presented in Appendix G.

Downgradient Pump Test

Drawdown and recovery data for well P-2 are presented in Figure 4-7. Recovery data are often more valuable than drawdown data because fluctuations

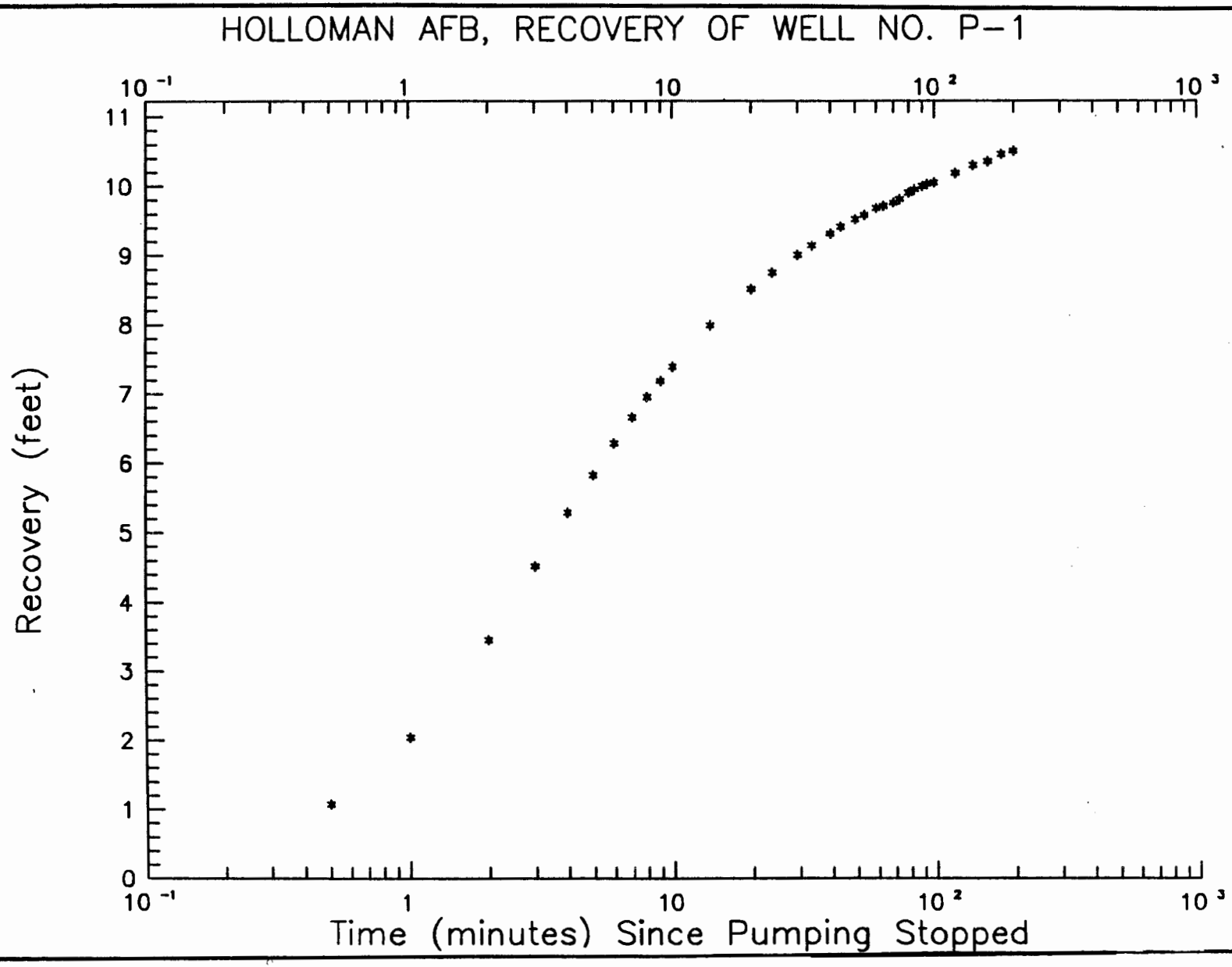
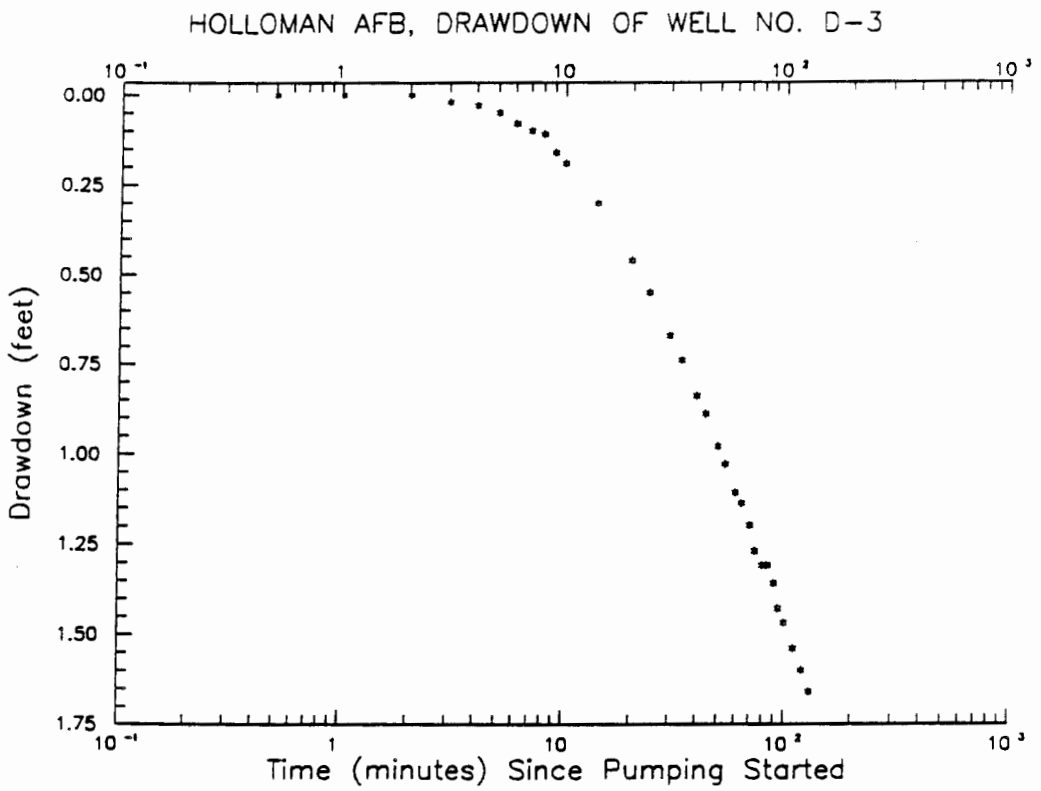


Figure 4-5. Time-Recovery Response of Upgradient Pump Well P-1, Zone 1, Holloman AFB, New Mexico



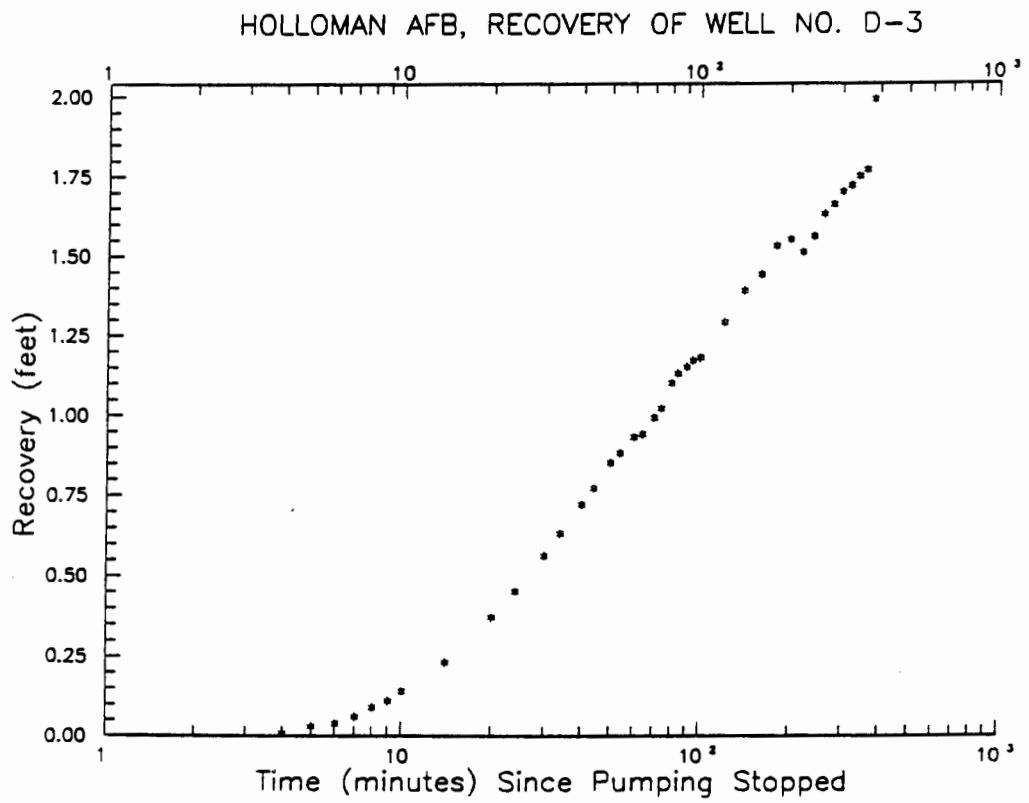


Figure 4-6. Time-Drawdown and Recovery Data, Upgradient Well D-3, Holloman AFB, New Mexico

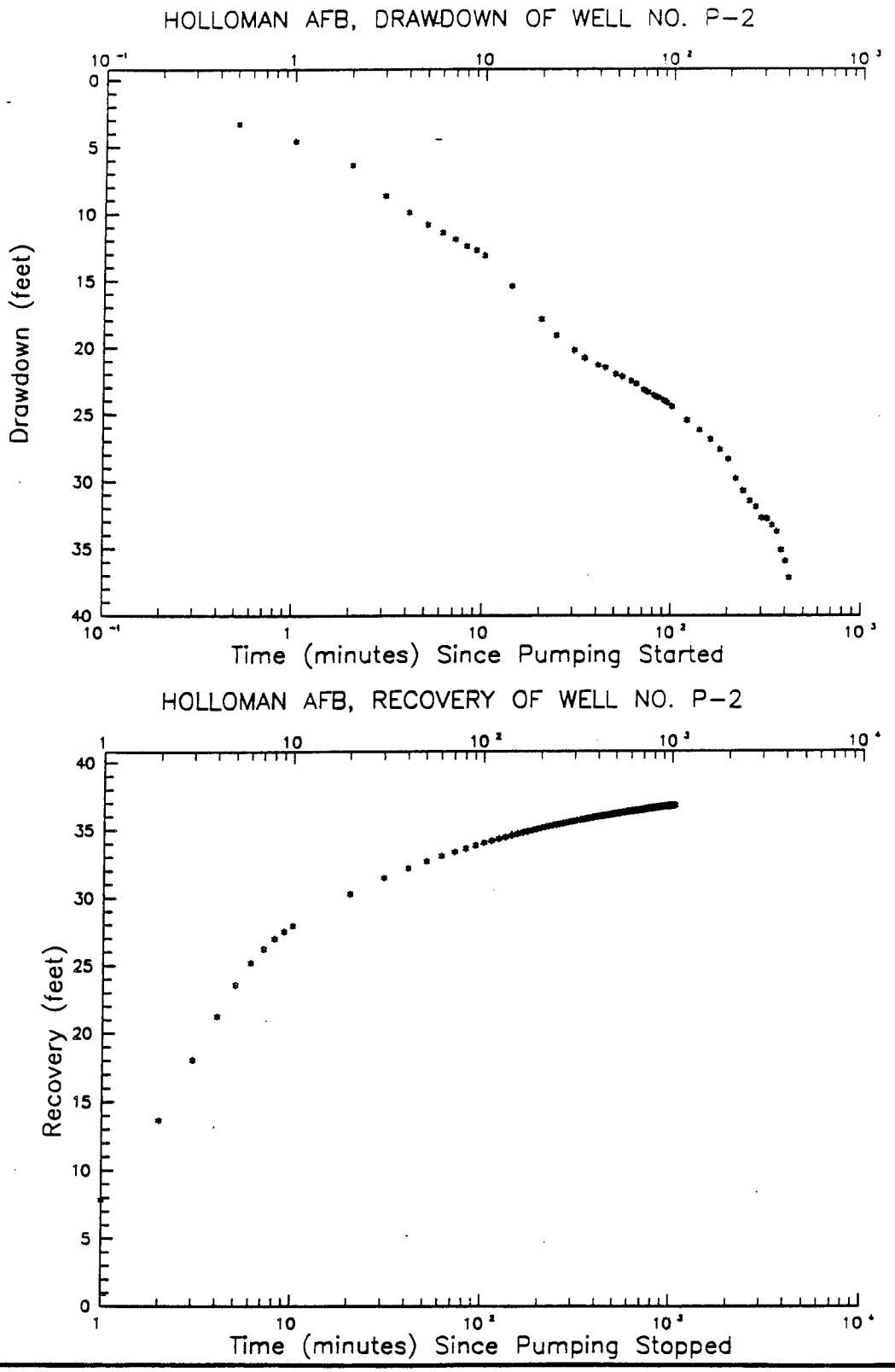


Figure 4-7. Time-Drawdown and Recovery Data, Pump Well P-2, Holloman AFB, New Mexico

in pumping rates are not encountered. In ideal situations (i.e., constant pumping rates in a homogeneous aquifer) the shape of the drawdown curve should precisely duplicate the shape of the recovery curve. However, these criteria are rarely met in field situations. This difference in curvature is shown in the P-2 drawdown and recovery graphs presented in Figure 4-7.

Observation well D-4 located 100 feet from P-2 exhibited constant drawdown during the 7-hour pump test. The characteristics of the drawdown curve were used to estimate transmissivity and coefficient of storage (T and S respectively) for D-4 (Figure 4-8).

Observation well S-14 exhibited only 0.35 feet of drawdown during the 7-hour test. This well was screened in a tight clayey silt occurring between a shallow sand unit screened by S-13 and deeper sand screened by D-4 (Table 4-5). Drawdown was expected in S-14 due to the saturated nature of the cores. After inspecting the field data, and plotting the results, the shape of the curve was found to be too erratic to obtain reliable T and S values using either Theis curve matching techniques or the Jacob method. These methods are discussed in detail in the following subsection. Shallow piezometer S-13 did not exhibit measurable drawdown during the downgradient test. The regulatory significance of the pump test results are discussed in Section 5.6 of this report.

4.4.6 Pump Test Analytical Methods

Pump-test data were collected and reviewed for reliability and accuracy. Transmissivity (T) and storage coefficient (S) values were derived from drawdown and recovery data.

Cooper and Jacob (1946) developed a method for conveniently obtaining T and S by plotting observed drawdown or recovery data on semilogarithmic paper. Values of drawdown are plotted on the arithmetic scale and time on the logarithmic scale. The resultant graph (which should be a straight line) is referred to as the time-drawdown graph. The method is commonly referred to as

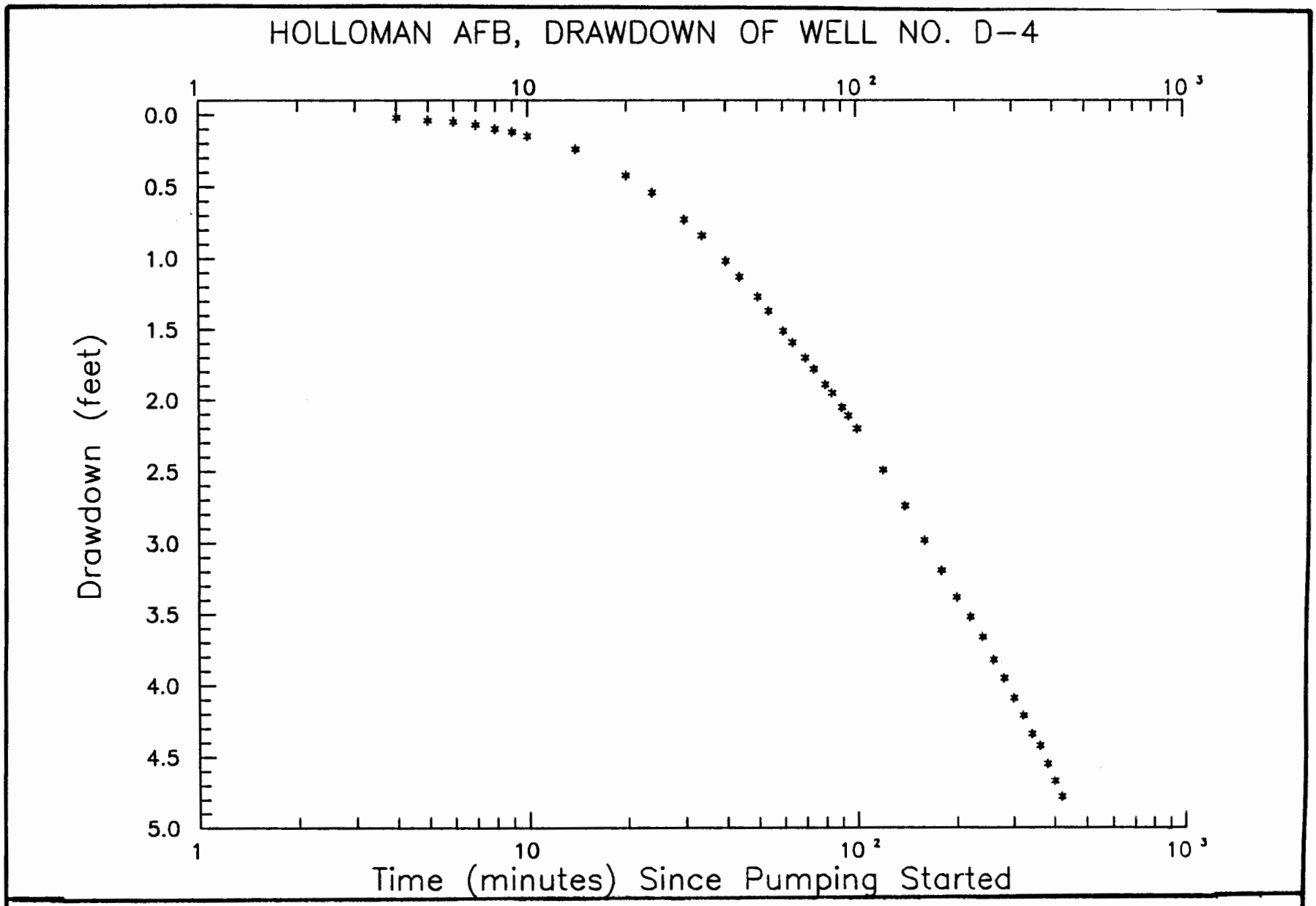


Figure 4-8. Time-Drawdown Response from Well D-4, Holloman AFB, New Mexico

the Jacob Straight Line Method. Graphic solutions to drawdown and recovery curves are presented in Appendix G.

In the units commonly used in the United States, the equation for the Jacob Straight Line Method for describing drawdown is written as

$$ho - h = \frac{246Q}{T} \log_{10} 0.3\ Tt/r^2S \qquad (4\text{-}3)$$

where, Q is discharged in gallons per minute,
T is transmissivity in gallons per day per foot (defined in Section 4.3),
t is pumping time in days,
r is distance in feet, and
S is storage coefficient dimensionless (defined in Section 4.3).

If values for time are selected one logarithmic cycle apart,

$$\log_{10} \frac{tz}{t_1} = 1$$

it may be shown that equation 4-3 reduces to

$$T = \frac{264Q}{\Delta h}$$

where h is the drawdown across one log cycle (Ferris, 1962). The equivalent equation for the coefficient of storage is

$$S = \frac{0.3Tt_o}{r^2} \qquad (4\text{-}4)$$

where, S, T, and r are as previously defined, and
t_o is the time intercept, in days, where the plotted straight line intersects the zero-drawdown axis.

The Jacob method gives reliable answers only when steady state conditions develop. Because steady state conditions develop first near the pumping wells, it was appropriate to apply this method since the distance between the pumping wells and observation wells was small (less than 105 feet).

Also, the Jacob method only applies to small values of u. For longer periods of time the value, u, becomes proportionally smaller.

$$u = \frac{r^2 s}{4Tt}$$

The Jacob method is not applicable when the value of u exceeds 0.02 (Jacob, 1946).

As a check, the time-drawdown values were run through a micro-computer program (Walton, 1986). The program is based, in part, on a program developed by Poole, et al. (1981), and uses the method of least squares. The program finds the best fit straight line to the data points and calculates the slope and zero-drawdown intercept of the line. Aquifer transmissivity and storativity are then calculated with slope and zero-intercept equations described earlier.

Several plots of the data revealed considerable scatter. After tentative values of transmissivity and storativity were calculated, the segment of the data where $u \leq 0.02$ was determined and compared with the segment of data through which the straight line was drawn. The time that elapsed before a semilogarithmic time-drawdown graph could be drawn with a straight line varied from several minutes to an hour or more.

It is very important to note that on several occasions aquifer storativity was impossible to determine with any degree of accuracy because the zero-drawdown intercept was either poorly defined or the slope of the line was small. Intercepts often occurred at points where time was very small, resulting in large variations in calculated values of storativity.

Transmissivities, storage coefficients, and hydraulic conductivity results are presented in Table 4-6. As discussed previously in this section, drawdown data for shallow wells, S-12, S-13, and S-14, was insufficient to obtain hydraulic parameters using either the Jacob Straight Line Method or

TABLE 4-6. TRANSMISSIVITY, STORAGE COEFFICIENT, AND HYDRAULIC CONDUCTIVITY DATA FROM PUMP TESTS

Well I.D.	Transmissivity (gpd/ft.)	Storage Coefficient	Hydraulic Conductivity (gpd/ft^2)	Hydraulic Conductivity (cm/sec)
P-1	126	NR	12.6	5.9×10^{-4}
D-3	377	0.00005	37.7	1.8×10^{-3}
S-12	ND	ND	ND	ND
P-2	106	NR	10.6	5.0×10^{-4}
S-13	ND	ND	ND	ND
S-14	ND	ND	ND	ND
D-4	330	0.0002	33	1.6×10^{-3}

NR - Not reported. Jacob straight line method and Theis curve matching technique unacceptable due to pump-well interference.

ND - Not determined. Drawdown response was insufficient or too sporadic to plot T and S values.

Theis Curve (Walton, 1986). However, aquifer characteristics of the deeper saturated zone were obtained in both cases. The transmissivity of the deep aquifer screened by the pumping well P-1 was 126 gpd/ft. The transmissivity of D-3 was 377 gpd/ft. The resultant storage coefficient (S) in D-3 was calculated to be 0.00005.

In the downgradient location, the transmissivity of the deep aquifer screened by P-2 was approximately 106 gpd/ft. Observation well D-4 near P-2 had a transmissivity value of 330 gpd/ft. The storage coefficient for D-4 was 0.0002. Observation well S-14, screened in the clay between the two sand units, produced 0.35 feet of drawdown; however, the water level fluctuation made it difficult to calculate T or S values with any degree of accuracy using Jacob Straight Line Method (Walton, 1986).

Observation well S-13, the shallow zone well, did not exhibit drawdown during the seven-hour pump test. During the pump test, approximately 2,100 gallons was discharged from P-2. The absence of any drawdown in S-13 suggests that the clay unit between the shallow and deeper sand units is semi-confining. As shown, the water level in S-14, completed in the aquitard, did respond, but only marginally (0.35 feet) during the pump test. It is estimated that the shallow sand would have begun to dewater as well if pumping had continued in P-2.

Table 4-7 is a summary of slug test and pump test information compiled by the USGS (1985), Wilson and Associates (1986) and Radian Corporation. Radian slug test results were determined using the method described by Ferris and Knowles (1963). Pump test results were obtained by using methods described by Cooper and Jacob (1946) and Walton (1986).

USGS data was analyzed using Hantush-Jacob, Hvorslev, and Papadopoulos methods. USGS well data is described in the Wilson report (1986).

TABLE 4-7. HORIZONTAL GROUNDWATER VELOCITY RESULTS, HOLLLOMAN AFB, NEW MEXICO

Well Number	Test Method	Hydraulic Conductivity (gpd/ft^2)	Hydraulic Conductivity (cm/sec)	Porosity[a] (%)	Velocity[b] (ft/day)	Velocity[b] (ft/year)
UPPER SATURATED ZONE						
S-2	Recovery	7.1	3.4×10^{-4}	40	0.007	2.6
S-4	Slug	85.6	4.0×10^{-3}	30	0.13	47.5
S-5	Slug	61.8	2.9×10^{-3}	40	0.07	25.6
S-8	Slug	56.2	2.6×10^{-3}	40	0.06	20.5
S-11	Slug	80.2	3.8×10^{-3}	30	0.12	43.8
S-15	Slug	69.9	3.3×10^{-3}	30	0.11	40.2
S-16	Slug	45.8	2.2×10^{-3}	40	0.05	18.3
SH2B[c]	Hvorslev	16.1	7.60×10^{-4}	30	0.02	8.0
SH3B[c]	Hvorslev	8.3	3.94×10^{-4}	30	0.01	4.0
SH4B[c]	Hvorslev	35.4	1.67×10^{-3}	30	0.05	17.0
SH6A[c]	Papadopoulos	57.0	2.69×10^{-3}	30	0.08	28.0
	Hvorslev	18.3	8.66×10^{-4}	30	0.02	9.0
SH6B[c]	Hvorslev	11.0	5.18×10^{-4}	30	0.01	5.0
DEEPER SATURATED ZONE						
D-2	Slug	2.8	1.3×10^{-4}	40	0.003	1.1
D-5	Slug	3.1	1.5×10^{-4}	30	0.004	1.5
D-3	Pump test	37.7	1.8×10^{-3}	40	0.03	11.0
D-4	Pump test	33.0	1.6×10^{-3}	30	0.04	16.0
P-1	Pump test	12.6	1.2×10^{-4}	40	0.01	4.6
P-2	Pump test	10.6	5.0×10^{-4}	30	0.014	5.0
SH2A[c]	Hantush-Jacob	4.7	2.20×10^{-4}	30	0.005	2.0
	Papadopoulos	8.9	4.22×10^{-4}	30	0.01	4.0
	Hvorslev	10.8	5.10×10^{-4}	30	0.01	5.0
SH3A[c]	Hantush-Jacob	17.7	8.37×10^{-4}	30	0.02	9.0
	Papadopoulos	52.1	2.46×10^{-3}	30	0.07	25.0
	Hvorslev	8.9	4.20×10^{-4}	30	0.01	4.0
SH4A[c]	Papadopoulos	6.9	3.28×10^{-4}	30	0.008	3.0
	Hvorslev	4.1	1.94×10^{-4}	30	0.005	2.0

[a]Based on the following values for porosity:
Sand = 30%, Silt = 40%, Clay = 50%

[b]Velocity (v) = $\frac{K(dh/dl)}{7.5a}$

dh/dl = Hydraulic gradient determined from piezometer elevation survey (0.003).

[c]USGS data from wells installed in 1985.

In comparing the information derived from these studies, it is evident that the aquifer below the base sewage lagoons is consistent in overall texture and aquifer characteristics. Well tests indicate that the horizontal velocity of groundwater is slow and ranges between 1.1 to 47.5 feet/year. Regardless of the analytical method, close agreement between Radian's data and previous aquifer test data was noted with several exceptions. Aquifer characteristics from monitor wells near the lagoons are summarized in the following section.

4.4.7 Summary of Slug and Pump Test Results

Based upon the results of the upgradient and downgradient pump tests, the following conclusions may be drawn:

- The first affected aquifer is composed of saturated sands, silts, and clays hydraulically interconnected.

- There are discontinuous clays separating coarser-grained, shallow water-bearing sand and silt units from deeper units of equal or greater grain size.

- The term "aquifer" may be used to describe hundreds of feet of bolson fill sediments below Holloman AFB. The basal contact of the bolson is estimated to be the top of Permian bedrock (depth unknown).

- The bolson fill aquifer exists under water table conditions in the first saturated shallow zone. However, with increased depth, successive clay and silt units create semi-confining conditions as shown in the response of observation wells S-13 and S-14 during the pump test. Artesian conditions do not exist at the depths investigated.

- Aquifer yield is based solely upon the porosity and permeability of the units screened. There are no secondary porosity factors to consider.

- Slug test methods generally revealed high T and S values, possibly due to the interference of the sand pack, and unsaturated portions of the screened interval above the static water level. Overall, the pump-test data is considered more reliable when comparing T and S values between Radian and USGS wells.

- A comparison of transmissivity and storage coefficient calculations in the slug tests and two pump tests yielded similar results. A comparison of the two test methods indicates that the first sat- urated sand has higher T and S values than deeper saturated units. The upper sand is well drained sandy loam of the Holloman-Gypsum land-Yesum complex. With depth, the sediments generally become progressively finer grained.

5.0 CONCLUSIONS

The following discussion presents the conclusions of the hydrogeologic investigation conducted on behalf of the U.S. Army Corps of Engineers at Holloman AFB. The conclusions are based on site-specific geologic and hydrologic data obtained during this investigation and from published sources.

The conclusions are summarized below according to zone. Each zone is described in terms of geology, surface water, groundwater, and contaminant pathways.

5.1 Zone 1 Conclusions

Zone 1 includes the runoff ditch, golf course, and flight line approach zone upgradient (east) of the sewage treatment lagoons. Piezometers were installed to obtain background information on groundwater characteristics and stratigraphic relationships between the shallow aquifers.

5.1.1 Geology

The surficial deposits east of the sewage lagoons consist of silt ranging from 5 to 10 feet thick. Cross-section H-H' (Plate 8) depicts the geologic setting of the upgradient area as predominantly silt with increasing amounts of clay with depth.

5.1.2 Hydrology

Surface water influences in Zone 1 include the runoff ditch, which is unlined, and irrigation runoff from the golf course. Due to the tight silt and clay in the saturated zone, it is unlikely that infiltration of the runoff ditch or golf course irrigation could significantly impact the shallow water quality. However, the runoff ditch carries water year-round which could percolate downward and dilute the existing poor quality groundwater with less saline runoff.

Groundwater occurs under water table conditions. The groundwater gradient in Zone 1 closely resembles the slope of the topography, which is toward the southwest (cross-section H-H'). Piezometer S-2 was installed close to Lagoon G. Resultant conductivity readings taken from piezometer S-2 were significantly less than all other well readings. This clearly indicates that groundwater dilution by "fresher" water from Lagoon G, or elsewhere, is taking place. An alternate source of dilution could be golf course irrigation water which could mix with the shallow groundwater in the S-2 area. However, piezometer S-1, located slightly west and downslope from the golf course green, showed no decrease in conductivities as would be expected if irrigation water were contributing fresh water to the shallow aquifer. The high evapotranspiration rate in this region (-59 inches per year) would prohibit downward migration of sporadic rainfall and/or irrigation waters.

5.1.3 Pathways for Contamination

The runoff ditch passes within 500 feet of piezometer well S-1. The ditch drains the area north and east of the sewage lagoons. Runoff, lawn-irrigation, and curb runoff enters the ditch from the base housing area. The bottom of the runoff ditch is actually at a lower elevation than the present water table near the ditch. Evidence of salt accumulations left from fluctuating groundwater levels and seeps may be seen along the ditch bank. The runoff ditch is unlined and is recharged by shallow groundwater. For this reason, the runoff ditch acts as a discharge point, and not a recharge source to the aquifer. It is unlikely that the ditch acts as a pathway for contamination to the aquifer.

Lagoon G has tentatively been determined to be the primary source of leakage in Zone 1 based on the low conductivity readings in the lagoon and corresponding low readings in piezometer S-2. Fairly permeable sands line the sides and base of the lagoon. Lagoon G was a natural playa lake before it was converted into a sewage lagoon. The playa sands and silts are naturally well sorted (based upon field inspection). The uppermost saturated unit in Zone 1

is silty, which could provide a slow avenue for migration. The horizontal velocity of groundwater through the shallow saturated silt was estimated to range from 2.5 feet/year (S-2 slug test) to 16 feet/year (from D-3 drawdown data).

5.2 Zone 2 Conclusions

Zone 2 includes the area immediately downgradient from sewage lagoons A through G. Groundwater in this zone would be most likely impacted by sewage effluent through downward percolation of contaminated surface water from the sewage treatment lagoons and entrainment into the groundwater flow toward the southwest.

5.2.1 Geology

The geologic setting of Zone 2 is best described by cross-section G-G'. Cross-section G-G' runs north-south along the western border of the sewage lagoons. The surficial desposits consist of soils of the Holloman-Gypsum land-Yesum Complex. The soils are typical of alluvial and eolian gypsiferous sediments. Below the soils are coarser alluvial sands which become saturated with depth. The dominant lithologies below the first saturated sand unit are interbedded sand and clay units.

5.2.2 Hydrology

Zone 2 is composed of fairly well drained soils from eolian deposition. Surface water influences such as leakage or overtopping of the lagoons have been documented in the past (CH2M-Hill, 1983). A small, unlined ditch captures runoff from the main taxiway and West New Mexico Avenue, and routes it along the western edge of the lagoon into a wide open plain west of the lagoons. A fairly dense stand of salt cedars grows along the shallow ditch. The ditch and dense growth contrast to an otherwise barren plain that can easily be recognized from air photos and on the ground.

Groundwater in Zone 2 occurs between 3 and 7 feet below ground level. Water levels are consistent with the slope of the topography with the exception of shallow piezometer S-15 which was installed in a low-lying "wetland" area where near-surface groundwater was expected. The corresponding water level in S-15 is significantly higher than D-5 located 300 feet north.

Piezometers D-5 and S-15 were placed along the west flank of the sewage lagoons. Since the surface of the lagoons is actually higher than the surrounding land surface, the potential exists for leakage from the lagoons to form a groundwater mound underneath the ponds. Since piezometers D-5 and S-15 are roughly 220 feet west of lagoons A and C respectively, potential mounding (if it exists) would be observed in one or both wells.

Interestingly, the water table elevations recorded in these two wells were dissimilar during the course of this study. Below is a summary of observed water levels and dates measured.

Well I.D.	Date Measured	Static Water Elevation
D-5	8/31/87	4031.38
D-5	10/18/87	4031.88
D-5	10/19/87	4030.51
D-5	11/16/87	4032.96
S-15	8/31/87	4034.20*
S-15	10/18/87	4032.14
S-15	10/19/87	4032.21
S-15	11/16/87	4032.07

*Possible operator error in reading tape on e-line during S-15 measurement on 8/31/87.

A potentially erroneous water level measurement of S-15 was made on 8/31/87. Therefore, this value was not factored into the average elevations of S-15 or temporal trends in water levels. The remaining water table elevations from D-5 and S-15 appear consistent when compared to one another. The average groundwater elevations in D-5 and S-15 were 4031.68 and 4032.14 feet msl respectively. The water table elevation in S-15 averaged 0.46 feet higher than in D-5 during the investigation.

During each water level survey, S-15 consistently revealed a higher water table than D-5. This finding is inconsistent with the regional gradient through the sewage lagoons and may indicate that the shallow piezometer was placed in a discharge area. The abundant salt cedars and "wetland" area suggests that groundwater is discharged near S-15. The abnormally high water table is either caused by the ditch nearby, sewage lagoons, naturally high groundwater conditions or combination of the above. Further water table survey data is needed to explain the observed high water table in S-15.

The differences in heads between S-15 and D-5 also suggest that there exists two aquifers below the lagoons. However, D-5 contained evidence of groundwater contamination which is suspected to be derived from shallow sands below the lagoon system. Without collecting water samples from S-15 and D-5 for comparative chemical analyses, the aquifer similarities and differences in the shallow and deeper saturated zones adjacent to the sewage lagoons cannot be verified.

5.2.3 Pathways for Contamination

Zone 2 presents the most unique hydrogeologic characteristics in terms of potential pathways for contamination. The only piezometer that revealed strong sewage odors in the groundwater was D-5. The piezometer was screened in a sand between 49-59 feet below ground level. It is possible that anaerobic conditions naturally exist in this low area and that water percolating through decomposing plant material has produced the offensive odors evident in the water. An alternative suggestion is that the clay units above

the screen are leaky, thus allowing sewage lagoon water to percolate downward into the deeper screened units. Further analytical investigation is necessary to determine the source of foul water in D-5.

Lagoon D has discharged in the past through side-wall seepage and by percolation through the unlined base of the lagoon. The USGS (1985) investigated the Lagoon D area where leakage occurred, as did Wilson and Associates (1986). Continued leakage from Lagoon D is a potential pathway for groundwater contamination. Pathways for groundwater contamination also exist through the USGS monitoring wells for two reasons:

- Well construction records for the USGS monitoring wells describe difficulties installing the casing due to swelling clays. This indicates that the bentonite seal was equally as difficult to install. Without a positive bentonite or grout seal, the wells may be promoting downward migration of effluent from the Lagoon D area into deeper saturated zones.

- The other, more obvious, pathway is through the currently uncapped USGS well casings into which foreign objects (small animals, etc.) have fallen. USGS wells installed in 1985 nearest Lagoon D (southwest corner) were left uncapped. In one well, SH-5, screen, rather than blank casing, was used as well completion material. The screen extends from land surface to below the water table. As a result, the well acts as a conduit for surface runoff to enter the well. Well SH-5 is also uncapped.

The extent of contamination downgradient from the sewage lagoons cannot be determined at this time. However, Radian-installed Zone 2 piezometers are constructed to EPA specifications and spaced apart both horizontally and vertically to supplement the placement of additional detection monitor wells in the Zone 2 area. Additional Zone 2 wells are discussed in Section 6.0.

Groundwater velocity measurements in Zone 2 were determined through slug tests of four piezometers, S-4, S-5, S-15, and D-5. The downgradient pump test in Zone 2 supplemented the findings of the slug tests. Horizontal velocities immediately downgradient from the sewage lagoons ranged from 25.6 to 47.5 feet per year in the shallow alluvium. In the deeper alluvium, the horizontal velocity determined from the pump test was slower, between 4.4 feet per year (P-2) and 13.7 feet per year (D-4).

5.3 Zone 3 Conclusions

Zone 3 encompasses a large area beginning half-way between the sewage lagoons and the lakes and extending westward to the eastern shore of Lake Holloman. All of the land in this area is public land maintained by the Bureau of Land Management. Concerns in this area focus on groundwater impacts from Lake Holloman (primarily) and the runoff ditch connecting Lake Holloman with the sewage lagoons. As discussed in Section 1.4, sewage effluent is routed to Lake Holloman from the lagoons.

5.3.1 Geology

The geologic setting of Zone 3 is shown in cross-sections E-E' and F-F' (Plates 5 and 6). Surficial soils range from well drained sandy soils in the northern (D-1) area to clayey soils in the central (S-11) area. The first saturated zone is composed mostly of sand and silt. Deeper piezometers show a complex relationship between intertonguing sandy silt, coarse sands, lacustrine clay, and evaporite gypsum deposits. Near the northern end of Lake Holloman, the first water-bearing zone is clay. All other piezometers encountered saturated sand and silt as the primary water-bearing units.

5.3.2 Hydrology

Surface water influences include Lake Holloman and the effluent ditch. Surface water quality measurements are frequently collected by base personnel. Groundwater mounding due to leakage of Lake Holloman was evident

in the comparison of water levels in piezometers S-6, S-8, and S-10. Well SH-8 was installed by the USGS and was drilled considerably deeper (189 feet) than the Radian-installed piezometers. However, the screen was set at 25.2-15.6 feet below ground level. The geologic and hydrologic data were used in the description of Zone 3.

Groundwater mounding below Lake Holloman is confirmed, since flow is directed from the lake toward the south-southeast. Water levels within the shallow piezometers nearest the lake are essentially at the same elevation as the surface of Lake Holloman. Therefore, groundwater/surface water mixing is likely occurring beneath the lake.

5.3.3 Pathways for Contamination

The effluent ditch passes approximately 500 feet north of piezometer D-2. The ditch is excavated to a depth at, or below, the existing water table. Because the ditch is excavated below the water table, it acts as a discharge point. As a result, the ditch is an unlikely path for groundwater contamination.

The main source of contamination in Zone 3 is likely attributable to Lakes Holloman and Stinky. However, groundwater quality analyses have not been performed to date to confirm if the two lakes have significantly impacted the existing water quality of the aquifer.

Groundwater velocity measurements in Zone 3 were obtained from slug tests performed on piezometers S-8 and D-2. The groundwater flow is altered due to mounding from Lake Holloman. The resultant horizontal velocity of groundwater was determined to be 18.3 feet per year in S-8 and 1.1 feet per year in D-2. As seen in Zone 2, values of groundwater flow are higher in the shallow piezometers.

5.4 Zone 4 Conclusions

Zone 4 covers the area west of Lakes Holloman and Stinky. The basis for installing piezometers in this zone was twofold: to correlate stratigraphic units beneath the lakes and to potentially monitor groundwater quality changes as groundwater flows downgradient and off Holloman AFB property.

5.4.1 Geology

Stratigraphic relationships in Zone 4 are depicted in cross-section D-D'. The surficial deposits are generally silty and range from 3 to 15 feet thick. The thickest silty zone is in the Lake Stinky area as depicted by S-9. The soil in this area is Mead clay soil type. With depth, the deposits are primarily composed of sand and silt with minor amounts of innerbedded clays. Piezometers S-9, S-16, and D-6 are screened in silt and sands and are very close to Lakes Holloman and Stinky. If groundwater contamination from these lakes were a concern, the piezometers in Zone 4 would serve to quantify groundwater impacts (if any).

The Hurtz Spring area represents the edge of a basin-forming fault scarp. The fault scarp extends northward from the southeastern Tularosa Basin to the north-central basin. The outcrop area represents a possible barrier to groundwater flow. However, borehole B-1 did not extend to the expected water table below that location, to verify whether or not groundwater exists at the same elevation on either side of the Hurtz Spring/bedrock outcrop area.

It should be emphasized that bolson fill alluvial deposits exist on all sides of the outcrop. The bolson fill deposits adjacent to the Hurtz Spring/outcrop area may be hundreds of feet thick. The outcrop area west of the base is perhaps a local barrier to shallow groundwater flow. The topographic high created by the consolidated outcrop may locally redirect groundwater toward Lake Holloman, creating a zone of stagnation in the area beneath the Lake. However, the regional groundwater flow gradient is to the southwest.

Hurtz Spring is a fault-type spring that originates from Permian age rocks (Hueco limestone) exposed at the surface. The spring is at least 30 feet higher than the regional water table based upon the results of this investigation. It produces less than one gallon per minute (estimated) and has not been developed at the present time. Groundwater from the spring contains extremely saline water produced from deeper Permian age rocks below the surface.

5.4.2 Hydrology

Groundwater impacts are likely restricted to Lake Holloman and adjacent areas. Lake Stinky fluctuates in water capacity and appears to serve as an effective evaporation pond whenever Lake Holloman overflows. Other sources of surface water could be the spray irrigation fields northwest of Lake Holloman. If the effluent discharged onto the irrigation fields percolated downward, groundwater contamination would be possible.

5.4.3 Pathways for Contamination

The major pathway for contamination is through seepage of effluent through the bottom of Lake Holloman. To a minor extent, seepage of Lake Stinky could impact groundwater quality. Without analyses, the existing groundwater quality cannot be quantified.

The horizontal groundwater velocity is approximately 18 feet per year (S-16 slug test). The outcrop area near Hurtz Spring may act as a barrier to flow which would result in stagnation of groundwater in Lake Holloman. However, alluvial deposits are several hundred feet thick on either side of the outcrop. The shallow saturated alluvium and general southwest hydraulic gradient would permit passage of groundwater around the outcrop into the central Tularosa Basin.

5.5 Regulatory Implications of Water Quality Results

The New Mexico Water Quality Control Commission has adopted regulations for discharges onto or below the surface of the ground. The purpose of the regulations is to protect all groundwater in the State of New Mexico which contains a TDS concentration of 10,000 mg/L or less, for present and future use (and users) as a domestic or agricultural supply. Part 3-103, "Standards for Ground Water of 10,000 mg/L TDS Concentration or Less" does not apply if groundwater exceeds this level. Based upon the preliminary results of this investigation, groundwater upgradient and downgradient from the sewage treatment lagoons exceeds 10,000 mg/L total dissolved solids. Areas where groundwater may contain less than 10,000 mg/L are in the Lagoon G area due to groundwater/surface water mixing. Well D-5, located 216 feet west of Lagoon A, did not exhibit lower conductivities when tested. However, noticeable sewage odors were detected in the well. A quantification of the groundwater contamination due to this leakage cannot be made at the present time. Detection monitoring of this and other wells is warranted and is discussed in Section 6.0 of this report.

There are no groundwater users in the vicinity of the sewage treatment lagoons. The nearest downgradient potable supply well is approximately 20 miles west of the base. The nearest livestock well is 3.5 miles to the southwest. If the groundwater were utilized, the naturally high total dissolved solids (sodium and chloride, primarily) would restrict its use for anything other than livestock watering.

5.6 Regulatory Implications of Pump Test Results

The geometry of the sediments beneath the sewage lagoons and Lakes Holloman and Stinky is such that no definable lower aquifer boundaries exist. Within the area of the hydrogeologic investigation, typical alluvial basin fine-grained sediments (silts and clays, primarily) occur with evaporite deposits composed almost entirely of gypsum (Appendix E). Eolian dune sands and coarser fluvial sands were also encountered. The deposits vary in thickness

and in lateral extent. In cross-sectional view, the upper aquifer consists of intertonguing clay, evaporites composed almost entirely of gypsum, fluvial and dune sands, all of which are saturated with saline water.

Typical of alluvial deposition in Basin and Range provinces, the hydrogeologic setting does not offer a clear confining layer. In this case, the uppermost aquifer must be defined as the uppermost portion of the saturated zone that can be monitored (screened) in accordance with regulatory guidelines. EPA has defined the uppermost aquifer as "the geologic formation, group of formations, or part of a formation that is the aquifer nearest to the ground surface and is capable of yielding a significant amount of groundwater to wells and springs (40 CFR 260.10)." It should be noted that quality and use of groundwater are not factors in the EPA definition. It can be argued that the saline water is not presently used and contains water unfit for human consumption. However, the groundwater may deserve protection under the federal regulations if contaminants introduced into the water threaten human health or the environment (EPA, TEGD, 1986).

For practical considerations, the pathways of contamination beneath the sewage lagoons and Lakes Holloman and Stinky are via shallow coarser-grained sand and silt units which underlie these impoundments. If groundwater monitoring of the sewage lagoons is enacted and is in accordance with 40 CFR 265 Subpart F, the first saturated sand and silt units identified by the 22 shallow piezometers installed during this investigation would serve as a guide in designing well materials, depths, and screened intervals for the groundwater monitoring program to follow.

6.0 PROPOSED GROUNDWATER MONITORING PLAN

This section discusses the plans and procedures for groundwater monitoring per 40 CFR 265 Subpart F. The proposed monitoring plan will follow the conditions and schedules set forth in Holloman AFB's Federal Facilities Compliance Agreement with EPA. Specifically items 2 through 9, pages 8 and 9 of the compliance agreement will be addressed.

It is understood that the conditions of the compliance agreement require that the Hydrogeologic Investigation Report accompany a proposed groundwater monitoring plan. The groundwater monitoring plan discussed in this section conforms to the TEGD and includes a groundwater sampling and analysis plan. An evaluation of existing wells and proposed locations for additional wells, groundwater sampling, analytical requirements, and statistical analyses are also discussed. Well construction specifications are presented in Appendix H. Chain of custody, documentation, and QA/QC requirements are presented in Appendix I. The schedule for the implementation of groundwater monitoring, as stated in the Federal Facilities Compliance Agreement, is provided in Section 7.0.

6.1 Evaluation of Existing Wells

The primary purpose of the piezometers installed during this investigation was to achieve a better understanding of the hydrogeologic setting of the sewage lagoons and receiving waters. However, they were designed and constructed to allow for the collection of representative groundwater samples for monitoring.

Some of the piezometers are not suitably located for conversion to monitoring wells. Piezometers that are not immediately adjacent to the downgradient perimeters of the sewage lagoons probably will not detect leakage from the lagoons. For example, a release from Lagoon D would theoretically take approximately 167 years to reach Lake Holloman (1.5 miles southwest) if it moved at the maximum calculated horizontal velocity, 47.5 feet per year

(S-4 slug test). Another aspect to consider is that groundwater monitored by wells in the Lake Holloman area would perhaps represent recharge from Lake Holloman. Therefore, a comparison of groundwater chemistry between Lake Holloman and the sewage lagoons would not be appropriate.

Lastly, if the flow gradients reflect accurately the direction of groundwater flow beneath the sewage lagoons, the mound created by Lake Holloman will create a hydrostatic boundary and restrict gravity drainage of groundwater from the sewage lagoons toward the lake (and Zone 3 monitoring wells). As discussed in Section 4.2.2, flow from the lagoons is south-southwest toward piezometer D-2. For these reasons, the piezometers encircling Lake Holloman (S-7, S-16, D-6, S-9, S-6, S-8, and S-10) would not function satisfactorily as groundwater monitoring wells for release from the sewage treatment lagoons.

Prior to installing additional monitoring wells, it is recommended that Holloman AFB proceed with minor "house cleaning" duties with respect to the existing USGS wells. Section 4.2.3 discusses technical problems associated with the USGS wells. USGS wells near the sewage treatment lagoons are suspect in construction integrity and should be destroyed by drilling out the PVC casing. This should be followed by pressure-grouting type I cement grout into the annulus of the uncased borehole. The primary reason for this recommendation is to reduce the possibility of obtaining questionable results from these wells because of poor construction and/or neglect. The USGS wells served a purpose in that they provided geologic data which were used in this investigation. However, the USGS wells are unusable as groundwater monitoring wells and should be properly destroyed.

6.2 Conversion of Piezometers to Groundwater Monitoring Wells

All Radian-installed piezometers have construction features suitable for groundwater sampling. Monitoring wells and piezometers that are suitable for groundwater monitoring have been chosen based on their proximity to the lagoon system. Two existing piezometers (S2, S4) have been selected for the

groundwater monitoring program, and are shown on Plate 11. The remaining existing piezometers are located over a large area surrounding the lagoons and are therefore not appropriate for inclusion in the RCRA groundwater monitoring well network. Therefore, these piezometers (supplemental wells) may be for determining groundwater levels, the potentiometric surface of the uppermost aquifer, and for calculation of the direction and magnitude of groundwater flow. In addition, these piezometers which are not put into use as groundwater monitoring wells will be available, if necessary, for water level measurements and field testing using parameters such as conductivity, pH, and temperature.

6.3 Installation of Additional Groundwater Monitoring Wells

The hydrogeologic setting of the base has been described sufficiently in terms of aquifer characteristics and groundwater flow patterns to support design of the RCRA groundwater monitoring system. Groundwater flow gradients and calculated velocities are also consistent and within reasonable ranges for the aquifer conditions encountered. The findings from the hydrogeologic investigation indicate that the uppermost aquifer consists of poorly stratified sand, silt, and clay bolson-fill deposits saturated with saline water.

For completion of the groundwater monitoring well network, several additional wells should be installed to complement the existing piezometers. The locations of additional groundwater monitoring wells are on base-owned property. These wells are located on-base since off-base sites for additional monitoring wells would involve siting difficulties (BLM land) and would not provide the capability to immediately detect groundwater contamination associated with the lagoons. The locations for the additional groundwater monitoring wells are identified in Table 6-1.

The groundwater monitoring wells will be screened at shallow depths, equivalent to the screened intervals of the existing piezometers. The monitoring well locations are intended to detect any changes in water quality that would occur as the result of sewage lagoon leakage. All of the

TABLE 6-1. MONITOR WELLS AND PIEZOMETERS PROPOSED FOR THE GROUNDWATER MONITORING NETWORK, HOLLOMAN AFB, NM

	Monitor Well	Piezometer	Total
Upgradient	MW-1	S-2	2
Downgradient	MW-2, 3, 4, 5, 6	S-4	6
TOTAL			8

hydrogeologic information derived from this investigation indicate that the groundwater monitoring network should focus on the interaction between the lagoons and groundwater adjacent to the lagoons.

6.4 Design and Construction Methods

A great deal of controversy surrounds well construction materials, especially those used in highly corrosive environments. The saline groundwater beneath the base is very corrosive to metal, as discussed in previous investigations (CH2M-Hill, 1983). On the other hand, adsorption of certain organic species from PVC is a laboratory concern. The intent of this monitoring program is to use the best material for the desired results. Stainless steel is less susceptible to corrosion than conventional steel, and is preferred in investigations involving organic contaminants. Therefore, for the groundwater monitoring program, the additional 6 monitoring wells will be constructed of type 316 stainless steel.

It is not considered cost-effective to eliminate usable PVC piezometers from the monitoring network based upon laboratory studies of PVC sorption characteristics. Laboratory tests show no significant difference between the responses of PVC, polytetrafluoroethylene, and 316 stainless steel well casings when they are exposed to volatile organic hydrocarbons (Radian, 1986, Gilliam, et al, 1988). Since previously installed PVC piezometers are proposed to be included in the monitoring network, groundwater analytical results from well casings made of the two materials can be compared. As a further check, one stainless steel monitoring well will be paired next to one upgradient and downgradient PVC well. Both pairs will be sampled and analyzed at the same time. A laboratory comparison of the results will determine whether corrosion of the steel or sorption of organics onto PVC is occurring.

Monitoring well depths shall depend upon the thickness of the first saturated zone. However, information about the geologic setting now indicates that wells will generally increase in depth the further downgradient they are

placed. Geologic cross-sections A-A' through H-H' provide very useful geologic data and water levels. Based upon these data, the depths for the additional monitoring wells will be approximately 15 feet below land surface.

Tables 6-2 and 6-3 list the proposed locations and depths of the existing and future groundwater monitoring wells at Holloman AFB. Included are screen lengths, well diameters, and construction specifications.

6.5 Definition of the Waste Management Area

The proposed groundwater network consists of a total of 8 wells: 2 existing piezometers and 6 new monitoring wells. The network is designed to be capable of yielding groundwater samples from the uppermost aquifer underlying sewage Lagoons A through G. The waste management area shown in Plate 11 is described by an imaginary boundary line which circumscribes the sewage lagoon system. The monitoring wells are located such that 2 wells are upgradient and 6 wells are downgradient of the lagoons. The numbers of wells and placement are intended to follow requirements set forth by 40 CFR 265.91(a) such that:

- The number of wells, locations, and depths must be representative of background water quality in the uppermost aquifer near the facility; and

- Background groundwater wells shall not be affected by the facility.

Since the intent is to treat all of the lagoons as the "waste management area" [265.91 (2)(B)], separate monitoring systems will not be installed for each lagoon. However, wells will be located at the waste management boundary to detect discharges from any lagoon within the waste management area.

TABLE 6-2. UPGRADIENT GROUNDWATER MONITORING WELL FEATURES, HOLLOMAN AFB, NM

Well No.	New Mexico State Plane Coordinates North	East	Total Depth (ft.)	Screened Interval (ft.)	Screen Length (ft.)	Construction Specs.
S-2	662911	547271	23.00	7-17	10	2-inch schedule 40 PVC
MW-1	666389	548527	15	10-15	5	4-inch 316 stainless steel

TABLE 6-3. DOWNGRADIENT GROUNDWATER MONITORING WELL FEATURES, HOLLOMAN AFB, NM

Well No.	New Mexico State Plane Coordinates North	East	Total Depth (ft.)	Screened Interval (ft.)	Screen Length (ft.)	Construction Specs.
S-4	662214	544927	18	6-11	5	2-inch schedule 40 PVC
MW-2	663720	544609	15	10-15	5	4-inch stainless steel (316)
MW-3	662837	544523	15	10-15	5	"
MW-4	660724	545341	15	10-15	5	"
MW-5	664784	544356	15	10-15	5	"
MW-6	661479	545271	15	10-15	5	"

6.5.1 Analytical Requirements

The analytical requirements for the groundwater monitoring plan are derived from 40 CFR Part 265, Subpart F, Section 265.92 "Sampling and Analysis." A list of the parameters is provided in Table 6-4 and found in Appendix III in 265.92, Subpart F. The list of parameters in Table 6-4 includes indicators of groundwater contamination and groundwater quality characteristics, interim drinking water parameters including RCRA metals, herbicides and pesticides, radioactivity, and coliform bacteria. It is understood that this list may be expanded on a site-by-site basis depending upon the facility and waste characteristics. However, the parameters listed in Table 6-4 are considered adequate for groundwater monitoring at Holloman AFB. If contamination is present, the groundwater monitoring wells and range of parameters to be sampled is sufficient to detect the release and, if required, an assessment monitoring plan would be developed, approved, and implemented as specified in 40 CFR 265.

6.5.2 Establishing Background Conditions

Referring to Plate 11, existing piezometer S-2 and proposed monitoring well MW-1 will likely represent background water quality conditions. Piezometers and monitoring wells immediately upgradient and downgradient from the lagoons may be subject to groundwater/surface water mixing below the lagoons. As stated in Part 265.92 (3)(c), the owner or operator (Holloman AFB) must establish initial background concentrations or values of all parameters listed in Table 6-4. This is usually done quarterly for one year. However, according to the Compliance Agreement (item 9), four sampling events are required on a monthly basis for four months. For the indicator parameters (pH, TOC, chloroform, and specific conductance), four replicate measurements will be made from the two designated upgradient wells sampled during the four-month period. During the fifth month, all eight groundwater monitoring wells including the upgradient wells will be sampled. Sample analyses and frequencies are shown in Table 6-5.

TABLE 6-4. INDICATOR AND APPENDIX III PARAMETERS INCLUDING SAMPLING AND PRESERVATION PROCEDURES FOR GROUNDWATER MONITORING[a]

Parameter	Recommended Container[b]	Preservative	Maximum Holding Time	Minimum Volume Required for Analysis
Indicator Parameters[c]				
pH	T, P, G	No Preservative	Field Determined	25 mL
Specific Conductance	T, P, G	No Preservative	Field Determined	100 mL
TOC	G, amber, T-lined cap[d]	Cool 4°C,[e] H_2SO_4 or HCl to pH <2	28 days	1,000 mL
Chloroform	G, amber, T-lined septa or caps	Cool 4°C	14 days	40 mL
Groundwater Quality Characteristics				
Chloride	T, P, G	Cool 4°C	28 days	50 mL
Iron Manganese Sodium	T, P	Field Acidified to pH <2 with HNO_3	6 months	200 mL
Phenols	G	4°C/H_2SO_4 to pH 2	28 days	500 mL
Sulfate	T, P, G	Cool 4°C	28 days	50 mL
EPA Interim Drinking Water Characteristics				
Arsenic Barium Cadmium Chromium	T, P	Total Metals Field Acidified to pH <2 with HNO_3	6 months	1,000 mL

(Continued)

TABLE 6-4. (Cont.)

Parameter	Recommended Container[b]	Preservative	Maximum Holding Time	Minimum Volume Required for Analysis
Lead	T, P	Dissolved Metals	6 months	1,000 mL
Mercury	T, P	Field Filtration		
Selenium	T, P	(0.45 micron)		
Silver	Dark Bottle	Acidify to pH <2 with HNO_3		
Fluoride	T, P	Cool, 4°	28 days	300 mL
Nitrate/Nitrite	T, P, G	$4^oC/H_2SO_4$ to pH <2	28 days	1,000 mL
Endrin Lindane Methoxyclor Toxaphene 2, 4 D 2, 4, 5 TP Silvex	T, G	Cool, 4^oC	7 days	2,000 mL
Coliform Bacteria	PP, G (Sterilized)	Cool, 4^oC	6 hours	200 mL

[a]References: Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, SW-846 (2nd Edition, 1982);
Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020; and
Standard Methods for the Examination of Water and Wastewater, 16th Edition (1985).

TABLE 6-4. (Cont.)

[b]Container Types:

P = Plastic (polyethylene)
G = Glass
T = Fluorocarbon resins (PTFE, Teflon, FEP, PFA, etc.)
PP = Polypropylene

[c]Sufficient volume must be collected to allow for analysis of four separate replicates per sampling episode

[d]T-lined = Teflon-lined

[e]Do not allow any head space in the container.

TABLE 6-5. ANALYTICAL PLAN AND SCHEDULE FOR GROUNDWATER MONITORING, HOLLOMAN AFB, NM

Date	Analyses	Wells	Submittal Requirements
Month 1-4	4 monthly sampling episodes for Appendix III parameters plus 4 replicate analyses/ month of indicator parameters (pH, chloroform, TOC, specific conductance)	2 background wells; S-2, MW-1	Submission of laboratory results within 15 days of each sampling episode.
Month 2-5			Holloman AFB submits to EPA and NMEID groundwater asssessment monitoring outline pursuant to 40 CFR 265.92(b)(2).
Month 5	One sampling episode of Appendix III parameters plus indicator parameters (pH, chloroform, TOC, specific conductance)	8 groundwater monitoring wells including 2 background wells	Detection monitoring begins per 265.92(b)(2)
Month 6			Holloman AFB submits to EPA and NMEID report summarizing groundwater monitoring including statistical interpretation of the results as discussed in the proposed detection monitoring plan.
Semi-Annual sampling after month 6	Continued groundwater monitoring; one sampling episode for indicator parameters (pH, chloroform, TOC, specific conductance)	8 groundwater monitoring wells including 2 background wells	Report to EPA and NMEID summarizing analytical results; provided no statistically significant changes in contaminants are detected from previous sampling episodes; otherwise, begin assessment monitoring.
Annual sampling after month 6	Groundwater quality parameters (chloride, iron, manganese, phenols, sodium sulfate)	8 groundwater monitoring wells including 2 background wells	Annual report to EPA and NMEID provided sampling results do not trigger assessment monitoring.

Concurrent with the collection of data, a comparison of upgradient and downgradient data will be made (265.93(c)(1)), and this report will be submitted to EPA and the state after the six-month sampling.

6.5.3 Sampling Methods

Sampling methods will be similar to methods discussed in Section 3.0 of this report for obtaining water samples.

To ensure the groundwater sample is representative of the formation, the well will be evacuated until indicator parameters, pH, temperature and conductivity, have stabilized. If one of these parameters does not stabilize, then purging will continue until 5 wetted well volumes have been evacuated before samples are collected. The best-suited sampling device for this operation is a 3-foot ball-type Teflon bailer. The bailer has a one-liter capacity, and is easy to operate and decontaminate. Purge water will be poured into a 5-gallon bucket and discharged away from the well to be sampled. Well volumes will be determined using the formula:

$$\text{Vol} = \pi r^2 h \times \frac{7.48 \text{ gal}}{1 \text{ cu. ft.}} \qquad (6\text{-}1)$$

where, r = radius of the well (feet); and
h = height of wetted column (feet).

Three indicator parameters, pH, conductivity, and temperature, will be measured during purging and after sample collection to check on the stability of the water sampled over time. Due to the extremely high conductivity values encountered during the hydrogeologic investigation, a field conductivity meter capable of accurately recording conductivities of 50,000 μmhos/cm^2 or more will be used.

Temperature will be obtained using a mercury in-glass thermometer. Conductivity and pH will be obtained using a S-C-T conductivity meter capable of recording conductivity values up to 100,000 μmhos/cm^2. Back-up units of each instrument will be kept in the field. Calibration techniques will be the same as discussed in Section 3.5 of this report.

Sample handling, labeling, shipping, and chain-of-custody documentation procedures will be discussed in a separate submittal entitled, "A-E Quality Control Plan/Sampling Plan (A-E QCP/SP)" produced under separate cover for the monitoring well installation and groundwater monitoring phase of the investigation. This plan shall provide the QA/QC requirements for the groundwater sampling and analysis as detailed in Table 6-5.

6.5.4 Statistical Analysis of the Background Data

There are four indicator parameters specified in 265.92(b)(3) and listed in Table 6-4 (pH, specific conductance, total organic carbon, and total organic halogen). The sampling is designed in a manner to calculate the arithmetic mean and variance based on at least four replicate measurements on each sample. The comparison must consider individually each of the four background wells in the monitoring system.

There are a number of statistical test methodologies in use. The owner/operator (Holloman AFB) proposes to use the averaged replicate (AR) t-test to analyze the groundwater monitoring data.

The test methodology will be submitted to include:

- A clear, understandable explanation of the AR test methodology;
- Presentation of explicit example calculations;

- Documentation of all original data used in the statistical analysis procedure;

- Literature and reference citations; and

- Detailed explanation of how the data were manipulated and evaluated prior to the statistical analysis, including goodness-of-fit testing, transformations, less than groundwater limit values, and power evaluations.

A professional statistician will evaluate the data to satisfy the necessary analytical and statistical t-test requirements as specified in CFR 265.93.

6.5.5 Presentation of Analytical Data

Within 30 days of EPA-NMEID approval of the Groundwater Monitoring Plan, the required six (6) groundwater monitoring wells shall be installed according to the schedule in Section 7.0. Upon EPA's approval, Holloman AFB will then proceed with an accelerated sampling schedule. Between the second and fifth month, Holloman will submit a groundwater assessment monitoring outline to EPA. Groundwater monitoring of the entire well network will begin during month 5. Within thirty (30) days of receipt of analysis of the fifth sampling event, Holloman AFB is required to submit a report summarizing the results of the previous five monthly sampling events including a statistical comparison of the results. This report shall be submitted in accordance with items 12 and 13, page 8, of the Compliance Agreement (20 December 88).

6.5.6 Analytical Methods, Quality Control and Quality Assurance

Water samples obtained during groundwater monitoring will be analyzed for the indicator and Appendix III parameters. The methods of

analysis, QA/QC procedures, and laboratory documentation are discussed in detail in Appendix I of this report.

6.6 Documentation

Full documentation of all field sampling activities is an essential part of the groundwater monitoring plan. The documentation will be provided in the A-E Daily Quality Control Report (A-E DQCR) and the A-E Quality Control Summary Report (A-E QCSR). The description of the contents of these reports is specified in Sections 6.6.7 and 6.6.8.

6.6.1 Well Logs

All observations made during drilling of each new groundwater monitoring well will be noted on a log of drilling operations as shown in Appendix B. Information will include:

- Lithologic descriptions;
- Sample intervals;
- Blow counts;
- HNU readings;
- Geologic symbols;
- Unified Soil Classification System symbols; and
- First and subsequent encounter of groundwater.

6.6.2 Groundwater Sampling Field Data Sheet

This form, as shown in Figure 6-1, will be used any time that a monitoring well is purged and/or sampled. The date and time of purging and/or sampling is recorded, as well as the water level and total depth of the well prior to purging. The volume of standing water in the well will also be calculated at this time using the depth from static water level to the well bottom, which is multiplied by the volume of water per foot of casing. The well volume is recorded in the project notebook. The volume removed before

GROUNDWATER FIELD DATA SHEET

Parameter Description	Value
SAMPLE CONTROL NUMBER	_____
DATE	_____
TIME	_____
SAMPLER'S INITIALS	_____
WELL/BORING LOCATION	_____
WELL/BORING DIAMETER (in)	_____
ELEVATION OF TOP OF WELL CASING	_____
REFERENCED TO MEAN SEA LEVEL (MSL)	_____
WATER-LEVEL MEASUREMENT	_____
Total Depth (ft)	_____
Depth to Groundwater (ft)	_____
CALCULATIONS	
Thickness of Groundwater (ft)	_____
Well Volume (gallons)	_____
Purge Volume (gallons)	_____
NUMBER OF SAMPLE BOTTLES AND TYPE COLLECTED	_____
	_____
	_____
	_____
pH	_____
Conductance (umhos)	_____
Temperature (°C)	_____

COMMENTS:

Figure 6-1. Groundwater Sampling Field Data Sheet

the well is sampled is also recorded. In addition, the sampler's initials, sample types collected, and field measurements will be recorded.

6.6.3 Sample Label

A sample label (Figure 6-2) will be affixed to all sampling containers submitted for laboratory analysis. Sample labels identify the sample by documenting the sample type, sampler(s) initials, sampling locations, depth, time, and date. The unique number assigned to each sample is also noted on the sample label.

6.6.4 Decontamination and Cleansing Requirements

To ensure that augering and water sampling equipment are not contaminated or cross-contaminated by materials and equipment used in the course of the investigation, the following procedures will be used to decontaminate the following items:

Hollow-Stem Auger Rig	Pressure washed after each borehole location.
Drill Pipe	Same as above.
Split Spoon Sampler	Wash with ALCONOX, water and/or steam after each borehole.
Water Level Probe	Wash with ALCONOX, tap rinse, distilled rinse between soundings of monitoring wells.
Teflon Bailer	Wash with ALCONOX, tap rinse, distilled rinse after each monitoring well.

6.6.5 Chain of Custody

A chain of custody form (Figure 6-3) will be used to record the number of samples collected and the corresponding laboratory analyses. Information on this form includes time and date of sample, sample number, type of

ATTENTION:
BEFORE OPENING NOTE IF BOTTLE WAS TAMPERED WITH.

RADIAN CORPORATION
8501 Mo-Pac Blvd. / P.O. Box 201088
Austin, Texas 78720-1088 / (512) 454-4797

SAMPLE# MW-1

ATTENTION:
BEFORE OPENING NOTE IF BOTTLE WAS TAMPERED WITH.

5-83-12896

RADIAN CORPORATION Field Number MW-1
8501 Mo-Pac Blvd. / P.O. Box 201088 / Austin, Texas 78720-1088 (512) 454-4797

Sample Type: Groundwater
Client: US Army Corps of Engineers
Location: Holloman AFB, NM
Preservative: HCL pH<2 4°C
Sampler: TKW
Date: 5/10/88 1300 hrs.
Comment: metals

3-85-20160

Figure 6-2. Sample Labels, Holloman AFB, New Mexico

RADIAN CORPORATION

8501 Mo-Pac Blvd.
P.O. Box 201088
Austin, TX 78720-1088

Chain of Custody Record

Analyses

PROJECT

SITE

COLLECTOR

SAMPLE I.D.	TYPE	DATE/TIME		REMARKS

RELINQUISHED BY:	DATE	TIME	RECEIVED BY:	RELINQUISHED BY:	DATE	TIME	RECEIVED BY:
RELINQUISHED BY:	DATE	TIME	RECEIVED BY:	RELINQUISHED BY:	DATE	TIME	RECEIVED BY:

RECEIVED FOR LABORATORY BY:	DATE	TIME	REMARKS

10-86-25948

Figure 6-3. Sample Chain of Custody Record for Groundwater Monitoring Program, Holloman, AFB, New Mexico

sample, sampler's name, preservatives used, and any special instructions. A copy of the chain of custody form will be retained by the sampler before the samples are shipped.

6.6.6 Field Log Book

The field log book serves primarily as a daily log of activities carried out during the investigation. Any observations during drilling activities not included in the drilling log will be recorded in this log. This field log book will also be used during sampling activities to record sampling locations and the unique number assigned to the corresponding samples collected from that particular monitor well. The field log book is a bound book with preprinted, sequentially numbered pages.

Other observations may be included as the situation dictates for a thorough record to reconstruct the events concerning all field activities.

6.6.7 A-E Daily Quality Control Reports (A-E DQCR)

The A-E DQCR is a report that will be submitted to the Omaha COE Project Manager and Holloman Environmental Coordinator on a daily basis. The information will be submitted on a form as shown in Figure 6-4 (and Appendix J). It will be a memorandum covering the following topics:

- Date;
- Weather, including temperature, wind speed, and direction, etc.;
- Work performed;
- Sampling performed, including specifics;
- Field parameter measurements, including calibration checks;
- Problems encountered and corrective actions taken;
- Quality control activities initiated; and
- Signature.

Date: _____

Sheet No.: _____

A-E DAILY QUALITY CONTROL REPORT FOR GROUNDWATER MONITORING
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: _____

Weather: _____

Work Performed: _____

_____

_____

_____

Sampling Performed: _____

_____

_____

_____

Problems and Corrective Actions: _____

_____

_____

_____

_____

_____

Quality Control Activities Initiated: _____

_____

_____

Signature: _____

Figure 6-4. Example of A-E Daily Quality Control Report.

In addition to these daily reports, the Omaha COE Project Manager will be immediately contacted by telephone when exceptional situations develop, including significant changes in the execution of this contract.

6.6.8 A-E Quality Control Summary Report (A-E QCSR)

This report, to be submitted by Radian at the end of the groundwater monitoring well installation phase, will address the following as a summary of the progress of the QC program and of the overall investigation:

- Scope of project;
- Project description;
- Sampling procedure, as planned and actually implemented;
- Summary of A-E daily QC reports;
- Analytical procedures;
- Data presentation;
- Quality control activities;
- Presentation of field and lab results;
- Discussion of reliability of resulting data; and
- Conclusions and recommendations.

7.0 SCHEDULE

A schedule of activities is presented in Table 7-1. The schedule is in part dictated by the terms and conditions listed in the Compliance Agreement between EPA and Holloman AFB (Appendix K).

Approval of the proposed Groundwater Monitoring Plan, discussed in Section 6.0, is also requested after EPA's review and approval of the Hydrogeologic Investigation. If approval of this report is obtained, Radian will begin installing groundwater monitoring wells within 30 days of the approval date. The techniques and methods of monitoring well installation will reflect the most recent technical and regulatory considerations available. (A copy of Radian's Scope of Services for the GWMP and HIR is provided in Appendix L.)

TABLE 7-1. SCHEDULE OF ACTIVITIES

Date	Days	Activity
July 1988		Submittal of Final Hydrogeologic Investigation Report and Groundwater Monitoring Plan to USACE, TAC and Holloman AFB
18 Aug 1988		Final HIR and GWMP Hand-Carried to USEPA by Holloman AFB
20 Dec 1988		Federal Facilities Compliance Agreement Signed between Holloman AFB and USEPA
27 Jan 1989		Received USEPA and NMEID Comments on HIR and GWMP
9 Mar 1989		Submitted Revised HIR and GWMP per USEPA and NMEID Comments
	+ 30	Final Approval of Revised HIR and GWMP by USEPA and NMEID
	+ 30	Commence Installation of Groundwater Monitoring System
	+ 60	Complete Installation of Groundwater Monitoring System
	+ 30	Submit Groundwater Monitoring Installation Report
	+ 45	USEPA and NMEID Review of Groundwater Installation Report and Return Comments to HAFB
	+ 45	Respond to USEPA/NMEID Comments and Demands for Approval
	+ 45	USEPA/NMEID Approves Groundwater Installation Report

(continued)

TABLE 7-1. (contd.)

Date	Days	Activity
	+ 15	First Round Groundwater Sampling Design
	+ 7	First Round Groundwater Sampling Complete
	+ 45	First Round Lab Analyses Complete and Reported
	+ 15	Submit Lab Report to USEPA/NMEID

REFERENCES

CH2M Hill, 1983, Installation Restoration Program Records Search, Holloman Air Force Base, New Mexico.

Computrac, Inc., 1986, DeListing Proposal Holloman Air Force Base Sewage Treatment Lagoons, 88p.

Cooper, H. S. and C. E. Jacob, 1946, A Generalized Graphic Method for Evaluating Formation Constants and Summarizing Well-Field History. Transactions of American Geophysical Union. Vol. 27, No. 4.

Dames and Moore, 1986, Holloman AFB Installation Air Force Base Installation Restoration Program-Phase I.

Ferris, J. G., and Knowles, D. B., 1954, Slug Test for Estimating Transmissibility: U.S. Geol. Survey Ground Water Note 26.

Ferris, J. G., Knowles, D. B., Brown, R. H. and Stallman, R. W., 1962, Theory of Aquifer Tests: U.S. Geol. Survey Water-Supply Paper 1536-E.

Fetter, C. W., 1980, Applied Hydrogeology. Bell and Howell Co., Columbus, OH. 488pp.

Freeze, A. R., Cherry, J. A., 1979a, Groundwater. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Gillham, R. W. and S. F. O'Hannesin, 1988, Sorption of Aromatic Hydrocarbons by Materials Used in Construction of Groundwater Sampling Wells. Institute for Groundwater Research, University of Waterloo, Waterloo, Ontario, ASTM Standards Development for Groundwater and Vadose Zone Investigations.

McLean, J. S., 1970, Saline Ground-water Resources of the Tularosa Basin, New Mexico: U. S. Department of the Interior, Office of Saline Water Research and Development Progress Report 561, 128pp.

Orr, Brennon, USGS Water Resources Division, Communication Between T. K. Walters and B. Orr on 17 September, 1987.

Poole, L., M. Borchers, and K. Koessel, 1981, Some Common BASIC Programs. OSBORNE/McGraw-Hill, 193pp.

Radian Corporation, 1986, Sorption of Organics by Monitoring Well Construction Materials, Groundwater Monitoring Review, 4pp.

U. S. Department of Agriculture Soil Conservation Service, 1971, Soil Survey of White Sands Missile Range, New Mexico, 64pp.

U. S. Environmental Protection Agency, 1975, Manual of Water Well Construction Practices, EPA-570/9-75-001, 156pp.

U. S. Environmental Protection Agency, 1986, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.

U. S. Environmental Protection Agency, Title 40 Code of Federal Regulations.

U. S. Geological Survey, 1963, Methods of Determining Permeability, Transmissibility and Drawdown. Water Supply Paper 1536-I.

U. S. Geological Survey, 1985, Hydrologic Data on the Shallow Bolson Fill near the Sewage Lagoons and Lake Holloman, Holloman Air Force Base, Alamogordo, New Mexico, 31p.

U. S. Geological Survey, 1986, Water Resources in Basin-Fill Deposits in the Tularosa Basin, New Mexico, Report 85-4219, 94pp.

Walton, W. C., 1986, Groundwater Pumping Tests Design and Analysis. Lewis Publishers, Chelsea, Michigan, 201pp.

Wilson and Company, Engineers and Architect, 1986, Evaluation of USGS Groundwater Data for Sewage Lagoons, Holloman AFB, New Mexico, unpubl.

APPENDIX I

ANALYTICAL REQUIREMENTS
FOR APPENDIX III AND IX ANALYSES
INCLUDING QA/QC AND INSTRUMENT METHODS
HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

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1.0 INTRODUCTION

According to 40 CFR 265.90 (Subpart F), the owner or operator of a surface impoundment, landfill, or land treatment facility which is used to manage hazardous waste must implement a ground-water monitoring program capable of determining the facility's impact on the quality of ground water in the uppermost aquifer underlying the facility. The ground-water monitoring program must determine the concentration of parameters listed in Appendix III of 40 CFR 265 to characterize the suitability of the ground water as a drinking water supply as stated in 40 CFR 265.92(b)(1). Other ground water quality and contamination parameters listed in 40 CFR 265.92(b)(2) and (3) are also required to be monitored. Any values which exceed the interim primary drinking water standards must be reported to the Regional Administrator according to 40 CFR 265.94(a)(2)(i).

During the detection monitoring program (after the first year of data gathering), if a significant increase is found in any of the monitoring wells, the owner or operator must immediately sample the ground water in all of the monitoring wells for Appendix IX constituents according to 40 CFR 264.98(h)(2). The owner or operator must determine if any of the Appendix IX constituents are present and at what concentrations.

Section 2 discusses the analytical methods for the ground water indicator, contamination, Appendix III, and Appendix IX parameters. Section 3 discusses the analytical and statistical control parameters for the ground water indicator, contamination, Appendix III, and Appendix IX parameters. Section 4 discusses the calibration procedures and their frequency for the analytical equipment. Section 5 discusses preventive maintenance of the analytical equipment, and Section 6 presents data analysis and reporting procedures.

2.0 ANALYTICAL METHODS AND PROCEDURES

Section 2 presents the analytical methods and procedures which will be used for analysis of the groundwater samples obtained at Holloman AFB. The discussion of these analytical methods is divided into two groups. Section 2.1 presents the analytical methods and procedures for ground-water quality indicators, contamination, and Appendix III parameters. Section 2.2 presents the analytical methods and procedures for Appendix IX parameters.

2.1 Analytical Methods and Procedures for Ground-Water Quality and Contamination Indicators and Appendix III Parameters

Water samples obtained from the monitoring wells will be analyzed by Radian Analytical Services (RAS) in Sacramento, California or Austin, Texas.

The specific methods to be used for ground water analysis are identified in Section 2.1.1. Corresponding detection limits are presented in Section 2.1.2. The methods are described in more detail in Section 2.1.3, including procedures for instrument operation and interference identification.

Procedures to be used for validating the analytical methods used, such as the analysis of spiked samples, are described in Section 2.1.4. Section 2.1.5 contains a discussion of laboratory instrumentation, reagents, and standards.

2.1.1 Identification of Analytical Methods

Test methods for analytical procedures will be performed according to procedures in the following publications:

- SW-846, Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, U.S. EPA, Office of Solid Waste and Emergency Response, November 1986, third edition.

- EPA, Methods for Analysis of Water and Wastes, EPA Publication No. 600/4-79-020, March 1979.

- EPA, Prescribed Procedures for Measurement of Radioactivity in Drinking Water, EPA Publication No. 600/4-80-032, August 1980.

Analytical methods to be used for ground water analysis are listed in Table 2-1. Procedures required for sample preparation, such as solvent extraction and acid dissolution, are also listed. References to laboratory manuals are included.

2.1.2 Limits of Detection

Limits of detection are presented in Table 2-2 for the analytical parameters and methods identified in Section 2.1.1.

The limit of detection has been defined as the minimum concentration of a substance that can be measured with 99 percent confidence. Detection limits depend on the sample matrix as well as instrument capability. The ground water samples to be analyzed are expected to contain high concentrations of chloride; total filterable residue is expected to be approximately 20,000 mg/L.

2.1.3 Description of Analytical Methods

The analytical methods identified in Section 2.1.1 are described in more detail in the following paragraphs. A summarized description is given for the methods by the references shown in Table 2-1.

2.1.3.1 TOC Analysis Using Method 9060

Method 9060 uses a carbonaceous analyzer to measure organic carbon. This instrument converts the organic carbon in a sample to carbon dioxide by either catalytic combustion or wet chemical oxidation. The carbon dioxide formed is then either measured directly by an infrared detector or converted to methane

TABLE 2-1. ANALYTICAL METHODS[a]

	Preparation		Analysis	
	Technique	Reference	Technique	Reference
TOC	----------	SW-846 : 9060	Carbonaceous Analyzer	SW-846 : 9060
POX	----------	SW-846 : 9021	Microcoulometric-titration	SW-846 : 9021
Chloride, Sulfate	----------	EPA : 300.0	Ion Chromatography	EPA : 300.0
Phenols	----------	SW-846 : 9066	Colorimetric	SW-846 : 9066
Nitrate/Nitrite	Nitrate Reduction	EPA : 353.1	Colorimetric	EPA : 353.1
Fluoride	----------	EPA : 340.2	Potentiometric	EPA : 340.2
Arsenic	Acid Digestion	SW-846 : 7060	Graphite AA	SW-846 : 7060
Lead	Acid Digestion	SW-846 : 7421	Graphite AA	SW-846 : 7421
Mercury	Acid Digestion	SW-846 : 7470	Cold Vapor AA	SW-846 : 7470
Selenium	Acid Digestion	SW-846 : 7740	Graphite AA	SW-846 : 7740
Additional Metals[b]	Acid Digestion	SW-846 : 6010	ICPES	SW-846 : 6010
Pesticides[c]	Solvent Extraction	SW-846 : 3510 or 3520	GC/ECD	SW-846 : 8080
Herbicides[d]	Solvent Extraction	SW-846 : 8150	GC/ECD	SW-846 : 8150
Radium	Precipitation	EPA : 903.0	Counting	EPA[1] : 903.0
Gross Alpha and Beta	Evaporation	EPA : 900.0	Counting	EPA[1] : 900.0
Total Coliform Bacteria	----------	SW-846 : 9132	Membrane Filter	SW-846 : 9132

[a]Analytical Methods references include:

SW-846: Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods, 3rd edition.

EPA: Methods for Analysis of Water and Wastes, March 1979, 600/4-79-020.

EPA[1]: Prescribed Procedures for Measurement of Radioactivity in Drinking Water, August 1980, 600/4-80-032.

[b]Additional metals include: iron, manganese, sodium, barium, cadmium, chromium, and silver.

[c]Pesticide analyses includes: endrin, lindane, methoxychlor, and toxaphene.

[d]Herbicide analyses includes: 2,4-D, and 2,4,5-TP (Silvex).

TABLE 2-2. DETECTION LIMITS FOR GROUND-WATER SAMPLES BASED ON METHODS IDENTIFIED IN TABLE 2-1

Parameter	Detection Limit	
TOC	1	mg/L
TOX	0.05	mg/L
Chloride	1	mg/L
Sulfate	1	mg/L
Phenols	0.005	mg/L
Nitrate/Nitrite	0.02	mg/L
Fluoride	0.1	mg/L
Arsenic	10	μg/L
Lead	5	μg/L
Mercury	0.2	μg/L
Selenium	5	μg/L
Iron	50	μg/L
Manganese	15	μg/L
Sodium	100	μg/L
Barium	20	μg/L
Cadmium	5	μg/L
Chromium	10	μg/L
Silver	10	μg/L
Endrin	0.01	μg/L
Lindane	0.01	μg/L
Methoxychlor	0.05	μg/L
Toxaphene	0.5	μg/L
2,4-D	1.2	μg/L
2,4,5-TP (Silvex)	0.17	μg/L
Radium	not to exceed 5	pCi/L
Gross Alpha	3	pCi/L
Gross Beta	4	pCi/L
Coliform Bacteria	<1/100	mg/L

and measured by a flame ionization detector. The amount of carbon dioxide or methane in a sample is directly proportional to the concentration of carbonaceous material in the sample. This method is most applicable to measurement of organic carbon above 1 mg/L.

2.1.3.2 POX Analysis Using Method 9021

Method 9021 determines purgeable organic halides (POX) using carbon adsorption with a microcoulometric-titration detector. The method detects all organic halides containing chlorine, bromine, and iodine that are adsorbed by granular activated carbon. Fluorine-containing species are not determined by this method.

A sample of water is protected against the loss of volatiles by the elimination of headspace in the sampling container. The sample is purged, swept into the oven, and combusted to convert the organohalides to HX, which is trapped and titrated electrolytically using a microcoulometric detector. Operating procedures and interferences are described in Method 9021.

2.1.3.3 Chloride and Sulfate Analyses Using EPA Method 300.0

Method 300.0 is an ion chromatographic method applicable to the determination of certain anions in water of which chloride and sulfate are included. A small volume of sample is introduced into an ion chromatograph. The anions of interest are separated and measured, using a system comprised of a guard column, separator column, suppressor column, and conductivity detector. Operating parameters and interferences are described in the Test Method.

2.1.3.4 Metal Analysis Using SW-846 Method 6010

Method 6010 uses Inductively Coupled Plasma (Atomic) Emission Spectrometry (ICPES) to determine the concentration of metals in the ground water. Prior to analysis, samples are subjected to the acid digestion procedures

described in Method 6010. The following metals will be analyzed for using this method: iron, manganese, sodium, barium, cadmium, chromium, and silver.

The basis of chemical analysis by ICPES is the measurement of atomic emission by an optical spectroscopic technique. Samples are nebulized, and the aerosol that is produced is transported to the plasma torch where excitation occurs. Characteristic atomic-line emission spectra are produced by a radio frequency inductively coupled plasma. The resulting spectra are dispersed by a grating spectrometer, and the intensities of the line are multiplied by photomultiplier tubes. Inter-element correction is used for all analyses. Operating parameters and interferences are described in Method 6010.

2.1.3.5 Phenol Analysis Using SW-846 Method 9066

Method 9066 is an automated colorimetric analysis. The method is based on the distillation of phenol and subsequent reaction of the distillate with alkaline ferricyanide and 4-amino-antipyrine to form a red complex which is measured at 505 or 520 nm. The method is capable of measuring phenolic materials from 2 to 500 ug/L in the aqueous phase using phenol as a standard. Operating procedures and interferences are described in Method 9066.

2.1.3.6 Arsenic, Lead, and Selenium Analysis Using SW-846 Methods 7060, 7421, and 7740

Furnace atomic absorption spectrophotometry is used for arsenic, lead, and selenium analysis, according to the procedures outlined in EPA SW-846 Methods 7060, 7421, and 7740 respectively. Prior to analysis, acid digestion of the sample is required as described by the above methods.

Following acid digestion, an aliquot of sample is dried, charred, and atomized in a graphite furnace. Light from a metal-specific hollow cathode lamp is passed through the resulting vapor containing ground-state atoms. The decrease in the spectral intensity across the vapor is proportional to the

concentration of the metal being determined. Operating parameters and interferences are described in the respective methods.

2.1.3.7 Mercury Analysis Using SW-846 Method 7470

Method 7470 uses cold vapor atomic absorption to determine concentration values of mercury in ground water. Prior to analysis, acid digestion of the sample is required as described in Method 7470.

Following acid digestion, mercury is reduced to its elemental state with stannous sulfate. The mercuric vapor is then pumped through a closed system to a cell positioned in the light path of an atomic absorption spectrophotometer. The amount of light absorbed is proportional to the amount of mercury in the sample. Operating parameters and interferences are described in Method 7470.

2.1.3.8 Fluoride Analysis Using EPA Method 340.2

The concentration values of fluoride is determined potentiometrically using a fluoride electrode in conjunction with a standard single junction sleeve-type reference electrode and a pH meter having an expanded millivolt scale or a selective ion meter having a direct concentration scale for fluoride. The fluoride electrode consists of a lanthanum fluoride crystal across which a potential is developed by fluoride ions. This method can measure concentrations from 0.1 to 1000 mg/L. Operating parameters and interferences are described in EPA Method 340.2.

2.1.3.9 Nitrate/Nitrite Analysis Using EPA Method 353.1

In this method nitrate is reduced to nitrite with hydrazine sulfate and the nitrite (that was originally present plus reduced nitrate) is determined by diazotizing with sulfanilamide and coupling with N-(1-naphthyl)-ethylenediamine dihydrochloride to form a highly colored azo dye which is measured colorimetrically. The applicable measurement range for this method is 0.01 to

10 mg/L. Operating parameters and interferences are describe in EPA Method 353.1.

2.1.3.10 Pesticide Analysis Using Methods 8080 and 3510 (3520)

Method 8080 is a gas chromatographic method using electron capture detection or halide-specific detection. This method is used to determine the concentration of certain organochlorine pesticides in a variety of matrices, including ground water. The pesticides to be measured include: endrin, lindane, methoxychlor, and toxaphene.

Prior to analysis, samples are extracted at a neutral pH using methylene chloride as a solvent. Ground water samples can be extracted using either Method 3510 (separatory funnel) or Method 3520 (continuous liquid-liquid extractor). Operating parameters and interferences are described in Methods 8080, 3510, and 3520.

2.1.3.11 Herbicide Analysis Using SW-846 Methods 8150 and 3510 (3520)

Method 8150 provides extraction, esterification, and gas chromatographic conditions for the analysis of chlorinated acid herbicides such as 2,4-D and 2,4,5-TP (Silvex). Spiked samples are used to verify the applicability of the chosen extraction technique to each new sample type. The esters are hydrolyzed with potassium hydroxide, and extraneous organic material is removed by a solvent wash. After acidification, the acids are extracted with solvent and converted to their methyl esters using diazomethane as the derivatizing agent. After excess reagent is removed, the esters are determined by gas chromatography employing an electron capture detector, microcoulometric detector, or electrolytic conductivity detector. The results are reported as the acid equivalents. The sensitivity of Method 8150 usually depends on the level of interferences rather than on instrumental limitations.

2.1.3.12 Radium Analysis Using EPA Method 903.0

The radium in the ground water sample is collected by coprecipitation with barium and lead sulfate, and purified by reprecipitation from EDTA solution. Citric acid is added to the ground water sample to assure that complete interchange occurs before the first precipitation step. The final barium sulfate precipitate, which includes radium-226, radium-224, and radium-223, is alpha counted to determine the total disintegration rate of the radium isotopes.

The radium activities are counted in an alpha counter where efficiency for determining radium-226 has been calibrated with a standard of known radium-226 activity. By making a correction for the ingrowth of alpha activity in radium-226 for the elapsed time after separation, one can determine radium activity in the sample. Since some daughter ingrowth can occur before the separated radium is counted, it is necessary to make activity corrections for the count rate. Operating parameters and interferences are described in Method 903.0.

2.1.3.13 Gross Alpha and Beta Analysis Using EPA Method 900.0

An aliquot of a preserved ground water sample is evaporated to a small volume and transferred quantitatively to a tared 2-inch stainless steel counting planchet. The sample residue is dried to constant weight, reweighed to determine dry residue weight, then counted for alpha and beta radioactivity.

Counting efficiencies for both alpha and beta particle activities are selected according to the amount of sample solids from counting efficiency versus sample solids standard curves. Operating parameters and interferences are described in Method 900.0.

2.1.3.14 Total Coliform Bacteria Analyses Using SW-846 Method 9132

The coliform bacteria group analyzed in this procedure includes all of the organisms that produce a colony with a golden-green metallic sheen within 24 hours of inoculation.

A predetermined amount of sample is filtered through a membrane filter which retains the bacteria found in the sample. In the two-step enrichment procedure, the filters containing bacteria are placed on an absorbent pad saturated with aluryl tryptose broth and incubated at approximately 35°C for 2 hours. The filters are then transferred to an absorbent pad saturated with M-Endo media or to a dish containing M-Endo agar and incubated for another 21 hours at approximately the same temperature. Sheen colonies are then counted under magnification and reported per 100 mL of original sample.

2.1.4 Validation of Analytical Methods

Several procedures will be used to validate the analytical methods as they are applied to the ground water matrix. The ground water samples to be analyzed are expected to contain high concentrations of chloride, total filterable residue is expected to be approximately 20,000 mg/L.

Validation procedures fall into two categories: 1) those designed to verify that the analytical system itself is performing as well as required; and 2) those designed to verify that the analytical methods are adequate for the ground water matrix being analyzed.

System validation procedures will consist of the following:

- Analysis of method blanks,
- Calibration checks,
- Analysis of surrogate standards, and
- Analysis of standard reference materials.

The following procedures will be used to verify that the analytical methods used are adequate for the ground water matrix being analyzed:

- Duplicate analysis of samples;
- Analysis of samples spiked with a known amount of analyte; and
- Analysis using the method of standard additions, if spiked ground water samples show interferences caused by the matrix.

The validation procedures listed above will be performed at the frequencies specified in Section 5.0. Section 5.0 also contains more detailed descriptions of these validation procedures.

2.1.5 Laboratory Instrumentation, Reagents, and Standards

The instrumentation that will be used for the analytical methods are listed in Table 2-3.

Laboratory reagents and standards are obtained from the following suppliers:

- For inorganic analysis, spectral grade and reagent grade standards and reagents are obtained from Spex, Fisher, and Ricca. Standard reference materials are obtained from the National Bureau of Standards and the EPA Environmental Monitoring and Support Laboratory.
- For organic analysis, spectral grade and reagent grade solvents and reagents are obtained from Aldridge, Sigma, and Burdick and Jackson. Analytical standards are obtained from

TABLE 2-3. INSTRUMENTATION USED FOR GROUND-WATER ANALYSES OF INDICATOR, QUALITY, AND APPENDIX III PARAMETERS

Parameter	Instrument
TOC	Dohrmann DC-80
POX	Dohrmann DX-20
Chloride, Sulfate	Dionex Model 2110
Phenols, Nitrate/Nitrite	Technicon Autoanalyzer II Photometer
Fluoride	Ion Selective Electrode
Metals - AA (excluding Hg)	Perkin Elmer 3030 and 3030 Zeeman AA
Metals - ICPES	Thermo Jarrell-Ash Model 61
Mercury	Perkin Elmer Model 403
Pesticides and Herbicides	Varian 3700 and Varian Vista 6000 GC with dual electron capture detectors and Model 8000 auto samplers
Radium, Gross Alpha and Beta	Tennelec LB1000 and Ludlum 148-2
Total Coliform Bacteria	Not Applicable

repositories maintained by EPA and by the National Toxicology Program administered by the National Institute of Environmental Health Sciences.

2.2 Analytical Methods and Procedures for Appendix IX Parameters

Water samples obtained from the monitoring wells will be analyzed by Radian Analytical Services (RAS) in Sacramento, California or Austin, Texas. Methanol will not be determined because it is in use throughout the organic laboratories as an extraction solvent and a carrier solvent. The resulting background concentration makes accurate trace analysis of methanol impractical, if not impossible.

The specific methods to be used for groundwater analysis are identified in Section 2.2.1. Corresponding detection limits are presented in Section 2.2.2. The methods are described in more detail in Section 2.2.3, including procedures for instrument operation and interference identification.

Procedures to be used for validating the analytical methods used, such as the analysis of spiked samples, are described in Section 2.2.4. Section 2.2.5 contains a discussion of laboratory instrumentation, reagents, and standards.

2.2.1 Identification of Analytical Methods

With one exception (fluoride), all parameters will be determined according to methods published in SW-846 (Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, U.S. EPA, Office of Solid Waste and Emergency Response, November 1986, third edition), as modified for the CLP scope of work effective August 1985. Fluoride will be determined according to the method published in Methods for Analysis of Water and Wastes, U.S. EPA, March 1979, Publication No. 600/4-79-020.

Analytical methods to be used for groundwater analysis are listed in Table 2-4. Procedures required for sample preparation, such as solvent extraction and acid dissolution, are also listed. References to laboratory manuals are included.

2.2.2 Limits of Detection

Limits of detection are presented in Table 2-5 for the analytical parameters and methods identified in Section 2.2.1.

The limit of detection has been defined as the minimum concentration of a substance that can be measured with 99 percent confidence. Detection limits depend on the sample matrix as well as instrument capability. The groundwater samples to be analyzed are expected to contain high concentrations of chloride; total filterable residue (total dissolved solids) is expected to be approximately 20,000 mg/L.

The limits of detection shown in Table 4-5 were taken from the following sources:

- For volatile organic compounds, data published in Method 8240 and experience by Radian Analytical Services (RAS) with Method 8240.

- For extractable organic compounds, RAS experience with Method 8270.

- For pesticides and polychlorinated biphenyls, RAS experience with Method 8080.

- For Appendix IX metals, RAS experience with Methods 6010/7060/7421/7470/7740.

- For sulfides, RAS experience with Method 9030.

TABLE 2-4. ANALYTICAL METHODS

Parameter	Preparation		Analysis	
	Technique	Reference	Technique	Reference
Volatile Organic Compounds (including Xylene)	Purge and Trap	SW-846 : 5030	GC/MS	SW-846 : 8240
Extractable Organic Compounds (acid and base/neutral fractions)	Solvent Extraction	SW-846 : 3530	GC/MS	SW-846 : 8270
Pesticides and Polychlorinated Biphenyls	Solvent Extraction	SW-846 : 3510 or 3520	GC/ECD	SW-846 : 8080
Arsenic	Acid Digestion	SW-846 : 7060	Graphite AA	SW-846 : 7060
Lead	Acid Digestion	SW-846 : 3010	Graphite AA	SW-846 : 7421
Mercury	Acid Digestion	SW-846 : 7470	Cold Vapor AA	SW-846 : 7470
Selenium	Acid Digestion	SW-846 : 7740	Graphite AA	SW-846 : 7740
Additional Appendix IX Metals[a]	Acid Digestion	SW-846 : 6010	ICPES	SW-846 : 6010
Cyanide	Distillation	SW-846 : 9012	Colorimetry	SW-846 : 9012
Polychlorinated Dioxins and Furans	Matrix-Specific Extraction	SW-846 : 8280	HRGC/LRMS	SW-846 : 8280
Fluoride	----------	EPA : 340.2	Potentiometric	EPA : 340.2
Organophosphorus Pesticides	Waste Dilution	SW-846 : 3580, 3620, or 3660	GC	SW-846 : 8140
Sulfides	Oxidization	SW-846 : 9030	Titration	SW-846 : 9030
Herbicides	Solvent Extraction	SW-846 : 8150	GC/ECD	SW-846 : 8150

(continued)

TABLE 2-4. (Cont.)

[a]Additional Appendix IX metals are: antimony, barium, beryllium, cadmium, chromium, cobalt, copper, nickel, silver, thallium, tin, vanadium, and zinc. (Source: Volume 52, Federal Register, No. 142, 9 July 1987.)

LEGEND:

SW-846	Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, July 1982, Second Edition.
GC/MS	Gas chromatography/mass spectrometry.
GC/ECD	Gas chromatography/electron capture detection.
AA	Atomic absorption spectrometry.
ICPES	Inductively coupled plasma (atomic) emission spectrometry.
HRGC/LRMS	High-resolution capillary column gas chromatography/low resolution mass spectrometry.
EPA	Methods for Analysis of Water and Wastes, March 1979, EPA Publication No. 600/4-79-020.

TABLE 2-5. DETECTION LIMITS FOR GROUND-WATER SAMPLES BASED ON METHODS IDENTIFIED IN TABLE 2-4

Parameter	Detection Limit (μg/L)
Volatile Organic Compounds	
Xylenes (total)	4.6
Chloromethane	5.0
Bromomethane	5.0
Vinyl Chloride	5.0
Chloroethane	5.0
Methylene Chloride	10
Acetone	25
Carbon Disulfide	2.0
Trichlorofluoromethane	10
1,1-Dichloroethene	4.7
1,1-Dichloroethane	2.8
trans-1,2-Dichloroethene	2.0
Chloroform	2.0
1,2-Dichloroethane	2.8
2-Butanone	25
1,1,1-Trichloroethane	3.8
Carbon tetrachloride	2.8
Vinyl acetate	6.9
Bromodichloromethane	2.2
1,2-Dichloropropane	6.0
trans-1,3-Dichloropropene	5.0
Trichloroethene	2.0
Benzene	4.4
Dibromochloromethane	3.1
1,1,2-Trichloroethane	5.0
cis-1,3-Dichloropropene	5.0
2-Chloroethyl vinyl ether	5.0
Bromoform	4.7
2-Hexanone	36
1,1,2,2-Tetrachloroethane	6.9
4-Methyl-2-pentanone	46
Tetrachloroethene	4.1
Toluene	6.0
Chlorobenzene	6.0
Ethyl benzene	7.2
Styrene	3.0
Acetonitrile	25
trans-1,4-Dichloro-2-butene	4.0
1,4-Dioxane	10 mg/L
Dibromomomethane	2.0
Iodomethane	2.0

(Continued)

TABLE 2-5. (Cont.)

Parameter	Detection Limit (μg/L)
Dichlorodifluoromethane	2.0
Trichloromethanethiol	(ND)
Ethylene Oxide	10 mg/L
1,2-Dibromo-3-chloropropane	2.0
1,2,3-Trichloropropane	5.0
Ethyl Cyanide	25
3-Chloropropionitrile	10 mg/L
Isobutyl Alcohol	10 mg/L
Acrolein	100
3-Chloropropene	2.0
Methacrylonitrile	10 mg/L
Acrylonitrile	25
Ethyl Methacrylate	50
Methyl Methacrylate	50
Allyl Alcohol	10 mg/L
2-propyn-1-01	10 mg/L
Extractable Organic Compounds	
2-Chlorophenol	10
2-Nitrophenol	50
Phenol	10
2,4-Dimethylphenol	10
2,4-Dichlorophenol	10
2,4,6-Trichlorophenol	50
4-Chloro-3-methylphenol	10
2,4-Dinitrophenol	50
2-Methyl-4,6-Dinitrophenol	50
Pentachlorophenol	50
4-Nitrophenol	50
Pronamide	100
5-Nitro-o-toluidine	50
p-Chloroaniline	20
p-Nitroaniline	50
4,4-Methylenebis (2-chloroaniline)	(ND)
Benzyl Alcohol	10
Benzenethiol	(ND)
Safrole	10
Benzoic Acid	10
3,3-Dimethylbenzidine	10
N-Nitrosodiethylamine	10
N-Nitrosomorpholine	10
1,4-Naphthoquinone	10

(Continued)

TABLE 2-5. (Cont.)

Parameter	Detection Limit (μg/L)
Ortho-Cresol	10
Hexachlorophene	(ND)
2,3,4,6-Tetrachlorophenol	100
Pyridine	10
N-Nitrosopyrrolidine	10
1,2-Dichlorobenzene	10
1,3-Dichlorobenzene	10
1,4-Dichlorobenzene	10
Hexachloroethane	10
Bis (2-chloroethyl) ether	10
N-Nitroso-di-N-propylamine	50
Nitrobenzene	10
Hexachlorobutadiene	10
1,2,4-Trichlorobenzene	10
Isophorone	10
Naphthalene	10
Bis (2-chloroethoxy) methane	10
Hexachlorocyclopentadiene	10
2-Chloronaphthalene	10
Acenaphthylene	10
Acenaphthene	10
Dimethyl phthalate	10
2,6-Dinitrotoluene	10
Fluorene	10
4-Chlorophenyl phenyl ether	10
2,4-Dinitrotoluene	10
Diethyl phthalate	10
N-Nitrosodiphenylamine	50
Hexachlorobenzene	10
4-Bromophenyl phenyl ether	10
Bis (2-chloroisopropyl) ether	10
Fluoranthene	10
Phenanthrene	10
Phenacetine	100
7,12-Dimethylbenz[a]anthracens	20
3-Methylcholanthrene	20
Aniline	20
2-Nitroaniline	50
3-Nitroaniline	50
Diphenylamine	10
p-Dimethylaminoazobenzene	10
1,2,4,5-Tetrachlorobenzene	100
meta-Dinitrobenzene	100
Pentachlorobenzene	10
Pentachloroethane	10

(Continued)

TABLE 2-5. (Cont.)

Parameter	Detection Limit (μg/L)
Pentachloronitrobenzene	100
alpha,alpha-Dimethylphenethylamine	25
3,3'-Dimethoxybenzidine	(ND)
4-Aminobiphenyl	250
N-Nitrosodi-n-butylamine	50
Dibenzofuran,	10
N-Nitrosomethylethylamine	(ND)
Acetophenone	10
1,2-Diphenylhydrazine	10
Methyl methanesulfonate	20
1-Napthylamine	100
2-Naphthylamine	100
2-Methylnapthalene	10
N-Nitrosopiperidine	50
2-Picoline	50
Anthracene	10
Dibutyl phthalate	10
Pyrene	2
Benzidine	40
Butyl benzyl phthalate	10
Bis (2-ethylhexyl) phthalate	10
Chrysene	10
Benzo (a) anthracene	10
3,3'-Dichlorobenzidine	20
Di-n-octyl phthalate	10
Benzo (b) fluoranthene	10
Benzo (k) fluoranthene	10
Benzo (a) pyrene	10
Indeno (1,2,3-c,d) pyrene	10
Dibenzo (a,h) anthracene	10
Benzo (g,h,i) perylene	10
N-Nitrosodimethylamine	50
Pesticides	
Aldrin	0.01
Alpha-BHC	0.01
Beta-BHC	0.01
Gamma-BHC (Lindane)	0.01
Delta-BHC	0.01
Chlordane	0.05
4,4'-DDD	0.01
4,4'-DDE	0.01

(Continued)

TABLE 2-5. (Cont.)

Parameter	Detection Limit (μg/L)
4,4'-DDT	0.02
Dieldrin	0.01
Endosulfan I	0.01
Endosulfan II	0.03
Endrin	0.01
Endrin Aldehyde	0.02
Heptachlor	0.01
Heptachlor Epoxide	0.01
Toxaphene	0.50
Methoxychlor	0.05
Polychlorinated Biphenyls	
Arochlor 1016	0.1
Arochlor 1221	0.2
Arochlor 1232	0.2
Arochlor 1242	0.1
Arochlor 1248	0.1
Arochlor 1254	0.2
Arochlor 1620	0.2
Metals	
Arsenic	10
Lead	5
Mercury	0.2
Selenium	5
Aluminum	200
Antimony	200
Barium	200
Beryllium	5
Cadmium	5
Calcium	5,000
Chromium	30
Cobalt	50
Copper	25
Iron	100
Magnesium	5,000
Manganese	15
Nickel	40
Potassium	5,000
Silver	30
Sodium	5,000
Thallium	100
Tin	600
Vanadium	50
Zinc	20

(Continued)

TABLE 2-5. (Cont.)

Parameter	Detection Limit (μg/L)
Cyanide	10
Sulfide	1,000
Fluoride	100
Herbicides	
2,4,5-T	0.15
Silvex	0.15
Dioxins, Furans	
2,3,7,8-Tetrachlorodibenzo-p-dioxin	10,000
Hexachlorodibenzo-p-dioxins	
Pentachlorodibenzo-p-dioxins	
Tetrachlorodibenzo-p-dioxins	
Organophosphorus Pesticides	
Phorate	0.15
Disulfoton	0.2
Famphur	0.15
Parathion	0.15
0,0-Diethyl 0-2-pyrazinyl phosphorothioate	(ND)
Methyl parathion	0.03
Tetraethyldithiopyrophosphate	(ND)

- For cyanide, RAS experience with Method 9012.
- For dioxins and furans, RAS experience with Method 8280.
- For fluoride, RAS experience with Method 340.2.
- For organophosphorus pesticides, RAS experience with Method 8140.
- For herbicides, RAS experience with Method 8150.

2.2.3 Description of Analytical Methods

The analytical methods identified in Section 2.2.1 are described in more detail in the following paragraphs. A complete description is given for most of the methods by the references shown in Table 2-4; for the remaining methods, a complete description is provided in this section. The descriptions include procedures for instrument operation and interference identification.

2.2.3.1 Volatile Organic Compound Analysis Using Methods 8240 and 5030

Method 8240 is a gas chromatographic/mass spectrometric method for determining volatile organic compounds in a variety of sample matrices, including groundwater. Sample introduction is accomplished by the purge-and-trap technique described in Method 5030. Operating parameters and interferences are described in Methods 8240 and 5030.

2.2.3.2 Extractable Organic Compound Analysis Using Methods 8270 and 3530

Method 8270 is a capillary column gas chromatographic/mass spectrometric technique used for determining acidic, basic, and neutral organic compounds that are soluble in methylene chloride; methylene chloride extraction is the

basis of Method 3530. Operating parameters and interferences are described in Methods 8270 and 3530.

2.2.3.3 Pesticide and Polychlorinated Biphenyl Analysis Using Methods 8080 and 3510 (or 3520)

Method 8080 is a gas chromatographic method using electron capture detection or halide-specific detection. This method is used to determine the concentration of certain organochlorine pesticides and polychlorinated biphenyls in a variety of matrices, including groundwater.

Prior to analysis, samples are extracted at a neutral pH using methylene chloride as a solvent. Groundwater samples can be extracted using either Method 3510 (separatory funnel) or Method 3520 (continuous liquid - liquid extractor). Operating parameters and interferences are described in Methods 8080, 3510, and 3520.

2.2.3.4 Arsenic, Lead, and Selenium Analysis Using Methods 7060, 7421, and 7740: Graphite Furnace Atomic Absorption

Furnace atomic absorption spectrophotometry is used for arsenic, lead, and selenium analysis, according to the procedures outlined in EPA Methods 7060, 7421, and 7740, respectively. Prior to analysis, acid digestion of the sample is required. Digestion methods are listed in Table 2-4.

Following acid digestion, an aliquot of sample is dried, charred, and atomized in a graphite furnace. Light from a metal-specific hollow cathode lamp is passed through the resulting vapor containing ground-state atoms. The decrease in the spectral intensity across the vapor is proportional to the concentration of the metal being determined. Operating parameters and interferences are described in Methods 7060, 7421, and 7740.

2.2.3.5 Mercury Analysis Using Method 7470: Cold Vapor Atomic Absorption

Following acid digestion as described in Method 7470, mercury is reduced to its elemental state with stannous sulfate. The mercuric vapor is then pumped through a closed system to a cell positioned in the light path of an atomic absorption spectrophotometer. The amount of light absorbed is proportional to the amount of mercury in the sample. Operating parameters and interferences are described in Method 7470.

2.2.3.6 Metal Analysis Using Method 6010: Inductively Coupled Plasma (Atomic) Emission Spectrometry

Prior to analysis, samples are subjected to the acid digestion procedures described in Method 6010. ICPES is used for Appendix IX metals other than arsenic, lead, mercury, and selenium. These metals are listed in Table 2-4.

The basis of chemical analysis by ICPES is the measurement of atomic emission by an optical spectroscopic technique. Samples are nebulized, and the aerosol that is produced is transported to the plasma torch where excitation occurs. Characteristic atomic-line emission spectra are produced by a radio frequency inductively coupled plasma. The resulting spectra are dispersed by a grating spectrometer, and the intensities of the line are multiplied by photomultiplier tubes. Inter-element correction is used for all analyses. Operating parameters and interferences are described in Method 6010.

2.2.3.7 Cyanide Analysis Using Method 9012

Method 9012 is used to determine the concentration of inorganic cyanide in groundwater and other sample types. Following distillation of the sample, cyanide is converted to a highly colored complex. The absorbance of the sample is compared to the absorbance of standard solutions to determine the cyanide concentrations of the sample.

Interferences, distillation, and the procedure for colorimetric determination are described in Method 9012. Automated apparatus will be used.

2.2.3.8 Polychlorinated dibenzo-p-dioxins and Polychlorinated debenzofurans Analysis Using Method 8280

Method 8280 uses a matrix-specific extraction, analyte-specific cleanup, and high-resolution capillary column gas chromatography/low resolution mass spectrometry technique. If interferents are encountered, the method provides selected cleanup procedures to aid the analyst in their elimination. The sensitivity of this method is dependent upon the level of interferents within a given matrix. Operating procedures and interferences are described in Method 8280.

2.2.3.9 Fluoride Analysis Using EPA Method 340.2

The concentration values of fluoride is determined poteniometrically using a fluoride electrode in conjunction with a standard single junction sleeve-type reference electrode and a pH meter having an expanded millivolt scale or a selective ion meter having a direct concentration scale for fluoride. The fluoride electrode consists of a lanthanum fluoride crystal across which a potential is developed by fluoride ions. This method can measure concentrations from 0.1 to 1000 mg/L. Operating procedures and interferences are described in EPA Method 340.2.

2.2.3.10 Organophosphorus Pesticides Analysis Using SW-846 Method 8140

Method 8140 provides gas chromatographic conditions for the detection of ppb levels of organophosphorus pesticides. Prior to analysis appropriate sample extraction techniques must be used. Both neat and diluted organic liquids may be analyzed by direct injection. A 2 to 5 microliter aliquot of the extract is injected into a gas chromatograph, and compounds in the GC effluent are detected with a flame photometric or thermionic detector. Operating procedures and interferences are described in Method 8140.

2.2.3.11 Sulfide Analysis Using SW-846 Method 9030

Method 9030 is used to measure the concentration of total and dissolved sulfides in water. The method does not measure acid-insoluble sulfides.

Excess iodine is added to a sample which has been treated with zinc acetate to produce zinc sulfide. The iodine oxidizes the sulfide to sulfur under acidic conditions. The excess iodine is back-titrated with sodium thiosulfate or phenylarsine oxide. Operating procedures and interferences are described in Method 9030.

2.2.3.12 Herbicide Analysis Using SW-846 Method 8150

Method 8150 provides extraction, esterification, and gas chromatographic conditions for the analysis of chlorinated acid herbicides. Spiked samples are used to verify the applicability of the chosen extraction technique to each new sample type. The esters are hydrolyzed with potassium hydroxide, and extraneous organic material is removed by a solvent wash. After acidification, the acids are extracted with solvent and converted to their methyl esters using diazomethane as the derivatizing agent. After excess reagent is removed, the esters are determined by gas chromatography employing an electron capture detector, microcoulometric detector, or electrolytic conductivity detector. The results are reported as the acid equivalents. The sensitivity of Method 8150 usually depends on the level of interferences rather than on instrumental limitations. Operating procedures and interferences are described in Method 8150.

2.2.4 Validation of Analytical Methods

Several procedures will be used to validate the analytical methods as they are applied to the groundwater matrix. The groundwater samples to be

analyzed are expected to contain high concentrations of chloride; total filterable residue (total dissolved solids) is expected to be approximately 20,000 mg/L.

Validation procedures fall into two categories: 1) those designed to verify that the analytical system itself is performing as well as required; and 2) those designed to verify that the analytical methods are adequate for the groundwater matrix being analyzed.

System validation procedures will consist of the following:

- Analysis of method blanks;
- Calibration checks;
- Analysis of surrogate standards; and
- Analysis of standard reference materials.

The following procedures will be used to verify that the analytical methods used are adequate for the groundwater matrix being analyzed:

- Duplicate analysis of samples;
- Analysis of samples spiked with a known amount of analyte; and
- Analysis using the method of standard additions, if spiked groundwater samples show interferences caused by the matrix.

The validation procedures listed above will be performed at the frequencies specified in Section 3.0. Section 3.0 also contains more detailed descriptions of these validation procedures.

2.2.5 Laboratory Instrumentation, Reagents, and Standards

The instrumentation listed below potentially will be used for the analytical methods as indicated.

- Volatile organic compound analysis using Method 8240: Finnegan model 4021 mass spectrometer with INCOS data system.

- Extractable organic compound analysis using Method 8270: Finnegan model 4021 mass spectrometer with INCOS data system and Finnegan model 3200 mass spectrometer with INCOS data system.

- Pesticides and polychlorinated biphenyls analysis using Method 8080, organophosphorus pesticides using Method 8140, and herbicides using Method 8150: 1) Varian Vista 6000 gas chromatograph with dual electron capture detectors and Model 8000 auto samplers; and 2) Varian 3700 gas chromatograph with dual electron capture detectors and model 8000 autosamplers.

- Arsenic, lead, and selenium analysis using Methods 7060, 7421, and 7740: Perkin Elmer models 3030 and 3030 Zeeman atomic absorption spectrophotometers.

- Mercury analysis using Method 7470: Perkin Elmer Model 403 atomic absorption spectrophotometers.

- Metal analysis using Method 6010: Thermo Jarrell-Ash Model 61 ICPES spectrometer, simultaneous detection, with a fixed array for 40 elements and a scanning monochromator.

- Cyanide analysis using Method 9012 (colorimetry): Technicon Autoanalyzer II.

- Dioxin and Furans analysis using Method 8280: HP 5985/87 GC/MS.

Laboratory reagents and standards are obtained from the following suppliers:

- For inorganic analysis, spectral grade and reagent grade standards and reagents are obtained from Spex, Fisher, and Ricca. Standard reference materials are obtained from the National Bureau of Standards and the EPA Environmental Monitoring and Support Laboratory.

- For organic analysis, spectral grade and reagent grade solvents and reagents are obtained from Aldridge, Sigma, and Burdick and Jackson. Analytical standards are obtained from repositories maintained by EPA and by the National Toxicology Program administered by the National Institute of Environmental Health Sciences.

3.0 ANALYTICAL/STATISTICAL CONTROL PARAMETERS

Section 3 presents the analytical/statistical control parameters which will be used for each method identified in Section 2. As in Section 2, the discussion of these parameters is divided into two groups. Section 3.1 presents the analytical/statistical control parameters for ground-water quality indicators, contamination, and Appendix III parameters. Section 3.2 presents the analytical/statistical control parameters for Appendix IX parameters.

3.1 Ground-Water Quality Contamination Indicators and Appendix III Parameters

The purpose of quality control procedures and documentation is to ensure that the analytical systems are operating within specified limits of accuracy and precision and that the conditions of control are properly documented. Results for quality control tests will also be used to estimate precision and bias associated with measurement data.

Specific measures taken to control analytical data quality include use of specific acceptance criteria for instrument calibration, QC check samples, duplicate analyses, blank samples and spiked samples. Acceptance criteria for each QC test, its required frequency, and corrective action are summarized in Table 3-1.

3.1.1 Data Quality Objectives

In formulating project-specific QA/QC strategies, Radian establishes specific objectives for measurement data quality for each measurement parameter. These objectives provide the framework for designing an effective QA/QC system which is responsive to the needs of the project.

Accuracy and precision objectives are presented in Table 3-2. These values are not intended to represent data validation criteria. Rather, these values represent estimates of the magnitude of uncertainty which might be associated with the measurement data due to measurement error.

TABLE 3-1. SUMMARY OF INTERNAL QUALITY CONTROL PROCEDURES FOR WATER SAMPLES

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Chloride/sulfate	300.0	Multipoint calibration	Daily	r ≥0.995	Repeat calibration
		QC check sample	Every 15 samples	±5% error	Repeat calibration
		Method blank	One per batch	None	Used to assess memory effects
		Duplicate analyses	5%	RPD ≤10%	1) Obtain third value, and 2) Flag data
		Matrix spike	5%	±15% error	Flag data
Total Organic	EPA 9060	Control sample	1) Following calibration 2) 10% (minumum 2) 3) Following sample analyses	Recovery between 90-110%	Repeat calibration
		Duplicate analyses	10% (minumum 1)	Relative percent difference (RPD) ≤20%	Repeat sample analyses
		Reagent blank	10% (minimum 1)	None	Will be used to indicate analytical contamination
SW-846 : 9021	POX	Duplicate analyses	10%	RPD ≤20%	Repeat sample analyses
		Reagent blank	10%	None	Will be used to indicate analytical contamination
		Control Standard	1) 10% 2) Following sample analyses	95-105%	Repeat analyses
SW-846 : 9066	Phenol	Calibration curve	Daily prior to sample analyses	r >0.995	Repeat calibration
		QC check standard	10%	±15% error	1) Reanlyze 2) Repeat calibration 3) See lab manager
		Reagent blank	1 per batch	Recovery less than 0.02 ug/L	1) Clean instrument/equipment 2) Rerun test
		Matrix spike	10%	±25% error	Flag data
		Matrix spike duplicate	10%	RPD ≤20%	Obtain third value

(Continued)

TABLE 3-1. (Cont.)

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
EPA : 353.1	Nitrate/ Nitrite	Calibration curve	Daily prior to sample analyses	r >0.995	Repeat calibration
		QC check standard	10%	±15% error	1) Reanlyze 2) Repeat calibration 3) See lab manager
		Reagent blank	1 per batch	Recovery less than 0.02 ug/L	1) Clean instrument/equipment 2) Rerun test
		Matrix spike	10%	±25% error	Flag data
		Matrix spike duplicate	10%	RPD ≤20%	Obtain third value
EPA : 903.0	Radium	Calibration standard	Daily prior to sample analysis	Recovery between 80-120%	Repeat calibration
		Duplicates	10%	±40%	Repeat analysis
EPA : 900.0	Gross Alpha and Beta	Duplicate analysis	10%	RPD ≤40%	Repeat analyses
SW-846 : 9132	Coliform Bacteria	Sterility control	1 per batch of reagent		Repeat
		Temperature control	1 per batch	44.5 ± 0.2°C	Repeat analysis
		Calibrate thermometer	1 per year	44.5 ± 0.2°C	Replace thermometer

TABLE 3-2. ESTIMATED ACCURACY AND PRECISION OBJECTIVES

Parameter	Method	Accuracy[a]	Precision[b]
Trace Elements	--	90-110%	20%[c]
TOC	SW-846: 9060	90-110%	10%
POX	SW-846: 9021	--	--
Chloride, Sulfate	EPA: 300.0	90-110%	10%
Flouride	EPA: 340.2	90-110%	10%
Phenol	SW-846: 9066	85-115%	15%
Nitrate/Nitrite	EPA: 353.1	85-115%	15%
Radium	EPA: 903.0	--	--
Gross Alpha and Beta	EPA: 900.0	--	--
Total Coliform Bacteria	SW-846: 9132	--	--
Herbicides	SW-846: 8150	85-115%	d
Pesticides	SW-846: 8080	85-115%	d

[a]Determined using QC acceptance criteria for matrix spikes.

[b]Percent difference for replicate analyses.

[c]Precision criteria for sample values greater than five times the detection limit.

[d]Refer to method.

Accuracy objectives reflect recovery of target analytes spiked into actual field samples, expressed as a percentage of the amount spiked. Precision objectives reflect differences between measurements of duplicate aliquots of field samples, expressed as a percentage of the mean measured value.

3.1.2 Internal Quality Control Checks

Internal quality control checks are discussed in detail in Section 3.2.2. Analytical calibration requirements are presented in the following subsections. Section 4 discusses calibration procedures for metals, pesticides, herbicides, and fluoride. Procedures for calibration of field measurement equipment are also included.

3.1.2.1 TOC - Method 9060

Method 9060 uses a carbonaceous analyzer to measure organic carbon.

A standard curve is set up using KHP for the expected concentration ranges of the samples to be analyzed. The calibration curve is verified by analyzing quality control check samples. The calibration curve is deemed acceptable if the QC check samples are in the range of 90 to 100 percent. The calibration is verified with an independently prepared check standard every 15 samples.

3.1.2.2 POX - Method 9021

Method 9021 determines purgeable organic halides using carbon adsorption with a microcoulometric-titration detector.

The adsorption efficiency of each newly prepared batch of carbon is checked by analyzing 100 mL of the adsorption efficiency standard, in duplicate, along with duplicates of the blank standard. The net recovery should be within 5 percent of the standard value.

The repeatability of the method background is established each day by first analyzing several nitrate-wash blank. The background is monitored between each group of eight pyrolysis determinations. The nitrate-wash blank values are obtained on single columns packed with 40 mg of activated carbon. It is washed with the nitrate solution and then the carbon is pyrolyzed.

Duplicate instrument-calibration standards and blank standards are pyrolyzed daily before beginning sample analysis. The net response to the calibration standards should be within 3 percent of the calibration-standard value. The instrument-calibration standard is repeated after each group of eight pyrolysis determinations and before resuming sample analysis, and after cleaning or reconditioning the titration cell or pyrolysis system.

3.1.2.3 Phenol - Method 9066

Method 9066 is an automated colorimetric analysis.

Phenol standards (minimum of a blank and three standards) are placed in the sampler in order of decreasing concentration. A linear standard curve is prepared by plotting peak heights of standards against concentration values. The calibration curve is verified by analyzing quality control check samples. A calibration curve is deemed acceptable if the correlation coefficient is greater than, or equal to 0.995 and recoveries for a QC check sample are within plus or minus 15 percent.

3.1.2.4 Nitrate/Nitrite - Method 353.1

Method 353.1 is a colorimetric analysis.

A multipoint calibration curve (minimum of three points) is prepared daily by analyzing standard solutions of nitrite. The calibration curve is verified by analyzing quality control check samples. A calibration curve is deemed acceptable if the correlation coefficient is greater than or equal to 0.995 and recoveries for a QC check sample are within plus or minus 15 percent.

3.1.2.5 Chloride and Sulfate Analysis - Method 300.0

Chloride and sulfate are analyzed by ion chromatography.

A multipoint calibration curve (minimum of three points) is prepared daily by analyzing standard solutions of each. The calibration curve is verified by analyzing quality control check samples. A calibration curve is deemed acceptable if the correlation coefficient is greater than or equal to 0.995 and recoveries for a QC check sample are within plus or minus 5 percent.

3.1.2.6 Radium, Gross Alpha and Beta, and Total Coliform Bacteria

Not applicable.

3.2 Appendix IX Parameters

The purpose of quality control procedures and documentation is to ensure that the analytical systems are operating within specified limits of accuracy and precision and that the conditions of control are properly documented. Results for quality control tests will also be used to estimate precision and bias associated with measurement data.

Specific measures taken to control analytical data quality include use of specific acceptance criteria for instrument calibration, QC check samples, duplicate analyses, blank samples and spiked samples. Acceptance criteria for each QC test, its required frequency, and corrective action are summarized in Table 3-3.

3.2.1 Data Quality Objectives

In formulating project-specific QA/QC strategies, Radian establishes specific objectives for measurement data quality for each measurement parameter.

TABLE 3-3. SUMMARY OF INTERNAL QUALITY CONTROL PROCEDURES

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Organochlorine Pesticides and PCBs	SW 8080	Multipoint calibration (minimum five points)	Initially, as required	RSD <20%	Repeat calibration
		Single point calibration	Daily prior to sample analyses	RPD <15%	Repeat 5-point calibration
		Surrogate standards	Every sample	±50%; lab must set own criteria (p±3s) after 30 samples	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike	5%	Refer to method	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike duplicate	5%	RPD <50%	Flag data
		Method blank	5%	None	Used to assess contamination
		QC check standard	Initially, and as required by method	Refer to method	1) Evaluate system 2) Repeat test for criteria that failed
Chlorinated Herbicides	SW 8150	Multipoint calibration, (minimum five points)	Initially, and as required by daily check	RSD <20% for RFs	Repeat calibration
		Single point calibration	Daily prior to sample analyses	RPD <15%	Repeat 5-point calibration
		Surrogate standards	Every sample	±30% error	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike	5%	Refer to method	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike duplicate	5%	RPD <50%	Flag data
		Method blank	5%	None	Used to assess contamination
		QC check standard	Initially, and as required by the method	Refer to method	1) Evaluate system 2) Repeat test for criteria that failed

(Continued)

TABLE 3-3. (Cont.)

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Organophosphorus Pesticides	SW 8140	Multipoint calibration, 5 points	Initially, and as required by daily check	RPD <20%	Repeat calibration
		Single point calibration	Daily prior to sample analyses	RPD <15%	Repeat calibration
		Surrogate standards	Every sample	±30% error	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike	5%	Refer to method	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike duplicate	5%	RPD <50%	Flag data
		Method blank	5%	None	Used to assess contamination
		QC check standard	Initially, and as required by method	Refer to method	1) Evaluate system 2) Repeat test for criteria that failed
Volatiles	SW 8240 (GC/MS)	Mass scale calibration using PFTBA	Daily prior to sample analyses	Refer to method	Repeat calibration
		Check of mass spectral ion intensities using BFB	Daily prior to sample analyses	Refer to method	Retune instrument Repeat BFB analysis
		System performance check compounds	Every 12 hours	RF ≥0.300 (0.250 for bromoform)	1) Evaluate system 2) Repeat calibration
		Calibration check compounds	Every 12 hours	% Difference <25%	1) Evaluate system 2) Repeat calibration
		Surrogate spikes	Every sample	Refer to method	1) Evaluate system 2) Recalculate data and/or reanalyze extract 3) Reextract and reanalyze sample or flag data
		Internal standard	Every sample	Refer to method	Flag data
		Method blank	Daily prior to sample analyses	None	1) Clean system 2) Repeat blank analysis

(Continued)

TABLE 3-3. (Cont.)

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Volatiles (Cont.)		Matrix spike	5%	Refer to method	1) Run check standard 2) Correct problem 3) Flag data
		Matrix spike duplicate	5%	RPD <50%	Flag data
Semivolatiles	8270 (GC/MS)	Mass scale calibration using PFTBA	Daily prior to sample analyses	Refer to method	Repeat calibration
		Check of mass spectral ion intensities using DFTPP	Daily prior to sample analyses	Refer to method	Retune instrument Repeat DFTPP analysis
		System performance check compounds	Every 12 hours	RF $\geq$0.050	1) Evaluate system 2) Repeat calibration
		Calibration check compounds	Every 12 hours	% Difference <30%	1) Evaluate system 2) Take corrective action 3) Repeat test 4) See lab manager
		Surrogate spikes	Every sample	Refer to method	1) Evaluate system 2) Recalculate data and/or reanalyze extract 3) Reextract and reanalyze sample or flag data
		Internal standards	Every sample	Refer to method	Flag data
		Extraction blank	5%	<5 X MDL	1) Run solvent blank 2) Evaluate system
		Matrix spike analysis	5%	Refer to method	1) Run check standard 2) Correct problem 3) Flag data
		Matrix spike duplicate samples	5%	RPD <50%	Evaluate system
Dioxins and Furans	SW 8280	Mass scale calibration using PFTBA	Daily prior to sample analyses	Refer to method	Repeat calibration
		Initial calibration Multipoint, 5 levels in triplicate	Yearly with fresh standards	Relative standard deviation (RSD) <30%	1) Repeat initial calibration 2) If still unacceptable, make necessary adjustment 3) Repeat initial calibration

(Continued)

TABLE 3-3. (Cont.)

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Dioxins and Furans (Cont.)		Single point check	Daily	Agreement within 30% of value predicted from multipoint calibration curve	1) Repeat single point check 2) If still unacceptable, perform new multi-point calibration
		TCDD chromatography check	Daily	25% valley between 1,2,3,4-TCDD and 2,3,7,8-TCDD	Replace column
		PCDD/PCDF retention time window check	Daily unless retention times internal standards	Less than ±0.2 min. variation on internal standards	Rerun retention time standard, adjust SIM windows
		Sensitivity check	Daily	50:1 S/N from 200 ng/mL 2,3,7,8-TCDD standard	Evaluate instrument Take corrective action
		QC sample	Once every project	Refer to method	1) Repeat test 2) Repeat calibration 3) See lab manager
		Extraction blank	5%	None	Used to assess memory effects
		Duplicate analyses	5%	Refer to method	Obtain third value
		Surrogate spike recovery	Every sample	Refer to method	1) Evaluate system 2) Flag data
Metals - ICPES	6010	Mixed standard calibration	Daily	Measured value for high (standard within 10% of expected value)	Repeat calibration
		Calibration check	10%	Measured value within 10% of true value for element of interest	Repeat calibration
		Method blank	10%	≤5 x MDL	1) Repeat test, average results 2) Evaluate system 3) Recalibrate
		Matrix spike analysis	5%	±25% error	Flag data
		Matrix spike duplicate	5%	RPD <20%	Flag data
		ICP interference check	Run at beginning, middle, and end of daily run	80-120% of true value for EPA check sample elements	1) Repeat calibration 2) See lab manager

(Continued)

TABLE 3-3. (Cont.)

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Metals ICPES (Cont.)		ICP linear range check	Quarterly	Measured value within ±5% of expected value	Tests upper limit of ICP linear range
		LOD check	Quarterly	None	Used to verify current LOD
Metals - AAS					
As	7060	Multipoint calibration	Daily prior to analyses	r ≥0.995	Repeat calibration
Se	7740				
Hg	7470				
Pb	7421	Calibration check	10%	±15% error	Recalibrate
		Method blank	10%	≤5 x MDL	Will be used to indicate analytical contaminants
		Matrix spike analysis	5%	±25% error	Flag data
		Matrix spike duplicate	5%	RPD <20%	Flag data
		LOD check	Quarterly	None	Used to verify current LOD
Sulfide	9030	Standardization of Iodine	Daily	RPD for standard duplicates <5%	Repeat calibration
		Blank	One per batch	None	Used to assess memory effects
		Duplicate analysis	5%	RPD <15%	1) Obtain third value 2) Flag data
		Matrix spike	5%	±20% error	Flag data
Cyanide	9012	Calibration curve	Daily prior to sample analyses	r >0.995	Repeat calibration
		QC check standard	10%	±15% error	1) Reanalyze 2) Repeat calibration 3) See lab manager
		Reagent blank	1 per batch	recovery less than 0.02 ug/L	1) Clean instrument/equipment 2) Rerun test
		Matrix spike	10%	±25% error	Flag data
		Matrix spike duplicate	10%	RPD ≤20%	Obtain third value

(Continued)

TABLE 3-3. (Cont.)

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Fluoride	340.2	Multipoint calibration	Daily prior to analyses	r $\geq$0.995	Repeat calibration
		QC Check Sample	10%	$\pm$10% error	Repeat calibration
		Blank	10%	None	Used to assess memory
		Duplicate analyses	10%	RPD <10%	1) Obtain third value 2) Flag data
		Matrix spike	10%	$\pm$10% error	Flag data

These objectives provide the framework for designing an effective QA/QC system which is responsive to the needs of the project.

Accuracy and precision objectives are presented in Table 5-4. These values are not intended to represent data validation criteria. Rather, these values represent estimates of the magnitude of uncertainty which might be associated with the measurement data due to measurement error.

Accuracy objectives reflect recovery of target analytes spiked into actual field samples, expressed as a percentage of the amount spiked. Precision objectives reflect differences between measurements of duplicate aliquots of field samples, expressed as a percentage of the mean measured value.

3.2.2 Internal Quality Control Checks

Specific QC procedures will be followed to ensure the production of valid data for this project. The QC checks and procedures described in this section represent an integral part of the overall sampling/analytical scheme. A discussion of sampling and analytical QC checks is discussed below.

3.2.3 Analytical Quality Control Procedures

Internal analytical QC checks will be performed according to the protocols and guidelines established for the EPA Contract Laboratory Program (CLP) for all parameters. The equipment, standards, procedures and calculations cited in the methods will be used. The methods were described in Table 2-1.

3.2.3.1 Definitions of Quality Control Samples

The following quality control samples will be used to control and assess data quality:

1) System blank - deionized water analyzed after calibration to assess system calibration.

TABLE 3-4. ESTIMATED ACCURACY AND PRECISION OBJECTIVES

Parameter	Method	Accuracy[a]	Precision[b]
Trace Elements		90-110%	20%[c]
Volatile Organics	8240	Per Method QC Acceptance Criteria	50%
Extractable Organics	8270	Per Method QC Acceptance Criteria	50%
Pesticides/PCBs	8080	Per Method QC Acceptance Criteria	50%
Cyanide	9012	85-115%	20%
Herbicides	8150	Per Method QC Acceptance Criteria	50%
Dioxins, Furans	8280	Per Method QC Acceptance Criteria	50%
Organophosphorus Pesticides	8140	See Method 8140 Table 1	50%
Fluoride	340.2	90-110%	10%
Sulfide	9030	90-110%	15%

[a]Determined using QC acceptance criteria for matrix spikes.

[b]Percent difference for replicate analyses.

[c]Precision criteria for sample values greater than five times the detection limit.

2) Reagent blank - an aliquot of reagent water taken through the digestion/extraction process as though it were an actual sample.

3) QC check sample - known concentration of reference materials spiked into an aliquot of deionized water. This is not taken through the digestion/extraction process. The purpose of a QC check sample analysis is to determine whether failure to meet QC acceptance criteria for matrix spike is due to matrix interference in the sample, or to an out-of-control condition associated with the analytical system.

4) Matrix spike - splits from field samples spiked with known concentrations of reference materials and taken through the entire digestion/extraction process. The matrix spike allows the laboratory to assess the efficiency of extraction, accuracy of the analysis, and possible matrix effects. For GC/MS analyses, surrogate spikes - easily identifiable compounds not present in the sample matrix - are added to every field sample.

5) Duplicate samples - samples split in the field and treated as two independent samples, although logged as splits of one sample.

6) Duplicate analyses - samples split in the lab and treated as two independent samples.

7) Dilution control sample - a control sample diluted in the same manner as required for actual field samples.

8) ICPES Interference check sample - an ICPES QC check sample which contains interferents and analyte concentrations at levels specified by EPA. Analyzed at the beginning and end

of each sample analysis run, results are used to verify inter-element and background correction factors.

3.2.3.2 Preparation of Controls

Internal quality control samples used in the laboratory will be prepared and inserted into the analytical queue by the bench analyst. Control samples will be prepared as follows:

1) Calibration standards will be prepared fresh daily from stock solutions.

2) QC check samples will be prepared daily from EPA QC samples (not the same source as the calibration standards) or other stock solutions prepared independently of the calibration standards. QC check samples will not be taken through any sample preparation/digestion procedures.

3) Aliquots taken for duplicate analyses will be split from the original sample prior to any sample preparation/digestion.

4) Spiked samples will be split and spiked prior to any preparation/digestion procedures. The spike solution will be prepared from the calibration stock solution. The spike to sample volume ratio must be negligible (1:100 to 1:1000). The concentration of analyte added should approximate a sample concentration between 10 times the detection limit and the mid-point of the calibration range.

5) Reagent blanks will be taken through all sample preparation/digestion procedures.

6) System blanks (deionized H_2O) will not be taken through any sample preparation/digestion procedures.

3.3 Corrective Action Procedures

Each measurement system must initially satisfy specific criteria for calibration linearity, reference material recovery, and freedom from contamination. Thereafter, control samples are analyzed at a 10% frequency to monitor any changes in the quality of the data being produced. An out-of-control condition is defined as:

1) Detection of any compounds of interest in a reagent blank at >3 times the limit of detection.

2) Failure to meet the acceptance criteria for recovery of any compound of interest in a QC sample.

3) Exceeding the action limit for matrix spike recovery and subsequent failure to meet the acceptance criteria for a QC check sample for the same parameter(s) which failed the matrix spike test. Any parameter which fails the matrix spike test but not the QC check sample test will be flagged as suspect for the parameter due to matrix effect.

When an out-of-control situation is detected, efforts are undertaken to determine the cause. Corrective action for routine QC checks is outlined in Table 3-3. Procedures related to corrective action are described below.

3.3.1 Roles and Responsibilities

The laboratory organizational structure and responsibilities for responding to an out-of-control event are outlined as follows:

1) The bench analyst reports the situation to the laboratory supervisor and the quality assurance officer.

2) The supervisor and analyst determine and implement the appropriate corrective action.

3) If routine corrective actions rectify the situation, analytical work is resumed. The event is documented and the RAS QA officer is advised.

4) If the situation cannot be corrected immediately, the supervisor will notify the RAS QA officer who will in turn notify the project Quality Assurance Coordinator.

3.3.2 Corrective Actions

During the course of the Holloman AFB Groundwater Study, it will be the responsibility of the laboratory QA officers, Project Director, Task Leaders, and other project team members to see that all measurement procedures are followed as specified and that measurement data meet the prescribed acceptance criteria. In the event a problem arises, it is imperative that prompt action be taken to correct the problem(s). Laboratory supervisors will initiate corrective action in the event of QC results which exceed acceptability limits. Corrective action may also be initiated upon identification of some other problems or potential problem. Corrective action may also be initiated by the Laboratory QA Officer based upon QC data or other anomalies noted during data review.

3.3.3 Documenting Malfunctions

Any events which might compromise data quality will be documented using the corrective action report form illustrated in Figure 3-1. This report format also provides the mechanism for formal documentation of the corrective action which is implemented to correct the out-of-control situation. In addition to this report, specific activities related to the malfunction incident may be recorded in analytical notebooks, on analytical bench sheets and data report forms, in instrument maintenance logbooks, etc., as applicable.

Corrective Action Report (CAR)

Part I Initial Information (Furnished by Originator)

Originator:

Urgency Level:

Requires resolution for immediate job ☐

Date:

Requires resolution for future jobs ☐

To Lab Manager Responsible for Action: _____

Present Situation Requiring Action:

Site / Lab: Type: QC Limit ☐ Documentation ☐ System ☐ Other ☐

Date / Time Identified:

Description of Situation: (attach supporting data if available)

Recommended Corrective Action or Improvement:

Description: Implemented by:

Technical Director Copy (White)

7-88-30544

Figure 3-1. Example of Malfunction/Correctable Action Report (side 1) (Cont.)

Part II Reply / Resolution (Furnished by Technical Director)

Proposed by: Date: CAR #:

Description: Scheduled Implementation:

Part III Implemented Correction Action (by:)

Description: Date Implemented:

Part IV Follow-Up Required: Yes ☐ No ☐ (by:)

Verified by: Date: Comments:

Information Copies, Distributed by Technical Director:

Figure 3-1. Example of Malfunction/Correctable Action Report (side 2)

3.4 Extended Quality Assurance Samples

External QA samples will consist of field duplicates and field blanks collected in the same sample containers and handled in the same manner as field samples. The duplicate and blank samples will be collected at a frequency of 10% of all samples collected. Assuming 30 field samples will be collected for each parameter group, a minimum of three field duplicate and three field blanks will be collected for each parameter group. These external QA samples will be sent to:

U.S. Army Engineer Division, Missouri River
Attn: MRDED-L (Joe Solsky)
427 South 18th Street
Omaha, NE 68102

3.5 Schedule of Inspections and Performance Audits

A laboratory inspection under the auspices of the Missouri River Division, Corps of Engineers has been conducted 15-16 October 1986. The objectives of such an inspection were to evaluate laboratory operations for compliance with the "A-E Guidance for Developing A-E Quality Management Procedures for Site Investigative Activities."

A performance audit was also performed as part of this project. Radian also participates in a number of other performance evaluation programs. Among these are programs sponsored by EPA, U.S. Navy, the California Department of Health Services (DHS), and commercial clients. Further, the corporate Quality Assurance group and the Quality Assurance Officer at each facility submit performance evaluation samples on a regular basis. The laboratories in Austin and Sacramento were, until recently, participants in the inorganic and organic phases, respectively, of the EPA-CLP. The performance of these laboratories was monitored by site audits and quarterly analysis of blind and/or double blind evaluation samples. Both laboratories continue to adhere to the CLP protocols for handling and analyzing samples. Radian participates in the EPA-EMSL Water Pollution Laboratory Performance Evaluation

Studies, the EPA-OSW Interlaboratory Comparison Studies, and performance evaluation programs necessary to qualify for specific EPA contracts.

Radian welcomes site audits by all Federal and state regulatory agencies, governmental clients, and commercial clients. The facility in Sacramento is certified for the analysis of water and hazardous waste by the California DHS. The facility in Austin has applied for similar certification. In the absence of a formal state certification program, the Austin laboratory is audited by the Texas Water Commission (TWC) to document proper and continuing laboratory performance. The Austin laboratory has satisfied the requirements of TWC during all site audits.

4.0 CALIBRATION PROCEDURES AND FREQUENCY

Information presented in this section pertains to calibration of equipment and instrumentation which will be used for this project. Included is a description of the procedure or reference to an applicable standard operating procedure.

4.1 Organochlorine Pesticides and PCBs - Method 8080

All samples for organochlorine pesticides and PCBs will be analyzed by gas chromatography following SW 846, Method 8080, 3rd ed.

The external standard quantitation discussed in the method will be used to quantitate all pesticides/PCBs. The retention time window will be calculated for each pesticide/PCB after adjusting the GC operating conditions for the routine retention times of 4,4'-DDT. Any compounds tentatively identified in the primary analysis will be confirmed on a second GC column. The GC/ECD will be calibrated at a minimum of five concentrations. Concentration of the components in a standard will vary depending on the response of the compounds in the analytical system. Breakdown of 4,4'-DDT and endrin will also be monitored. Breakdown may not exceed 20 percent. A daily single-point calibration check must agree within ±15 percent or the instrument is recalibrated.

4.2 Chlorinated Herbicides - Method 8150

Method 8150 is a gas chromatographic (GC) method for determining certain chlorinated acid herbicides.

The external standard quantitation method will be used to quantitate all herbicides. The retention time window will be calculated for each herbicide after adjusting the GC operating conditions for the routine retention times of each parameter of interest. Any compounds tentatively identified in the primary analysis will be confirmed on a second GC column. The GC/ECD will be calibrated

at a minimum of five concentrations. Concentration of the components in a standard will vary depending on the response of the compounds in the analytical system. A daily single-point calibration check must agree within ±15 percent of the multipoint response or the instrument is recalibrated.

4.3 Organophosphorus Pesticides - Method 8140

Method 8140 is a gas chromatographic (GC) method used to determine the concentration of various organophosphorus pesticides.

The external standard quantitation method will be used to quantitate all pesticides. The retention time window will be calculated for each pesticide after adjusting the GC operating conditions for the routine retention times of each parameter of interest. Any compounds tentatively identified in the primary analysis will be confirmed on a second GC column. The GC/NPD will be calibrated at a minimum of five concentrations. Concentration of the components in a standard will vary depending on the response of the compounds in the analytical system. A daily single-point calibration check must agree within ±15 percent or the instrument is recalibrated.

4.4 Volatile Organics - Method 8240

Samples for volatile organics will be analyzed by scanning gas chromatography/mass spectrometry (GC/MS) following SW-846 Method 8240, 3rd ed. Analyte identification and quantitation will be performed using response factors and retention times generated from a five point calibration curve, relative to the closest eluting of three internal standards. The three internal standards are:

- Bromochloromethane;
- 1,4-Difluorobenzene; and
- Chlorobenzene-d_5.

Tentatively identified compounds are identified only when a good match (Purity & Fit >.75) is obtained between the unknown spectra and the library spectra. The tentatively identified compound is then quantitated using a response factor of 1.0, with respect to the closest eluting internal standard.

The mass spectrometer will be tuned daily to give an acceptable spectrum for bromofluorobenzene (BFB). Relative ion abundance criteria for BFB are given in SW-846.

System performance will be verified initially and after every 12 hours to ensure a minimum average response factor of 0.3 (0.25 for bromoform) for the following system performance check compounds (SPCCs):

- Chloromethane;
- 1,1-Dichloroethane;
- Bromoform;
- 1,1,2,2-Tetrachloroethane; and
- Chlorobenzene.

A 5-point calibration, used for generating response factors, will be performed initially using 10, 20, 50, 100, and 200 μg/L standards. The relative standard deviation (RSD) must be less than 30 percent for the five response factors calculated for each of the following calibration check compounds (CCCs):

- 1,1-Dichloroethene;
- Chloroform;
- 1,2-Dichloropropane;
- Toluene;
- Ethylbenzene; and
- Vinyl chloride.

A continuing (every 12 hours) calibration check will be performed, following the system performance check, using the CCCs listed above. A single

concentration of each CCC will be analyzed and a response factor calculated. The single-point RF for each CCC must be within 25 percent of the average five-point RF; otherwise, a new five-point calibration must be generated.

4.5 Semivolatile Organics - Method 8270

Semivolatile extracts will be analyzed by high resolution gas chromatography/mass spectrometry following SW-846 Method 8270, 3rd ed. All samples will be prepared following extraction procedures outlined in SW-846. Identification and quantitation will be performed using response factors and retention times generated from a five point calibration curve, relative to the closest eluting of six internal standards. The six internal standards are:

- 1,4-Dichlorobenzene-d_4;
- Naphthalene-d_8;
- Acenaphthene-d_{10};
- Phenanthrene-d_{10};
- Chrysene-d_{12}; and
- Perylene-d_{12}.

Tentatively identified compounds are identified only when a good match (Purity & Fit >.75) is obtained between the unknown spectra and the library spectra. The tentatively identified compound is then quantitated using a response factor of 1.0, with respect to the closest eluting internal standard.

The mass spectrometer will be tuned daily to give an acceptable spectrum for DFTPP. DFTPP ion abundance criteria are given in SW-846.

System performance will be verified initially and after every 12 hours to ensure a minimum average response factor of 0.050 for the following system performance check compounds (SPCCs):

- N-nitroso-di-n-propylamine;
- Hexachlorocyclopentadiene;

- 2,4-Dichlorophenol; and
- 4-Nitrophenol.

A 5-point calibration, used for generating response factors, will be performed initially using 10, 20, 50, 100, and 200 μg/L standards. The variability for specific ion response factors for Method 8270 calibration check compounds must be less than 30 percent RSD over the range calibrated. The CCCs are:

- Phenol;
- 1,4-Dichlorobenzene;
- 2-Nitrophenol;
- 2,4-Dichlorophenol;
- Hexachlorobutadiene;
- 4-Chloro-3-methylphenol;
- Acenaphthene;
- 2,4,6-Trichlorophenol;
- N-nitroso-di-n-phenylamine;
- Pentachlorophenol;
- Fluoranthene;
- Di-n-octylphthalate; and
- Benzo(a)pyrene.

A continuing (every 12 hours) calibration check will be performed, following the system performance check, using the CCCs listed above. A single concentration of each CCC will be analyzed and a response factor calculated. The single-point RF for each CCC must be within 30 percent of the average five-point RF; otherwise, a new five-point calibration must be generated.

4.6 Dioxins and Furans - Method 8280

Instrumentation Calibration and Tuning--PCDDs/PCDFs will be analyzed according to the procedures outlined in Method 8280, SW-846, 3rd ed., with minor modifications. Mass calibration of the instrument will be performed daily with

PFTBA and verified using DFTPP ion abundance criteria (as specified in SW-8 4 6 Method 8270) for mass 198 and greater. Adherence to Method 8280 criteria for isotopic ratio measurements for PCDDs and PCDFs will then be verified.

PCDD/PCDF Retention Time Group Determination--Since selected-ion-monitoring mass spectrometry is used for PCDD/ PCDF analysis, it is first necessary to determine the retention time windows for each isomer group. This is accomplished by injection of a PCDD/PCDF retention time standard which contains the first and last eluter from each isomer group. The isomer group retention time analysis is performed once at the beginning of each project and again if retention times shift more than ±0.2 minutes. Adequate sensitivity is also verified from the retention time standard which contains 2,3,7,8-TCDD at a concentration of 0.2 ug/mL.

Chromatography Performance Check--A TCDD chromatographic test mixture is analyzed daily to verify that there is at least 25 percent valley resolution between 2,3,7,8-TCDD and 1,2,3,4-TCDD.

PCDD/PCDF Calibration--Response factors for each PCDD/PCDF isomer class are determined from a five point calibration at 0.1, 0.2, 0.5, 1.0, and 2.5 ug/mL concentrations. This five-point calibration is performed in triplicate and the average response factors are calculated. The response factors determined for each isomer class must not have a percent RSD greater than 15 percent. Radian uses a calibration standard containing the following analytes:

- 2,3,7,8-TCDD;
- 1,2,3,7,8-PeCDF;
- 2,3,4,7,8-PeCDF;
- 1,2,3,8,9-PeCDF;
- 1,2,3,4,7,8-HxCDF;
- 1,2,3,4,8,9-HxCDF;
- 1,2,3,4,6,7,8-HpCDF;
- OCDF;

- 2,3,7,8-TCDF;
- 1,2,3,7,8-PeCDD;
- 1,2,3,4,7-PeCDD;
- 1,2,3,4,7,8-HxCDD;
- 1,2,3,4,6,7,8-HpCDD; and
- OCDD.

Where more than one isomer per isomer group is present, the average response factor is used.

For quantitation, the following mixture of internal standards is contained in the calibration standard solutions. This mixture is also added to each sample before extraction:

- $^{13}C_{12}$-2,3,7,8-TCDD;
- $^{13}C_{12}$-2,3,7,8-TCDF;
- $^{13}C_{12}$-1,2,3,7,8-PeCDD;
- $^{13}C_{12}$-1,2,3,7,8-PeCDF;
- $^{13}C_{12}$-1,2,3,6,7,8-HxCDD;
- $^{13}C_{12}$-1,2,3,4,7,8-HxCDF;
- $^{13}C_{12}$-1,2,3,4,6,7,8-HpCDD;
- $^{13}C_{12}$-1,2,3,4,6,7,8-HpCDF;
- $^{13}C_{12}$-OCDD; and
- $^{13}C_{12}$-OCDF.

Each isomer class is quantitated using a C-13 internal standard from that class.

Daily Response Factor Check--The 1.0 μg/mL PCDD/PCDF standard is analyzed at the beginning of each working day to verify that the response factors obtained for that day agree to within $\pm$30 percent of those obtained from the initial five-point calibration in triplicate. Also, isotope ratios for each PCDD/PCDF isomer class are verified to be within $\pm$15 percent of their theoretical values.

QC Check Sample--An EPA or NBS check sample is analyzed after every five-point calibration to determine that the PCDD/PCDF standards and calibration curve used are acceptable.

4.7 Metals by ICPES - Method 6010

Method 6010 describes the simultaneous, or sequential, determination of elements using inductively coupled plasma atomic emission spectroscopy.

Detailed calibration procedures for ICPES systems are described in SW-846, 3rd ed. A response factor is calculated daily for each metal based on three exposures of a calibration standard and calibration blank. The RF is calculated and stored in the ICPES computer. Following calibration, a mid-level calibration check sample is analyzed; agreement between the measured value and the expected value must be within 5 percent for analyses to proceed. Calibration is verified by analyzing a QC check standard (prepared independently of calibration standards) every 10 samples; agreement within ±10 percent of the expected value is required for all metals analyzed by ICPES.

4.8 Metals by AAS - Methods 7060, 7421, 7740, 7470

Method 7060, 7421, and 7740 are graphite furnace atomic absorption techniques for determination of arsenic, lead, and selenium, respectively.

Method 7470 is a cold-vapor atomic absorption procedure for determining the concentration of mercury in aqueous samples.

The calibration procedures for the graphite furnace and cold vapor AAS systems are described in the respective method in SW-846, 3rd ed. A multipoint calibration curve is generated daily for each element using a calibration blank and three upscale standards. The correlation coefficient for the linear regression equation must exceed 0.995 to be acceptable. Calibration will be verified every 10 samples by analyzing a QC check sample and calibration blank. Agreement within ±15 percent of the expected value is required;

otherwise, a new calibration curve must be generated.

4.9 Total and Amenable Cyanide - Method 9012

Method 9012 is used to determine the concentration of inorganic cyanide in an aqueous waste or leachate. The method detects inorganic cyanides that are present as either sample soluble salts or complex radicals. It is used to determine values for both total cyanide and cyanide amenable to chlorination.

A daily calibration curve is prepared using a blank and a minimum of three standards, with a correlation coefficient greater than 0.995. A high and a low standard should be distilled and compared with similar values on the curve to ensure that the distillation technique is reliable. The distilled standards should agree within ±10 percent of the undistilled standards.

4.10 Fluoride - Method 340.2

This method is applicable to the measurement of fluoride in drinking, surface and saline waters, domestic and industrial wastes. The fluoride is determined potentiometrically using a fluoride electrode in conjunction with a standard single junction sleeve-type reference electrode and a pH meter having an expanded millivolt scale or a selective ion meter having a direct concentration scale for fluoride.

A calibration curve will be generated using a matrix blank and five to nine standards ranging from zero to 2.0 mg/L fluoride. The correlation coefficient must exceed 0.995 for the calibration equation. A quality control check sample will be analyzed every 10 samples; recovery must be within ±10 percent of the expected value.

4.11 Sulfides - Method 9030

Method 9030 is used to measure the concentration of total and dissolved sulfides in drinking, surface, and saline waters. Excess iodine is added to a sample which has been treated with zinc acetate to produce zinc sulfide. The iodine oxidizes the sulfide to sulfur under acidic conditions. The excess iodine is back titrated with sodium thiosulfate or phenylarsine oxide.

The thiosulfate solution is standardized periodically against primary standard potassium dichromate. The iodine solution is standardized daily against the standardized thiosulfate solution.

4.12 Calibration of Field Equipment

Conductivity Meter

The conductivity meter will be calibrated daily prior to field work using a 0.01 Molar KCl solution, which produces a 1413 μmhos/cm reading at 25°C.

pH Meter

The pH meter will be calibrated daily during groundwater sampling activities. Calibration will include setting the range and span using pH 4.0, 7.0 and 10.0 laboratory buffer solutions. In order to ensure proper calibration, pH 7.0 buffer will be used as a single point check between each sampling location.

HNU Photoionizer

Prior to initial field activities, the HNU will be calibrated in the laboratory by a qualified equipment technician. From three to five calibration gases of different concentrations are used to check instrument response, linearity and ensure proper operation before the instrument is taken into the field. In daily use, the instrument will be used as a qualitative

indicator of the presence of nonspecific volatile organics and therefore will not be calibrated in the field. The instrument will be set to zero daily in an area selected for a background measurement. Readings after this point will indicate deviation of the air quality relative to background conditions.

5.0 PREVENTIVE MAINTENANCE

The preventive maintenance program used by Radian is designed to minimize the downtime of analytical equipment. Routine preventive maintenance is performed on all instruments at Radian. Maintenance is based on manufacturers' recommendations and performed on a regular schedule. Service agreements are in place for about half of the instruments to be used for the Holloman groundwater study. All aspects of routine and nonroutine instrument maintenance are recorded in logbooks; a logbook is dedicated to each instrument.

6.0 DATA ANALYSIS AND REPORTING

The data analysis required to calculate sample concentrations will proceed according to procedures outlined in the analytical methods identified in Table 2-1.

After final review of raw analytical data in the laboratory, the laboratory supervisor transfers the data to the Sample Control area of Radian Analytical Services (RAS); the raw data are filed for subsequent review by the RAS Quality Assurance Officer. Raw data, along with all supporting documentation, are stored permanently in confidential files by RAS Sample Control.

After all analyses have been completed, a preliminary report is generated for review by the laboratory supervisors and the Quality Control Officer. Data integrity is ensured by this review, as the Quality Control Officer includes a review of the data for adherence to the quality control objectives of the project.

Identification of outliers is also a part of the data review. An outlier is an unusually large (or small) value in a set of observations. There are many possible reasons for outliers. Among them are:

1) A faulty instrument or component part;
2) Inaccurate reading of a record, dialing error, etc.;
3) Error in transcribing data; or
4) Calculation errors.

Sometimes analysts or operators can identify outliers by noting the above types of occurrences when they record observations. These faulty observations may then be removed from the dataset before it is summarized. If no such information exists, the Dixon Criteria will be used to test suspected outliers at the 5 percent significance level.[1]

---

[1]W.J. Dixon, "Processing Data for Outliers," Biometrics, 1953, Vol. 9, No. 1, pp. 74-89.

6.1 Statistical Analysis of the Background Data

The four indicator parameters specified in 265.92(b)(3) are pH, specific conductance, total organic carbon, and total organic halogen. The sampling is designed in a manner to calculate the arithmetic mean and variance based on at least four replicate measurements on each sample. The comparison must consider individually each of the two background wells in the monitoring system.

There are a number of statistical test methodologies in use. The owner/operator (Holloman AFB) proposes to use the averaged replicate (AR) t-test to analyze the groundwater monitoring data.

The test methodology will be submitted to include:

- A clear, understandable explanation of the AR test methodology;
- Presentation of explicit example calculations;
- Documentation of all original data used in the statistical analysis procedure;
- Literature and reference citations; and
- Detailed explanation of how the data were manipulated and evaluated prior to the statistical analysis, including goodness-of-fit testing, transformations, less than groundwater limit values, and power evaluations.

A professional statistician will evaluate the data to satisfy the necessary analytical and statistical t-test requirements as specified in CFR 265.93.

6.2 Data Management System

Radian's Analytical Services laboratories use a data management system known as SAM (Sample and Analysis Management System for Laboratory Information). Radian will use SAM to log samples, track status, and report analytical data. The pertinent technical and administrative information logged using SAM will include sample identification numbers, analyses required, sampling dates, and due dates. The laboratory supervisors will be notified of analysis required by work sheets and data sheets, generated by SAM, that specify the tests to be performed in the respective laboratories. All samples will be stored in secured areas, usually under refrigeration as specified by EPA storage protocols. Access to the samples will be limited to the analysts and supervisors and will be documented by logbooks located at each storage area. Thus, chain of custody will be maintained and documented using SAM and written documentation. Transfer of samples from laboratories and Radian facilities will be documented by completing a new chain-of-custody form, attaching a photocopy of the original form, and filing the original.

6.3 A-E Daily Quality Control Reports (A-E DQCR)

The A-E DQCR is a report that will be submitted to the Omaha COE Project Manager and Holloman Environmental Coordinator on a daily basis. The information will be submitted on a form as shown in Figure 6-1. It will be a memorandum covering the following topics:

- Date;
- Weather, including temperature, wind speed, and direction, etc.;
- Work performed;
- Sampling performed, including specifics;
- Field parameter measurements, including calibration checks;
- Problems encountered and corrective actions taken;
- Quality control activities initiated; and
- Signature.

Date: _____

Sheet No.: _____

A-E DAILY QUALITY CONTROL REPORT FOR GROUNDWATER MONITORING
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: _____

Weather: _____

Work Performed: _____

_____

_____

_____

Sampling Performed: _____

_____

_____

_____

Problems and Corrective Actions: _____

_____

_____

_____

_____

_____

Quality Control Activities Initiated: _____

_____

_____

Signature: _____

Figure 6-1. Example of A-E Daily Quality Control Report.

In addition to these daily reports, the Omaha COE Project Manager will be immediately contacted by telephone when exceptional situations develop, including significant changes in the execution of this contract.

6.4 A-E Quality Control Summary Report (A-E QCSR)

This report, to be submitted by Radian at the end of the groundwater monitoring well installation phase, will address the following as a summary of the progress of the QC program and of the overall investigation:

- Scope of project;
- Project description;
- Sampling procedure, as planned and actually implemented;
- Summary of A-E daily QC reports;
- Analytical procedures;
- Data presentation;
- Quality control activities;
- Presentation of field and lab results;
- Discussion of reliability of resulting data; and
- Conclusions and recommendations.

20th Anniversary

RADIAN CORPORATION

8501 Mo-Pac Blvd.
P.O. Box 201088
Austin, TX 78720-1088
(512)454-4797

July 6, 1989

Department of the Army
Omaha District, Corps of Engineers
ATTN: CEMRO-ED-EB (Brian Stewart)
Executive Building
1624 Douglas, Room 608
Omaha, NE 68102

Subject: Revised Plates 11 and 12, Hydrogeologic Investigation Report and Groundwater Monitoring Plan (HIR/GWMP) for the Sewage Treatment Lagoons, Holloman AFB, New Mexico

Dear Brian:

Enclosed are five copies of the updated versions of Plates 11 and 12 of the HIR/GWMP. The revisions to the plates include the addition of two more monitor wells, MW-7 and MW-8 as requested by NMEID/EPA, and information about the estimated well locations, depths, and screened intervals.

Please replace the 8 March 1989 Plates 11 and 12 with the included revised Plates 11 and 12. If you have any questions, please contact me.

Sincerely,

James H. Clary
Project Director

taj

Enclosures

cc: W.L. Boettner/4
N.H. Lund/4
C. Fesmire/EPA (2)
B. Hamilton/NMEID (1)
W. Trippet, III/IT (2)
[redacted]
G. Burnet/HQ, TAC (2)
K. Schenk/MRD (1)
T. Boone/CSG/DEEV (3)
File 269-001-01-08

20th★★★★ Anniversary

RADIAN CORPORATION

LOGGED IN

8501 Mo-Pac Blvd.
P.O. Box 201088
Austin, TX 78720-1088
(512)454-4797

3 July 1989

U.S. Army Engineer District, Omaha
ATTN: MROED-EB (Brian Stewart)
215 North 17th Street
Omaha, NE 68102-4910

Subject: Final Submittal with Review Comments/Responses of the *Final Hydrogeologic Investigation Report and Groundwater Monitoring Plan, Holloman Air Force Base, New Mexico*

Dear Brian:

Enclosed for your review and approval are COE copies of the **Final Hydrogeological Investigation Report and Groundwater Monitoring Plan for the Sewage Lagoons (HIR/GWMP) Holloman Air Force Base, NM.** Also included are Radian's annotated responses to reviewer's comments on the HIR/GWMP. We have revised the HIR/GWMP to comply with the EPA/NMEID (letter dated June 2, 1989) requirements to install two more downgradient wells, to use a 40/60 gradation sand for the monitor well filter pack, and to sample all the monitor wells in the detection system for Appendix IX parameters in Month 5. It is our understanding that the NMEID/EPA have approved the proposed monitoring system with the incorporation of the required revisions.

If you have any questions, please contact me.

Sincerely,

James H Clary by Gary Chand

James H. Clary
Project Director

taj

Enclosures

cc: W.L. Boettner/4
N.H. Lund/4
File 269-001-01

RESPONSE TO COMMENTS ON THE FINAL HYDROGEOLOGIC INVESTIGATION REPORT AND GROUNDWATER MONITORING PLAN FOR THE SEWAGE TREATMENT LAGOONS, HOLLOMAN AIR FORCE BASE, NEW MEXICO

Location	Item No.	Description
REVIEWER--MIKE CRAIN		
Sheet 11	1	Comment noted. EPA has approved The Waste Management boundary so no change will be made to the boundary or to the proposed monitor well locations.
Sheet 11	2	Comment noted. MW-7 and MW-8 are two additional wells added to sheet 11 at the locations requested by the EPA.
App. H, p. H-3	3	Sieve analyses have been previously conducted (Appendix C of the HIR). A sentence will be added to paragraph 3 of Section 2.1 mentioning this.
App. H, p. H-3	4	Comment noted. Gradation specification (40/60 silica sand) will be added to the first sentence in section 2.3.
App. H, Sec. 1.2	5	Comment noted. Sentence will be expanded.

20th Anniversary

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8501 Mo-Pac Blvd.
P.O. Box 201088
Austin, TX 78720-1088
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DCN 89-269-001-01-02

FINAL
HYDROGEOLOGIC INVESTIGATION REPORT AND GROUNDWATER MONITORING PLAN FOR THE SEWAGE TREATMENT LAGOONS HOLLOMAN AIR FORCE BASE, NEW MEXICO

VOLUME 2. APPENDICES A-L

Prepared by:
Radian Corporation
8501 Mo-Pac Boulevard
Austin, Texas 78766

Under Contract With:
Omaha District, Corps of Engineers
215 North 17th Street
Omaha, Nebraska 68102

For

Headquarters, Tactical Air Command
HQ, TAC/DEEV
Langley Air Force Base, Virginia 23665

July 1989

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APPENDIX H

WELL CONSTRUCTION AND COMPLETION DETAILS FOR STAINLESS STEEL WELLS HOLLOMAN AFB, NEW MEXICO

APPENDIX H

Appendix H contains well construction information pertaining to the installation of eight additional detection monitoring wells at Holloman AFB, New Mexico. The monitoring wells will be drilled in a manner similar to the existing piezometers installed during the hydrogeologic investigation. Specifications for well construction are derived primarily from the requirements of the Corps of Engineers which in turn conform with EPA well construction guidelines (EPA TEGD, 1986).

1.0 DRILLING TECHNIQUES

A hollow-stem auger drill rig will be used to install the wells. This method has proven satisfactory in the past because the rig operated without the use of potentially contaminating drilling fluids (water or foam). The drill rig was also easy to maneuver during the project, even during rainy days.

1.1 Borehole Drilling

During drilling operations, a Radian geologist will log the borehole from the cuttings. Drilling methods are discussed below:

Boreholes will be drilled using a Mobil Drilling hollow-stem auger rig. Each auger flight is 5 feet in length. Auger dimensions will be 12-inch outside diameter (O.D.) and 6-5/8-inch inside diameter (I.D.). Soil cuttings produced during the drilling activities will be left on site after well completion. All sites will be raked and smoothed to a pre-disturbance condition as required by Base Environmental Engineer. When the borehole reaches total depth, as determined by the supervising geologist, it will be completed as a monitor well as described in the following sections.

1.2 Decontamination Techniques

All augers, split spoons, and drill rods will be steam cleaned, washed (ALCONOX), and rinsed prior to beginning the work and following completion of the well at an area designated for decontamination activities. The drill rig will be steam cleaned prior to beginning work and following completion of each well.

2.0 MONITOR WELL CONSTRUCTION

2.1 Screen and Casing

Because the sand units are quite thin, ranging from 7 to 20 feet thick and averaging approximately 10 feet thick, 5- or 10-foot screens are proposed in order to bridge thin units of interest and detect contaminants concentrated within each unit. The rationale is that the shorter well screen will permit the sand interval of interest to be monitored.

After the site geologist determines the total depth of the well, the screen and casing will be set into the borehole. The casing will continue from the screen to approximately 2 to 3 feet above the ground surface (Figure 1).

Screen and casing for the wells will consist of 316 stainless steel 4-inch inside-diameter material. Stainless steel was selected for two reasons: 1) it is recommended by RCRA (1986), and 2) it is highly resistant to corrosion. The screen will be between 5 and 10 feet long, machine pre-slotted, with a sealed end cap. The slot size will be 0.010 inch, which was found during piezometer installation to be compatible with the grain size of sediment in the aquifer (see Appendix C) and sand pack. All joints between the screen and casing and separate casing sections will be tightly connected with flush-joint threaded couplings. No glues, lead shot, or lead wool will be used on any part of the screen or casing.

2.2 Well Plumbness and Alignment

All risers shall be set round, plumb, and true to line. If the borehole remains open, the screen and casing will be set into the well after the drill bit and auger flights have been removed. Very little deviation from vertical is anticipated during drilling because of the unconsolidated nature of the fine grained material beneath the site. For this reason, centralizers will not be used.

2.3 Sand Pack

The sand/gravel filter pack will consist of clean, bagged silica (Colorado Silica) sand of fine enough mesh size (40/60 gradation) to prevent siltation of the well. Sand will be placed from the bottom of the boring to approximately 2 feet above the top of the screen (Figure 1).

Sand will be poured directly down the annulus between the screen and borehole. The top of the casing string will be plugged during this operation to avoid pouring sand into the well. After a calculated volume of sand has been poured down the hole, the sand pack will be tamped and measured with a weighted tape. By sounding the level of the sand in the hole, the sand above the top of the screen may be determined. Some sand will always remain in the annular space between the casing string and the borehole. Sounding the sand level with a measuring tape will detect any potential bridging that might occur.

2.4 Bentonite Seal and Grout

A bentonite seal 2 feet thick will be emplaced on top of the sand pack (Figure 1). The bentonite seal, consisting of granular bentonite, will be poured directly down between the well casing and borehole. If the bentonite bridges inside the well, the bentonite will be emplaced in the

WELL CONSTRUCTION SCHEMATIC

PROJECT: Detection Monitoring Well Installation	WELL NO.: To be assigned
SITE: Holloman AFB, NM	
COORDINATES: To be surveyed to SPCS coord.	AQUIFER: Uppermost
DATE COMPLETED: 1988	
SUPERVISED BY: Radian Corporation	DEPTH TO WATER: To be surveyed
DRILLER: Winnek Incorporated	
DRILLING METHOD: Hollow Stem Auger	

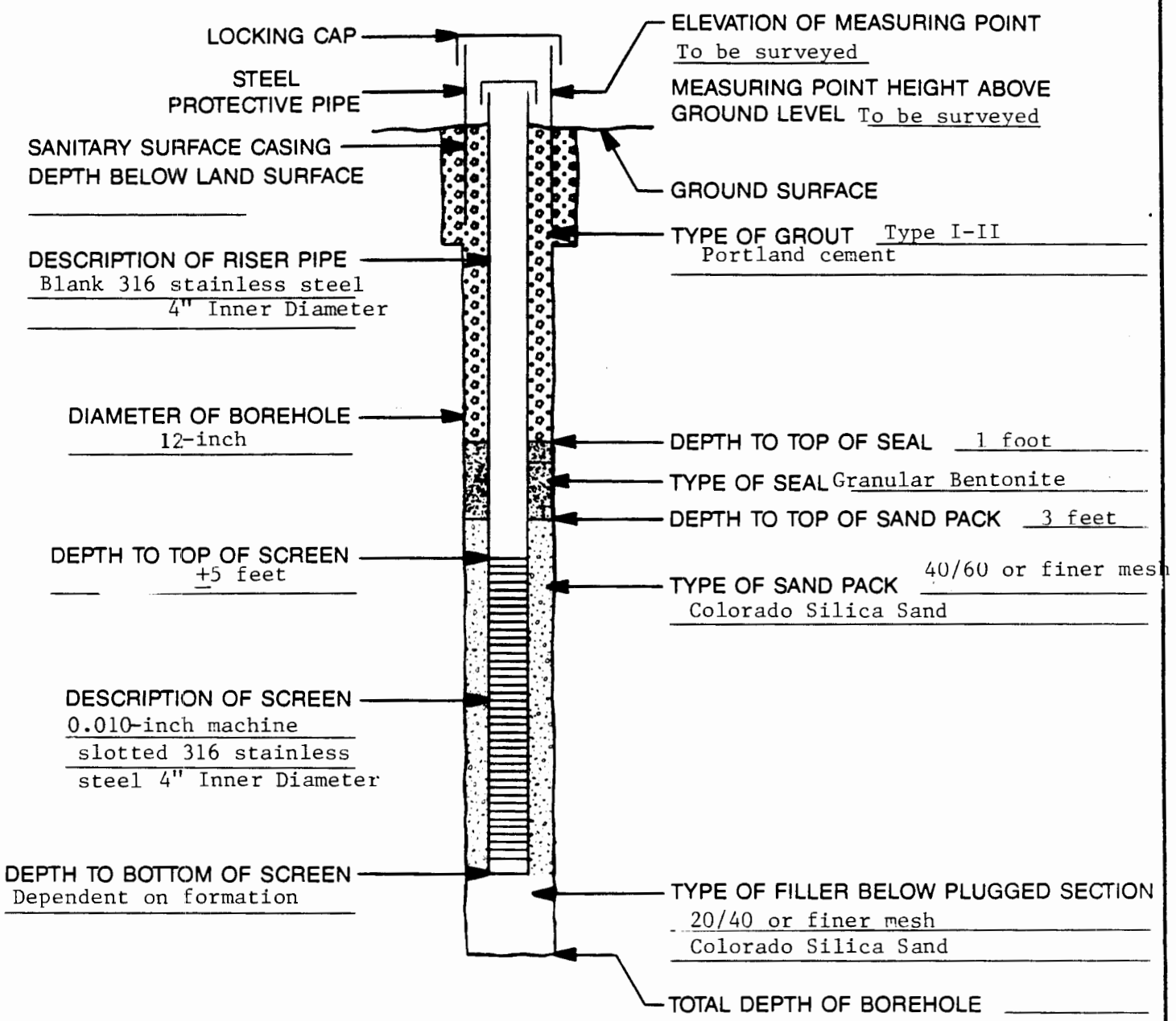

Figure 1. Example of Stainless Steel Detection Monitoring Well, Holloman AFB, New Mexico

D87 - 1240A

hole through a tremie pipe. However, experience has shown that the sediments are tight, permitting the borehole to remain open. The bentonite will be sounded and packed down with a weighted tape (as with the sand pack). The bentonite seal will be allowed to hydrate for 8 to 12 hours before grouting.

A cement grout mix will be emplaced into the hole from the top of the bentonite seal to the ground surface. The cement grout will consist of a mixture of Type 1 Portland cement (ASTM-C 150) and water. The mix will not exceed 7 1/2 gallons of clean water per bag of cement (94 lbs.). The grout mix will contain up to 3 percent bentonite powder by weight. The grout will be pumped under pressure through a tremie pipe to ensure positive placement of the grout. The pumping will continue until grout reaches land surface, at which time the tremie pipe will be removed.

2.5 Well Protection

If a well is temporarily left uncompleted, it will be protected with a heavy metal cover to avoid contamination of down-hole water and sediments.

Approximately 2 to 3 feet of stainless steel well casing will be left above ground after completion of the well (Figure 1). A PVC screw-joint cap will be placed on the top of the stickup casing. To protect the casing stick-up against vandalism or vehicles, a five-foot protective steel casing will be slipped over the well stick-up and anchored 2 to 3 feet into the grout (before it sets) so that the protective steel casing will extend 2 to 3 feet above land surface. The steel casing will have a locking cap and lock. A 3-foot by 3-foot by 4-inch concrete pad will be poured into a form around the protective steel casing. The concrete pad will be set at ground level and will slope away from the well casing. Three 3-inch diameter steel posts will be placed radially around the well and set into concrete (Figure 1). The posts will extend approximately 3 feet above the concrete pad and will be painted. The ground surface around the well will be sloped away from the casing. The well number will be set using a die set on the outside of the protective casing and on the well cover.

2.6 Well Construction Logs

The Radian geologist supervising the drilling procedures will prepare a log of well construction activities. Two copies with original signatures will be submitted to the Omaha District Corp of Engineers Contracting Officer within ten days of well completion. Well construction and completion logs, similar to the example in Figure 2, will be used. The following information will be included in the drilling, construction, and completion logs:

- Reference elevation for all depth measurement.
- Depth of each change of stratum.
- Thickness of each stratum.
- Identification of the material of which each stratum is composed according to the Unified Soil Classification System, or standard rock nomenclature, as necessary. Identification will also include a description of grain-size, angularity, color, and fining sequence.
- Depth interval from which each formation sample was taken.
- Depth at which groundwater is first encountered.
- Depth to the static water level and changes in static water level with well depth.
- Total depth of completed well.
- Nominal diameter of borings.
- Depth of any grouting or sealing.

Hole No.

DRILLING LOG	DIVISION	INSTALLATION	SHEET OF SHEETS

1. PROJECT	10. SIZE AND TYPE OF BIT
	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	
	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	
4. HOLE NO. (As shown on drawing title and file number)	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.	16. DATE HOLE — STARTED — COMPLETED
	17. ELEVATION TOP OF HOLE
7. THICKNESS OF OVERBURDEN	18. TOTAL CORE RECOVERY FOR BORING %
8. DEPTH DRILLED INTO ROCK	19. SIGNATURE OF INSPECTOR
9. TOTAL DEPTH OF HOLE	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g

Figure 2. Well Log

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT | HOLE NO.

- Amount, type, and manufacturer of all materials used in well construction.

- Depth and type of well casing.

- Description (to include length, location, diameter, slot sizes, material, and manufacturer) of well screens.

- Method of well development.

- Static water level upon completion of the well and after development.

- Drilling date or dates.

- Construction details of monitoring well as installed.

3.0 WELL DEVELOPMENT

Bailing and surging using pumps, bailers, surge blocks or a combination of these methods will be used for development of the monitor wells. Well development will proceed no sooner than 48 hours after well completion. Development will continue for a minimum of 4 hours, or until groundwater is free from sand and drill cuttings. Water from development procedures will be deposited onto land surface via a discharge hose. A photographic slide will be taken of the development water and will be sufficiently back-lit to observe the clarity of the water after the well is developed. The well depth will be rechecked before and after development to ensure that all sand and fines have been removed from the well. Well development information will be maintained as part of the record-keeping process and recorded onto a form shown in Figure 4. In addition, volumes of purged water during development activities will be calculated. All other testing methods and results compiled during field activities will be recorded in the project notebook.

4.0 SURVEYING

At the completion of drilling operations, a State of New Mexico licensed and registered surveyor will determine the vertical and horizontal position of the newly installed wells. Elevations for the wells will be referenced to the 1929 National Geodetic Vertical Datum and will be referenced to the State Plane Coordinate System. Elevation and survey requirements are as follows:

- The top of ground elevation to the nearest 0.1 foot;
- The top of the well casing elevation to the nearest 0.01 foot;
- Survey points taken on the top of the well casing will be notched for future reference; and
- Horizontal coordinates will be accurate to the nearest 1.0 foot.

Wells and survey control monuments will be located on a plan map of suitable scale to accurately plot these locations as required in the Statement of Work.

20th Anniversary
RADIAN CORPORATION

8501 Mo-Pac Blvd.
P.O. Box 201088
Austin, TX 78720-1088
(512)454-4797

July 6, 1989

Department of the Army
Omaha District, Corps of Engineers
ATTN: CEMRO-ED-EB (Brian Stewart)
Executive Building
1624 Douglas, Room 608
Omaha, NE 68102

Subject: Final Submittal with Review Comments/Responses of the A-E Quality Control Plan/Sampling Plan (A-E QCP/SP) for the Sewage Treatment Lagoons, Holloman AFB, New Mexico

Dear Brian:

Transmitted herewith are the latest revised versions of the A-E QCP/SP and Appendix I of the Hydrogeologic Investigation Report and Groundwater Monitoring Plan (HIR/GWMP). Please replace the March 1989 Appendix I with the enclosed revised Appendix I.

Also included are Radian's annotated responses to reviewer's comments on the A-E QCP/SP and a revised "spine" for Volume 1 of the HIR/GWMP.

If you have any questions, please contact me.

Sincerely,

James H. Clary
Project Director

taj

Enclosures

cc: W.L. Boettner/4
N.H. Lund/4
C. Fesmire/EPA (2)
B. Hamilton/NMEID (1)
W. Trippet, III/IT (2)
M. Peycke/EPA (1)
G. Burnet/HQ, TAC (2)
K. Schenk/MRD (1)
T. Boone/CSG/DEEV (3)
File 269-001-01-08

20th Anniversary

RADIAN CORPORATION

8501 Mo-Pac Blvd.
P.O. Box 201088
Austin, TX 78720-1088
(512)454-4797

April 26, 1989

Mr. Courtland Fesmire, Environmental Engineer
U.S. Environmental Protection Agency, Region VI, 6H-CS
First Interstate Bank Tower
1445 Ross Avenue
Dallas, TX 75202-2733

Dear Mr. Fesmire:

Enclosed are two revised copies of Appendix I of the **Hydrogeological Investigation Report and Groundwater Monitoring Plan for the Sewage Treatment Lagoons at Holloman AFB, New Mexico.** Corrections were made to this appendix to bring it into conformance with the revised A-E QCP/SP.

If you should have any questions concerning this insert, please call me at (512) 454-4797.

Sincerely,

William L. Boettner

William L. Boettner, P.G.
Program Manager

taj

Enclosure(s)

cc: G.S. Shaw/4
File 269-001-01-08

RESPONSE TO COMMENTS ON THE FINAL HYDROGEOLOGIC INVESTIGATION REPORT AND GROUNDWATER MONITORING PLAN FOR THE SEWAGE TREATMENT LAGOONS, HOLLOMAN AIR FORCE BASE, NEW MEXICO

Location	Item No.	Description
REVIEWER--MIKE CRAIN		
Sheet 11	1	Comment noted. EPA has approved The Waste Management boundary so no change will be made to the boundary or to the proposed monitor well locations.
Sheet 11	2	Comment noted. MW-7 and MW-8 are two additional wells added to sheet 11 at the locations requested by the EPA.
App. H, p. H-3	3	Sieve analyses have been previously conducted (Appendix C of the HIR). A sentence will be added to paragraph 3 of Section 2.1 mentioning this.
App. H, p. H-3	4	Comment noted. Gradation specification (40/60 silica sand) will be added to the first sentence in section 2.3.
App. H, Sec. 1.2	5	Comment noted. Sentence will be expanded.

17-B-47

20th★★★★ Anniversary

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DCN 89-269-001-01-02

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Austin, TX 78720-1088
(512)454-4797

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FINAL
HYDROGEOLOGIC INVESTIGATION REPORT AND GROUNDWATER MONITORING PLAN FOR THE SEWAGE TREATMENT LAGOONS HOLLOMAN AIR FORCE BASE, NEW MEXICO 88330

VOLUME 2. APPENDICES A-L

Prepared by:
Radian Corporation
8501 Mo-Pac Boulevard
Austin, Texas 78766

Under Contract With:
Omaha District, Corps of Engineers
215 North 17th Street
Omaha, Nebraska 68102

For

Headquarters, Tactical Air Command
HQ, TAC/DEEV
Langley Air Force Base, Virginia 23665

March 1989

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APPENDIX A

RIGHT-OF-ENTRY AGREEMENTS
FROM OFF-BASE LAND OWNERS
HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

DEPARTMENT OF THE ARMY
ALBUQUERQUE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1580
ALBUQUERQUE, NEW MEXICO 87103-1580

REPLY TO
ATTENTION OF

SWARE-A

17 September 1987

SUBJECT: Distribution of: Right of Entry for Survey and Exploration, Holloman AFB, NM

Wesley Walker et al

TO: ( ) HQDA (DAEN-) WASH DC 20314

( ) Cdr, USA Engr Div, SW, ATTN:CESWDRE , 1114 Commerce St., Dallas, TX 75242

( ) Cdr, HQ USAF/LEERB, WASH DC 20332

( ) Cdr, HQ AFSC/DEPE, Andrews AFB, WASH DC 20334

( ) Cdr, HQ TAC/DEPE, Langley AFB, VA 23665

( ) Cdr, 27th CSG/DEIE, Cannon AFB, NM 88101

(X) Cdr, 833d CSG/DEER, Holloman AFB, NM 88330

( ) Cdr, HQ MAC/DEPR, Scott AFB, IL 62225

( ) Cdr, 1606th ABW (MAC)/DEEV-R, Kirtland AFB, NM 87117

( ) Cdr, USA Engr Dist, FW, ATTN: SWFRM-F, PO Box 17300, Ft Worth, TX 76102

( ) Grantee by sep ltr

(X) Grantor by sep ltr

(X) Toby Walters, Radian Corporation, 8501 Mo-Pac Blvd, Austin, TX 78759

FOR THE COMMANDER:

Encl

Donald N. Satz
DONALD N. SATZ
Chief, Real Estate Division

Copy furnished:

(X) RE Files
( )

SWA FL 37
12 Jan 87

DEPARTMENT OF THE ARMY

RIGHT-OF-ENTRY FOR SURVEY AND EXPLORATION

Test Bore Hole, EPA Study
Holloman Air Force Base, NM
(Project, Installation or Activity)

Wesley Walker, et al S½ SW¼ T17S, R8E Sec 28
(Tract Number or Other Property Identification)

The undersigned, hereinafter called the "Owner", hereby grants to the UNITED STATES OF AMERICA, hereinafter called the "Government", a permit or right-of-entry upon the following terms and conditions:

1. The Owner hereby grants to the Government an irrevocable right to enter upon the lands hereinafter described at any time within a period of twenty four (24) *months from the date of this instrument, in order to survey, make test borings, and carry out such other exploratory work as may be necessary to complete the investigation being made of said lands by the Government.*

2. The permit includes the right of ingress and egress on other lands of the Owner not described below, provided such ingress and egress is necessary and not otherwise conveniently available to the Government.

3. All tools, equipment, and other property taken upon or placed upon the land by the Government shall remain the property of the Government and may be removed by the Government at any time within a reasonable period after the expiration of this permit or right-of-entry.

4. The Government agrees to be responsible for damages arising from the activity of the Government, its officers, employees, or representatives on said land, in the exercise of rights under this permit or right-of-entry, either by repairing such damage or at the option of the Government by making an appropriate settlement with the Owner in lieu thereof.

5. If aircraft flights over said lands, or entry upon the land by means of helicopter or other type aircraft, are necessary, the Government shall inform the Owner, in advance, of each such flight or entry.

6. The land affected by this permit or right-of-entry is located in the State of New Mexico, *County of* Otero, *and is described as follows:*

Sec 28 - S½ SW¼; T17S, R8E

7. The Grantor will be furnished a copy of the results of the study upon completion.

WITNESS MY HAND AND SEAL this 16 *day of* September, 1987

Wesley Walker (SEAL)
WESLEY WALKER

(SEAL)

UNITED STATES OF AMERICA

By Doyle Wingenried
for DONALD N. SATZ, Chief, Real Estate Division
Albuquerque District, COE, Albuquerque, NM

ENG FORM 1 APR 74 1258 EDITION OF 1 DEC 62 IS OBSOLETE. (ER 405-1-11 and EP 405-1-2)

DEPARTMENT OF THE ARMY
ALBUQUERQUE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1580
ALBUQUERQUE, NEW MEXICO 87103-1580

REPLY TO
ATTENTION OF:

September 23, 1987

Real Estate Division
Actions Branch

Mr. Toby Walters
Project Director
Radian Corporation
8501 Mo-Pac Blvd
Austin, Texas 78766

Dear Mr. Walters:

Enclosed is a fully executed Right of Way Reservation, NM 67595, our number DACA47-5-87-107, Holloman AFB, New Mexico. The ROW is for a 25 year term.

Sincerely,

Doyle Winzenried

Doyle Winzenried
Chief, Actions Branch
Real Estate Division

Enclosure

NM NM 67595
2800 (032)

RIGHT-OF-WAY RESERVATION

Title V, Section 507, of the Act of October 21, 1976 (43 U.S.C. 1767)

KNOW ALL MEN BY THESE PRESENTS, that the United States of America acting by and through the Bureau of Land Management, U.S. Department of the Interior, does hereby reserve for the U.S. Army, Corps of Engineers, a right-of-way to locate, construct, use, maintain, improve, relocate (within the exterior boundaries of said right-of-way), and repair seven piezometer sites over, upon, under, and through the following described public lands situated in the County of Otero, State of New Mexico, to wit:

New Mexico Principal Meridian, New Mexico

T. 17 S., R. 8 E.,

Sec. 21, SE¼NE¼;
Sec. 22, SW¼NW¼, SE¼SW¼, NW¼SE¼;
Sec. 27, SE¼NW¼;
Sec. 28, NE¼SE¼, SW¼SE¼.

Said sites being five feet by five feet each.

The parcel of land to which the above description applies contains .004 acres, more or less.

A map showing the right-of-way described above is attached hereto as Exhibit A.

The right-of-way herein granted is for the full use of the above described land for piezometer sites by the U.S. Army, Corps of Engineers, its licensees, permittees, agents and contractors. The Bureau of Land Management, however, reserves the right to occupy and use the right-of-way issued, and to issue or grant additional rights-of-way or other land uses over, upon, under and through the above described lands, provided that the occupancy and use and the additional grants do not interfere unreasonably with the rights granted herein, as determined

by the Authorized Officer: Provided further, that should said site be abandoned or the use thereof be discontinued for a continuous 5-year period, this right-of-way may be terminated and full jurisdiction and administration returned to the Bureau of Land Management upon delivery of written notice to the holder hereof.

Additional terms, conditions/stipulations are attached hereto as Exhibit B and made a part hereof.

This right-of-way is issued subject to all valid rights existing on the date of the grant.

This right-of-way may be renewed. If renewed, the right-of-way will be subject to regulations existing at the time of renewal and such other terms and conditions deemed necessary to protect the public interest.

TO HAVE AND TO HOLD said right-of-way unto the U.S. Army, Corps of Engineers, for a term of 25 years, commencing on the date of execution shown below.

The undersigned agrees to the terms, conditions and stipulations of this right-of-way reservation.

U.S. Army, Corps of Engineers

By: Donald N. Satz

DONALD N. SATZ
Chief, Real Estate Division
Albuquerque District, Corps of Engineers
Albuquerque, New Mexico

Title

11 SEP 1987
Date

The right-of-way reservation executed this 14th day of September 1987.

Bureau of Land Management

By: H. Jerome Lee
Authorized Officer

District Manager
Title

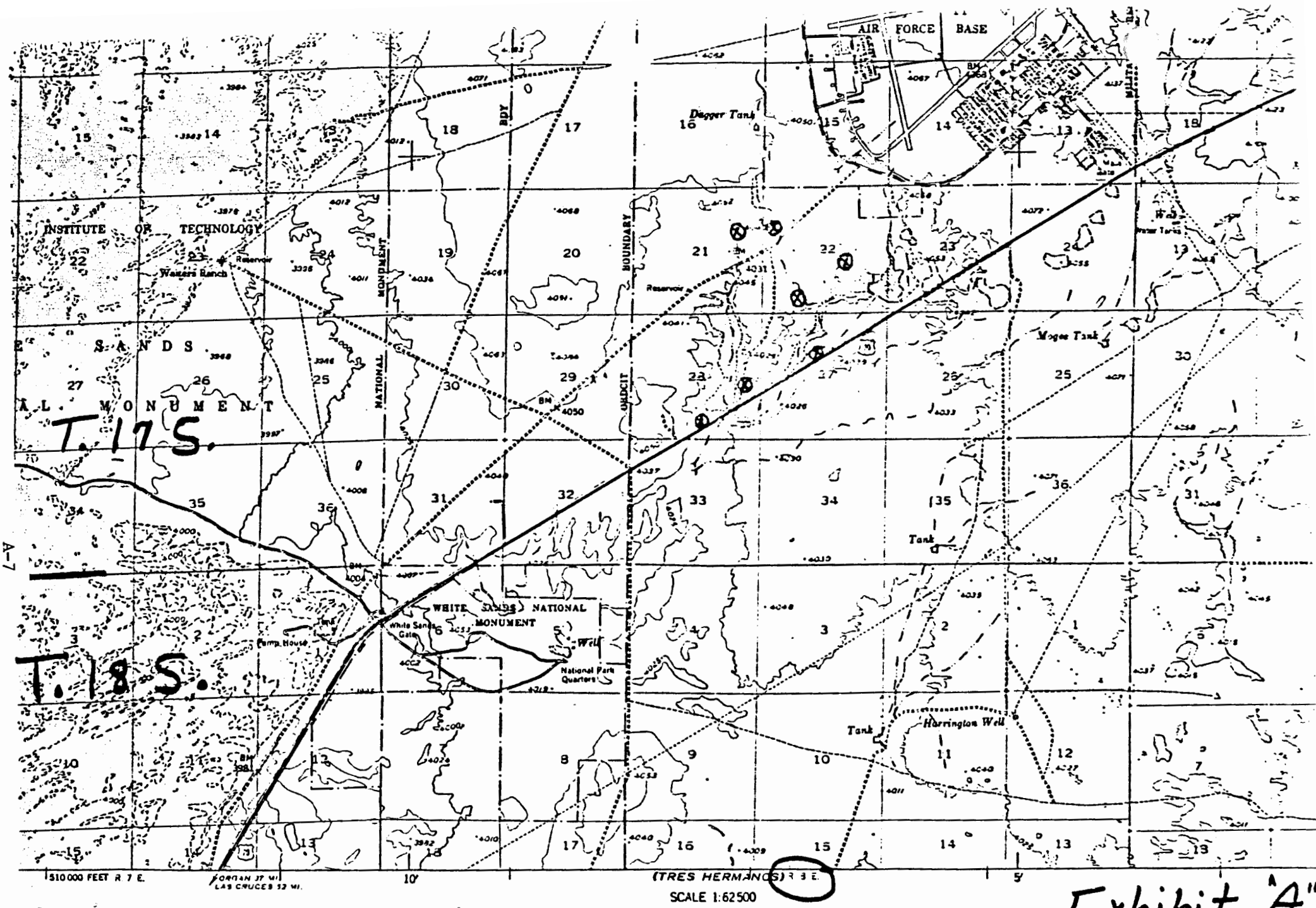

Exhibit "A"

NM NM 67595

A-7

cal Survey

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8
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rdinate system,

NM NM 67599

EXHIBIT "B"
STIPULATIONS

1. All construction work and vehicular traffic is to be confined to the permit area and existing road access unless otherwise authorized by specific written permission.

2. The manner of any construction or blade work authorized will be in compliance with procedures or specifications agreed upon.

3. No maintenance of existing roads will be permitted without prior consultation with the District Manager's authorized representative.

4. Good housekeeping (site free of rubble, materials, debris, etc.) will be expected. All earthmoving work will be under a foreman's supervision.

5. At any time during use, maintenance or rehabilitation of the right-of-way that archaeological, rare, historical, or paleontological discoveries are made, the permittee will immediately cease operations and notify the District Manager, Las Cruces District Office, Bureau of Land Management. Construction, maintenance, or other work will not be resumed until authorized.

6. Copies of drill logs, including formations penetrated, and depth to water, will be submitted to the BLM Las Cruces District.

7. Copies of all water quality test results will be submitted to this office as soon as results are known.

8. All permanent metal pipes on BLM managed lands will be identified with a permanent marker with the BLM right-of-way reservation number, Holloman well number, and date of installation.

9. Discharge and storage of the drilling fluid will be in a manner so as to prevent contamination of the groundwater and minimize any visual impacts.

10. All clearing, grading, and other soil and vegetative disturbance kept to the minimum necessary for construction. Utilize topographic screening for aboveground facilities and nonreflective materials to minimize the visual effect on the environment. Painting would also be accepted.

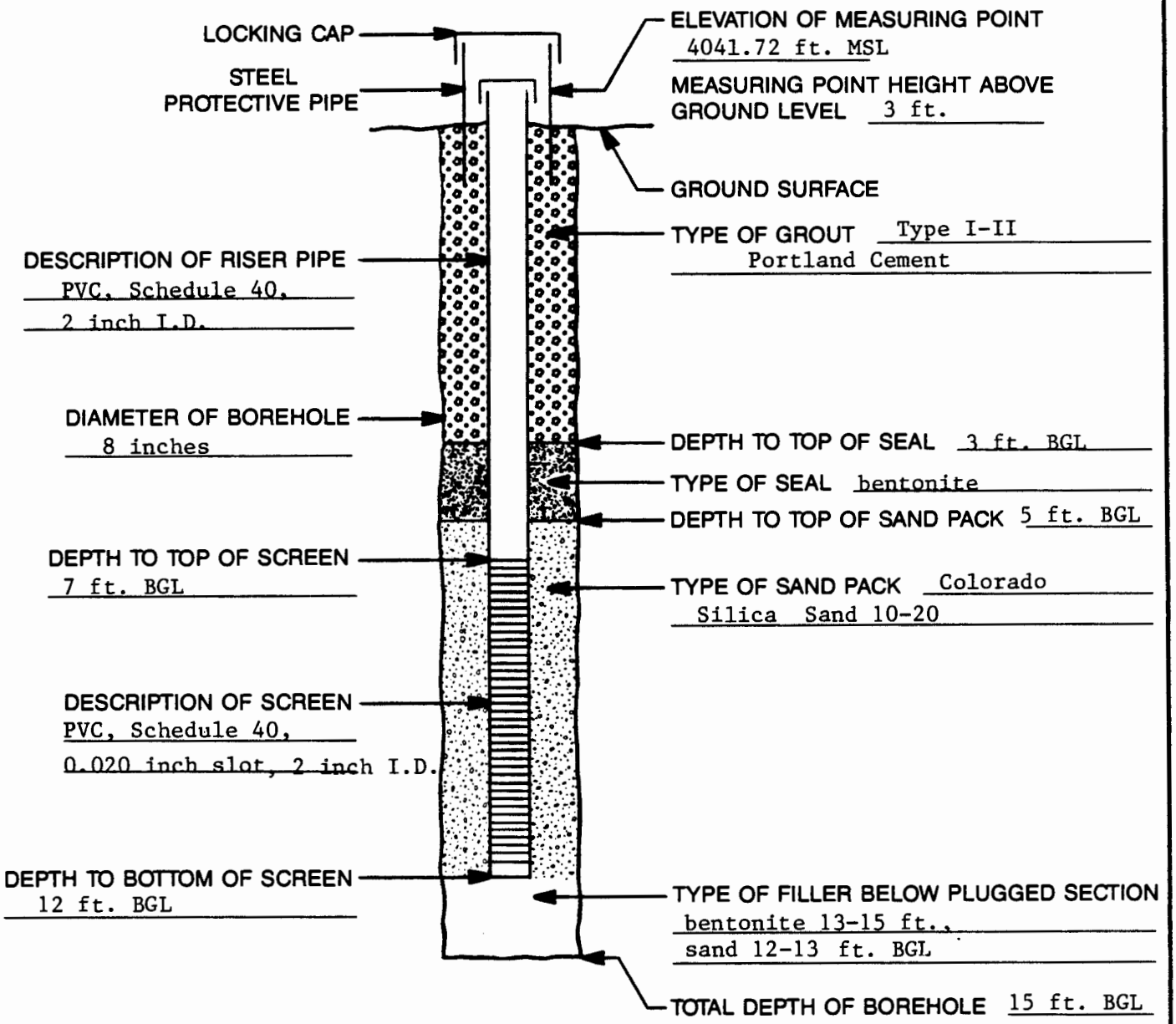
APPENDIX B

WELL COMPLETION AND CONSTRUCTION SCHEMATICS
HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 547227.8560, y = 664038.3872
DATE COMPLETED 11 August 1987
SUPERVISED BY Wendy Rozacky
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

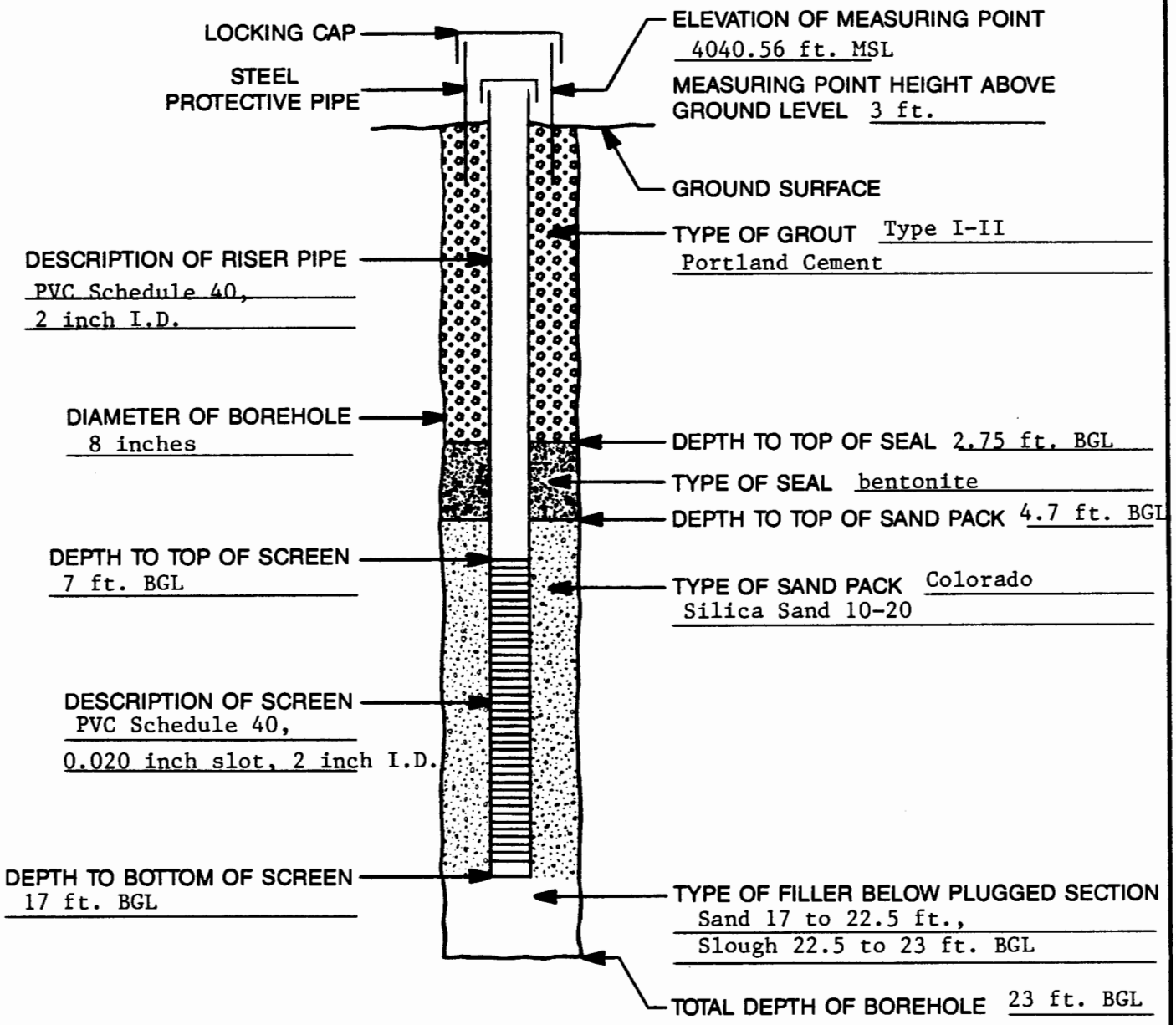
WELL NO. S-1
AQUIFER Shallow
DEPTH TO WATER 7 ft. BGL



WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 547271.0679, y = 662911.0500
DATE COMPLETED 17 August 1987
SUPERVISED BY Wendy Rozacky/Gary Henderson
DRILLER Kingsley/Winnek Inc.
DRILLING METHOD Hollow stem auger

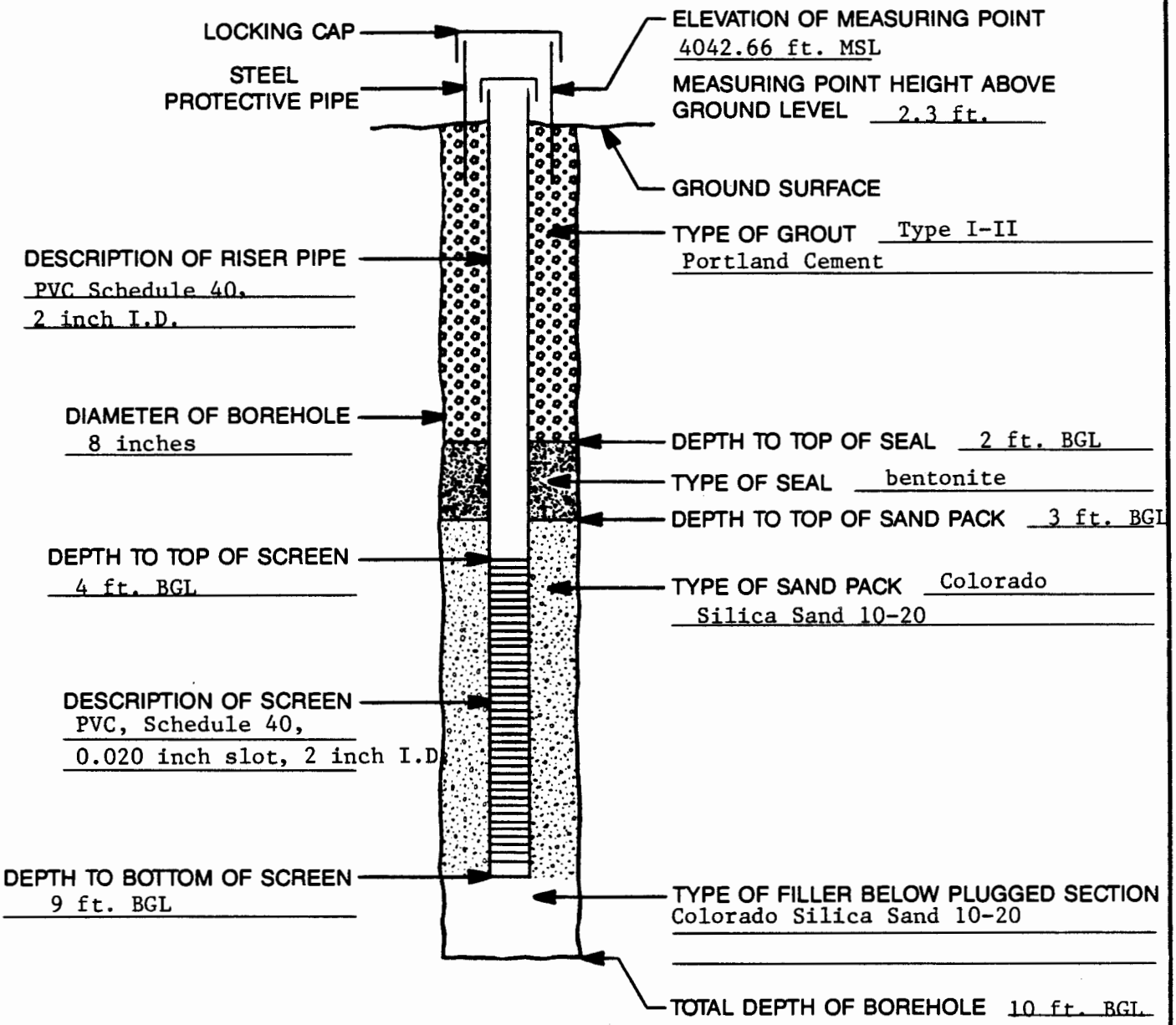
WELL NO. S-2
AQUIFER Shallow
DEPTH TO WATER 9 ft. BGL



WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 544339.4419, y = 666310.2590
DATE COMPLETED 5 August 1987
SUPERVISED BY Toby Walters/Wendy Rozacky
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. S-3
AQUIFER Shallow
DEPTH TO WATER 3 ft. BGL

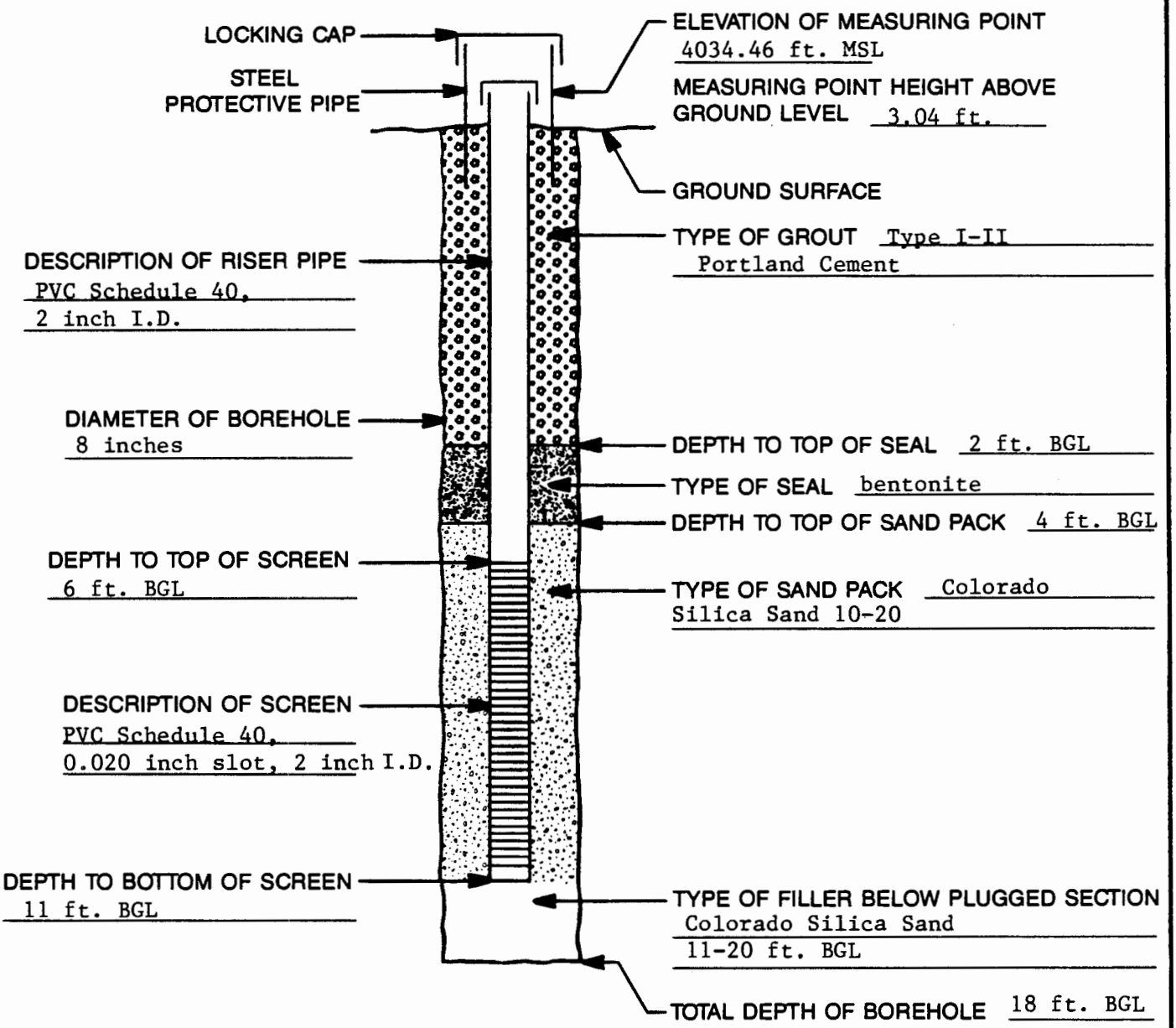


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 544926.5640, y = 662213.6641
DATE COMPLETED 21 August 1987
SUPERVISED BY Gary Henderson
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. S-4
AQUIFER Shallow
DEPTH TO WATER 8 ft. BGL

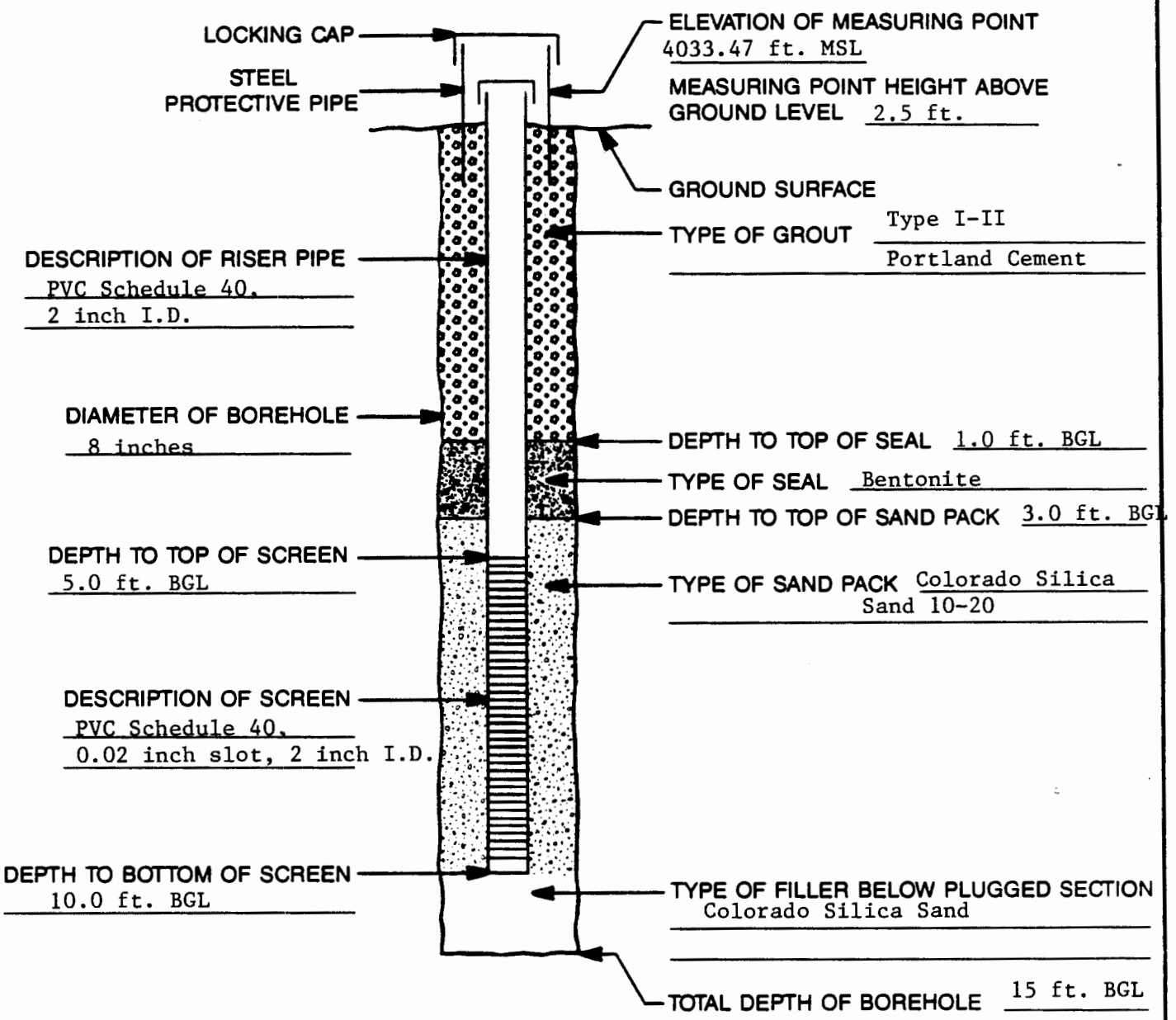


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 543989.3052, y = 662360.6421
DATE COMPLETED 25 September 1987
SUPERVISED BY Heidi Tomich
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

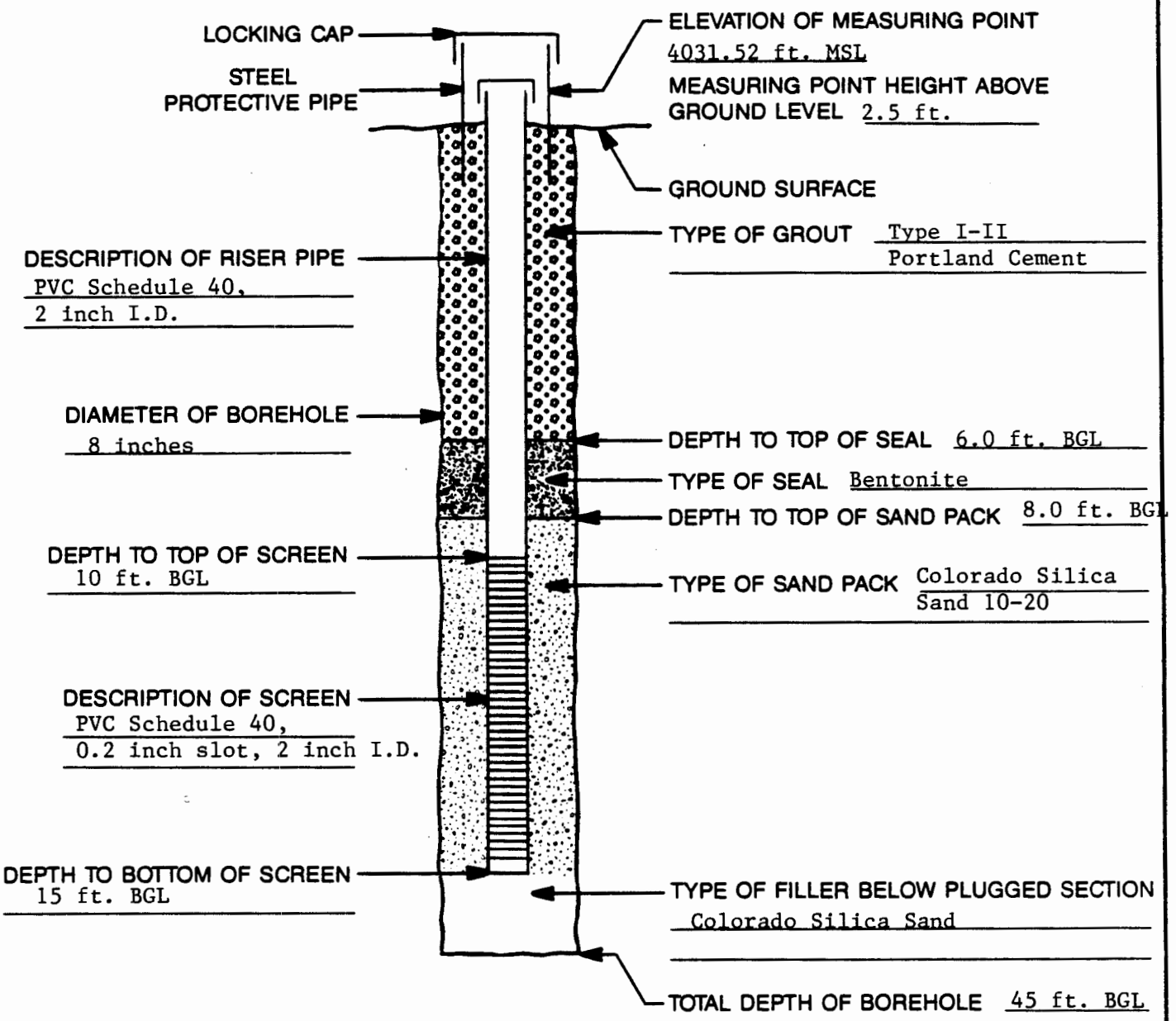
WELL NO. S-5
AQUIFER Shallow
DEPTH TO WATER 8 ft. BGL



WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 539431.6543, y = 663611.0007
DATE COMPLETED 25 September 1987
SUPERVISED BY Heidi Tomich
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. S-6
AQUIFER Shallow
DEPTH TO WATER 10 ft. BGL

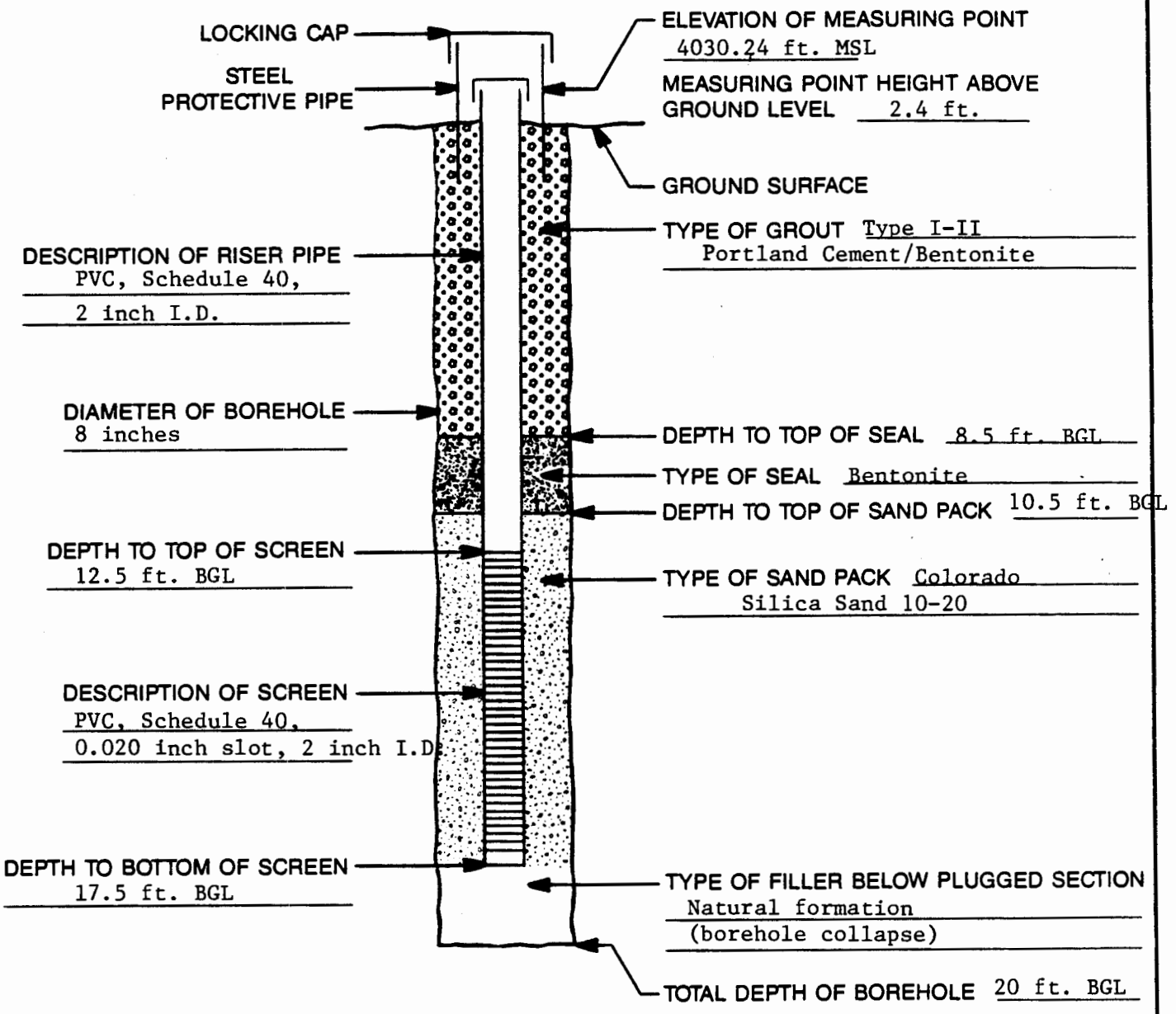


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 538199.1724, y = 662546.2710
DATE COMPLETED 3 October 1987
SUPERVISED BY Gary Henderson
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

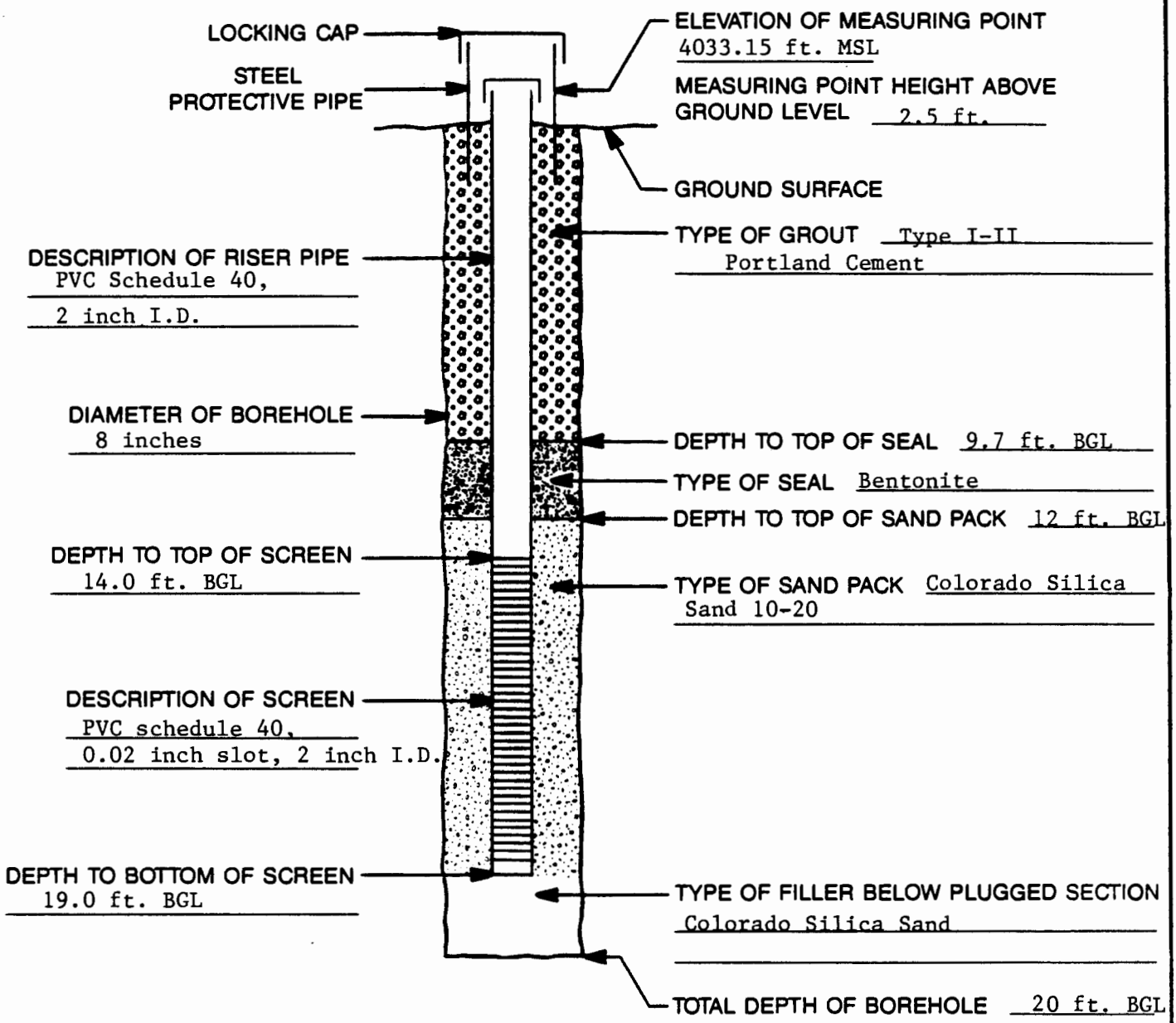
WELL NO. S-7
AQUIFER Shallow
DEPTH TO WATER 14 ft. BGL



WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, NM
COORDINATES x = 539393.4084, y = 660347.1843
DATE COMPLETED 25 September 1987
SUPERVISED BY Heidi Tomich
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. S-8
AQUIFER Shallow
DEPTH TO WATER 10.0 ft BGL

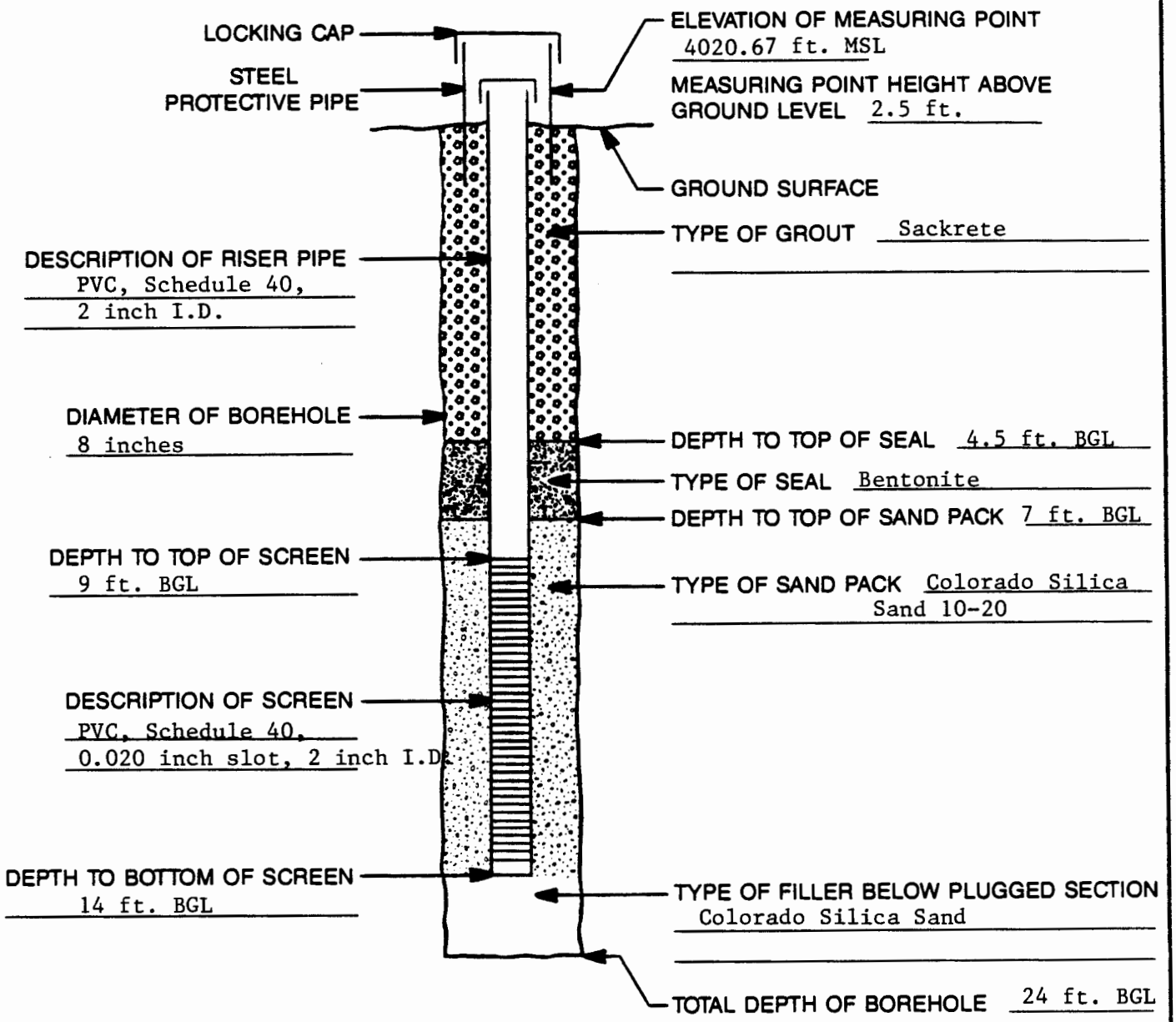


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB, Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 537626.7751, y = 655436.2842
DATE COMPLETED 7 October 1987
SUPERVISED BY Gary Henderson
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

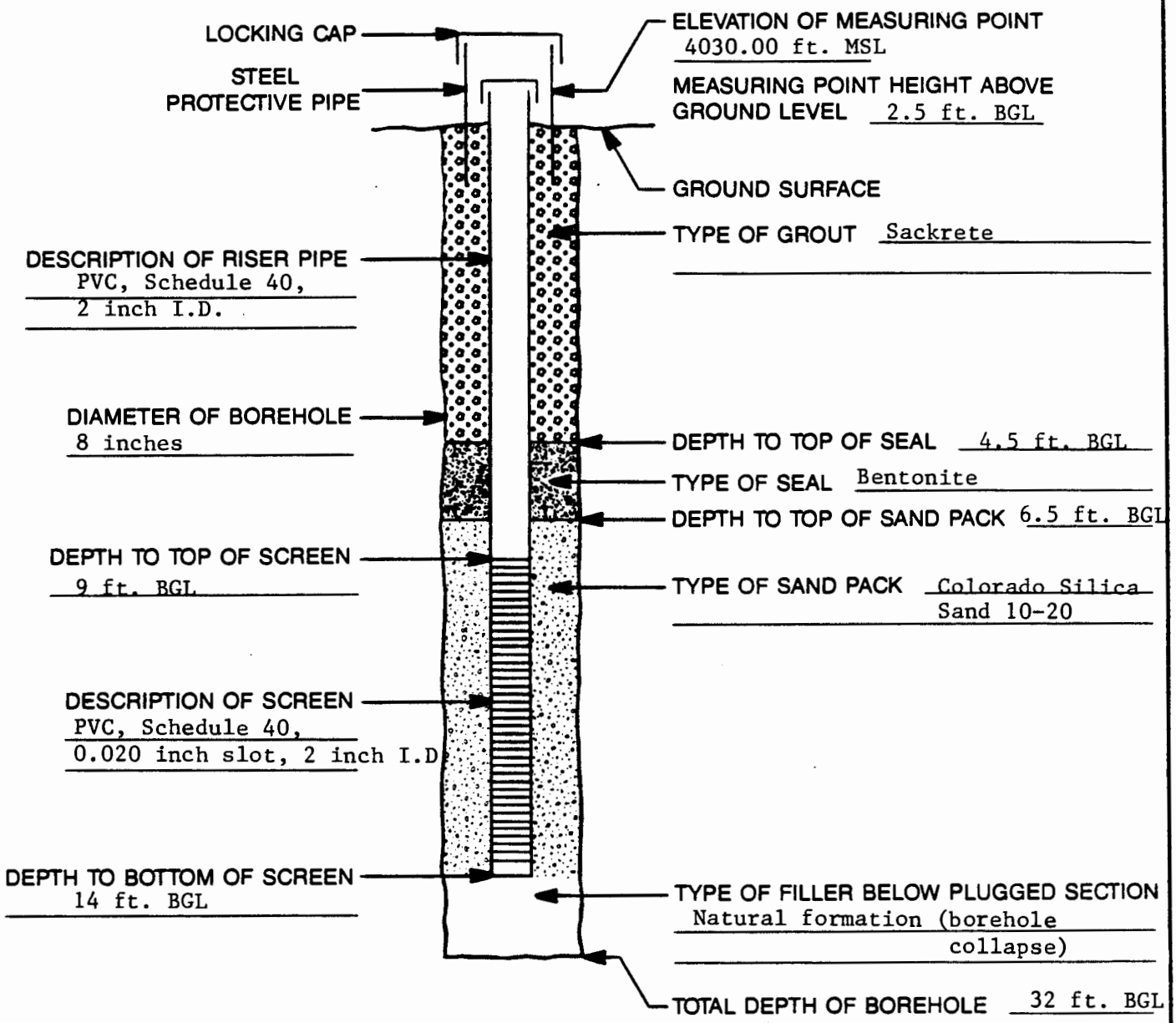
WELL NO. S-9
AQUIFER Shallow
DEPTH TO WATER 12 ft. BGL



WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 539544.9966, y = 657713.5806
DATE COMPLETED 2 October 1987
SUPERVISED BY Gary Henderson
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

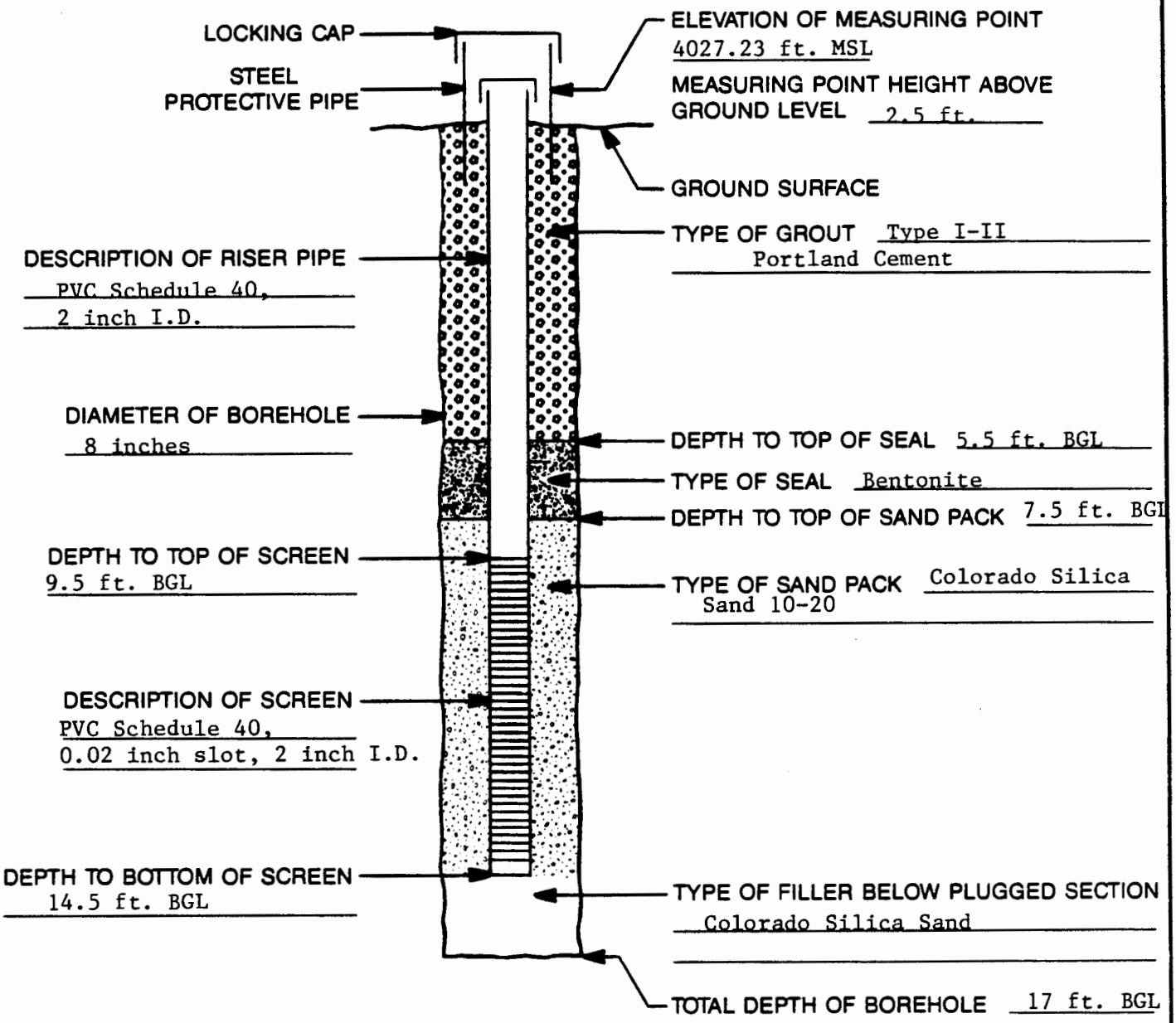
WELL NO. S-10
AQUIFER Shallow
DEPTH TO WATER 8 ft. BGL



WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 541772.1089, y = 660788.5884
DATE COMPLETED 24 September 1987
SUPERVISED BY Heidi Tomich
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. S-11
AQUIFER Shallow
DEPTH TO WATER 10 ft. BGL

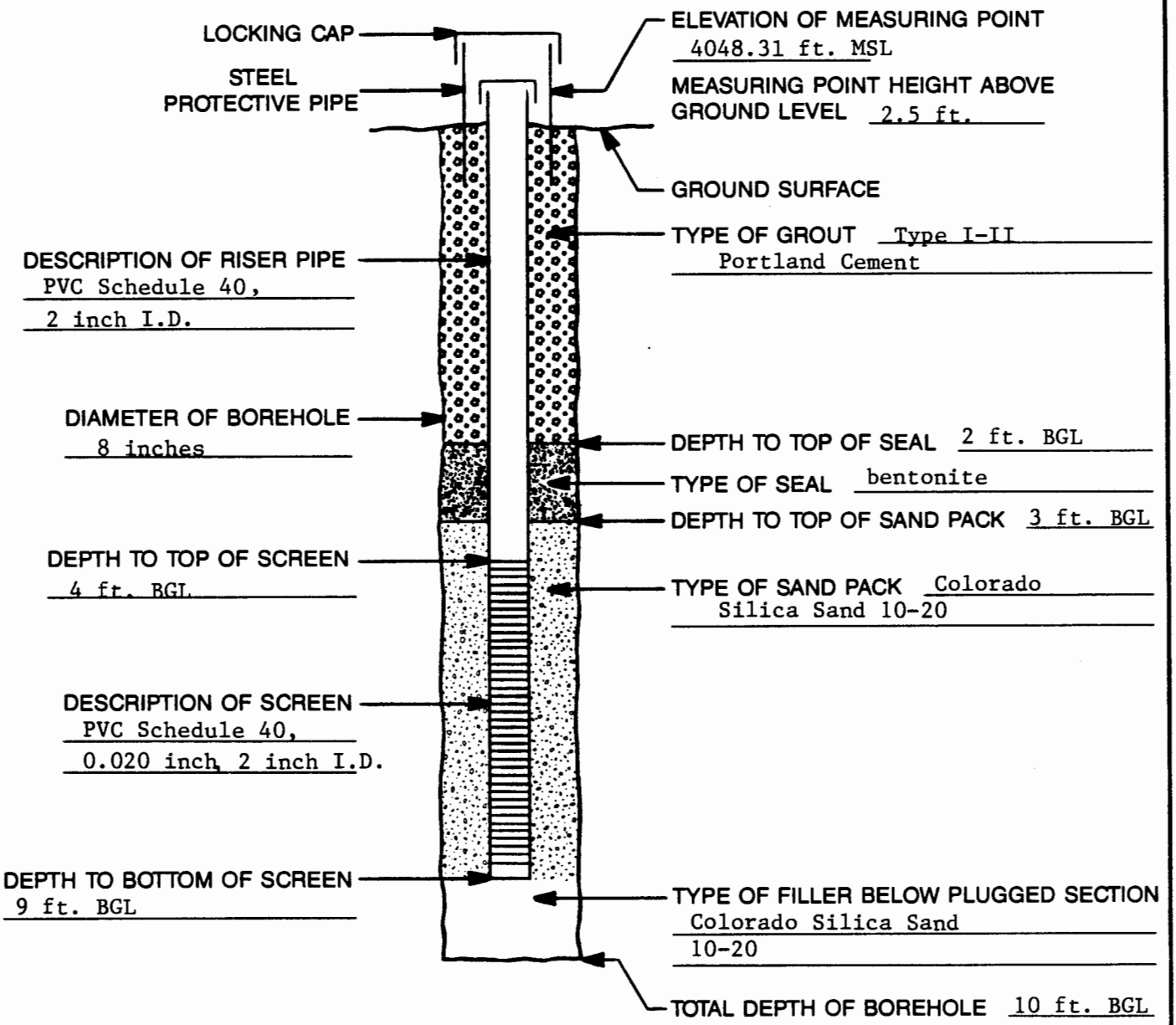


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

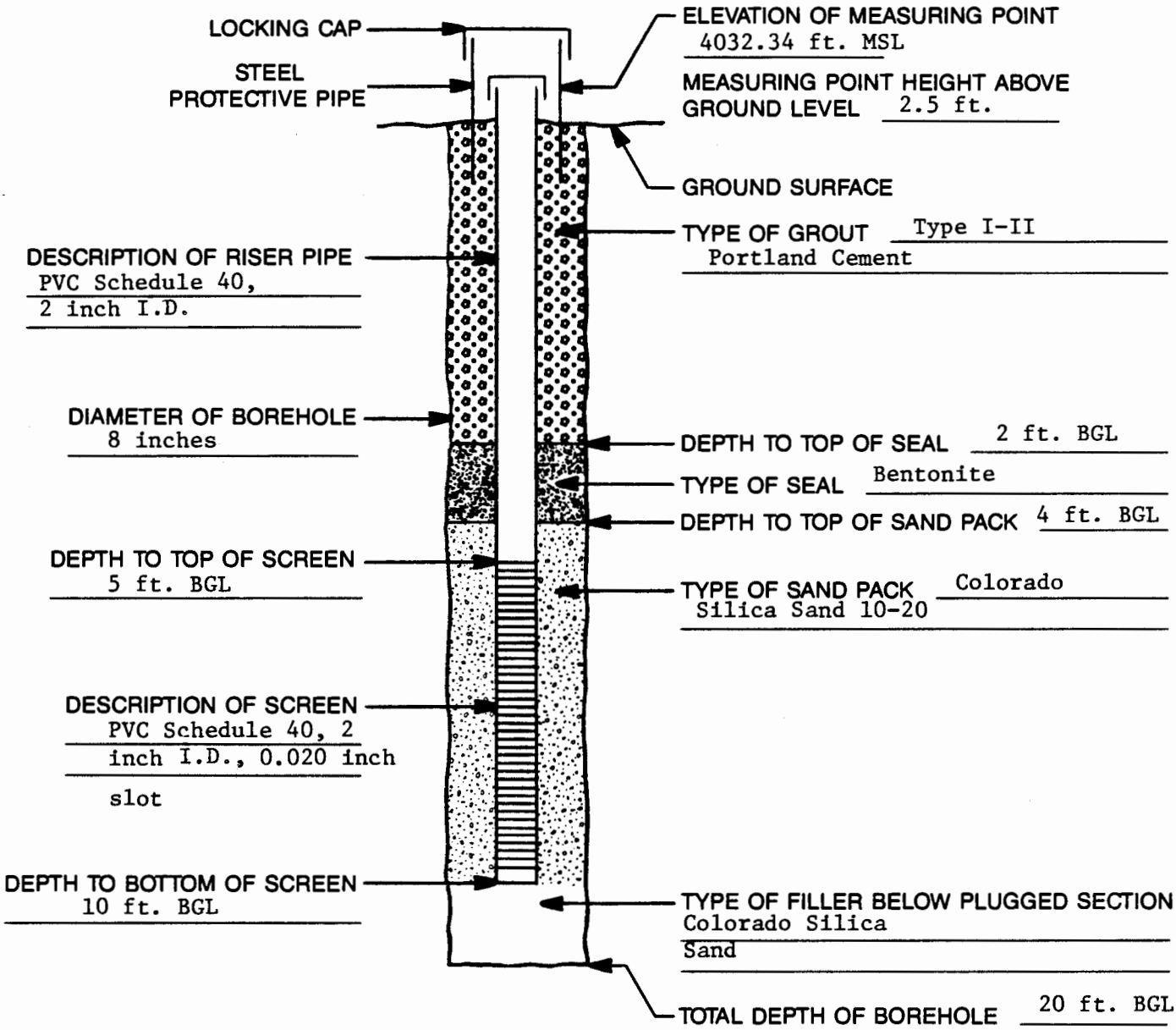
PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 547576.0190, y = 665999.0471
DATE COMPLETED 11 August 1987
SUPERVISED BY Wendy Rozacky
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. S-12
AQUIFER Shallow
DEPTH TO WATER 4 ft. BGL



WELL CONSTRUCTION SCHEMATIC

PROJECT	Holloman AFB Hydrogeologic Investigation	WELL NO.	S-13
SITE	Holloman AFB, New Mexico		
COORDINATES	x = 544352.8779, y = 661961.1260	AQUIFER	Shallow
DATE COMPLETED	3 September 1987		
SUPERVISED BY	Wendy Rozacky	DEPTH TO WATER	5 ft. BGL
DRILLER	Kingsley/Winnek, Inc.		
DRILLING METHOD	Hollow Stem Auger		

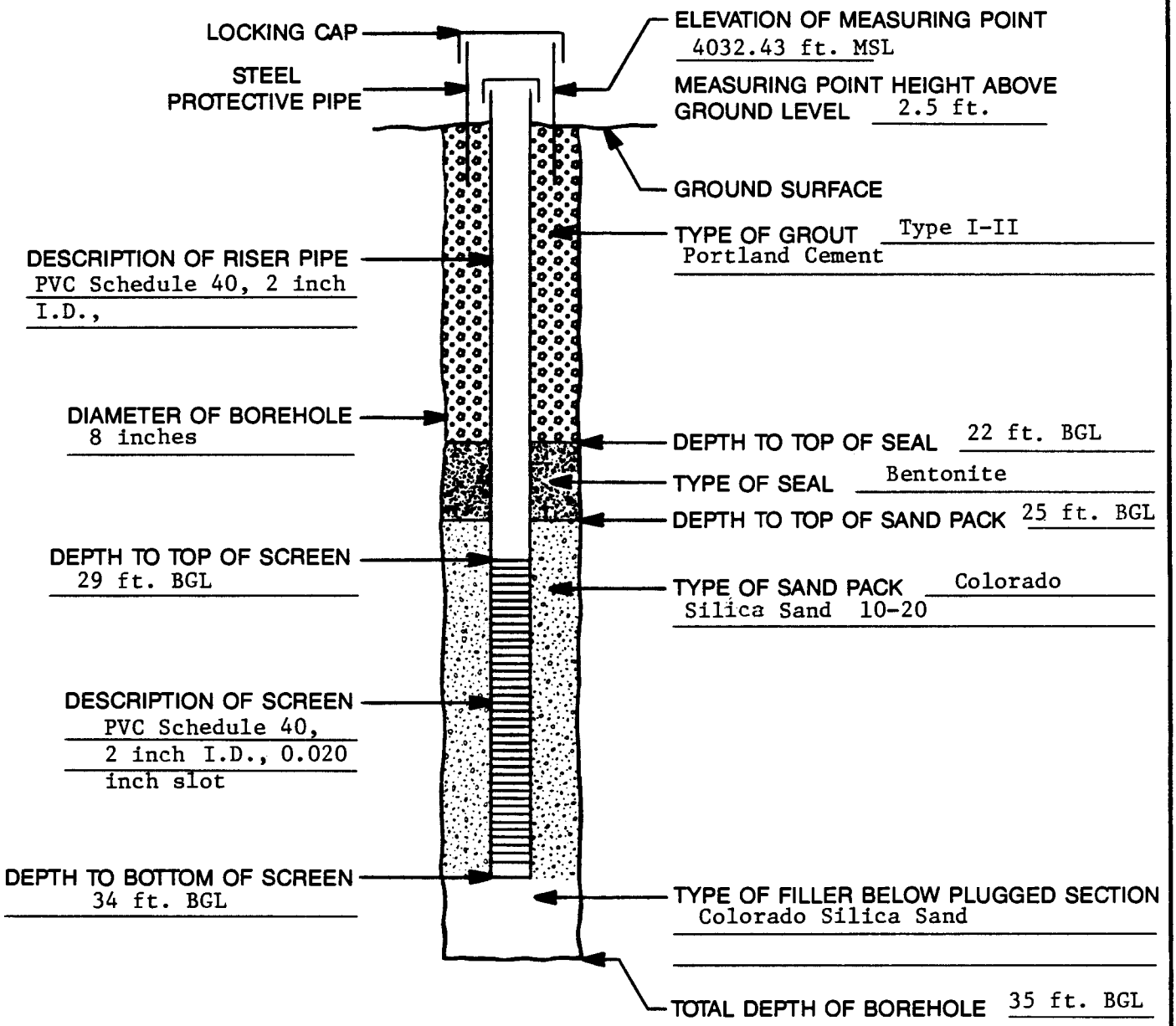


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 544338.7419, y = 661960.5151
DATE COMPLETED 3 September 1987
SUPERVISED BY Wendy Rozacky
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow Stem Auger

WELL NO. S-14
AQUIFER Shallow
DEPTH TO WATER 5 ft.

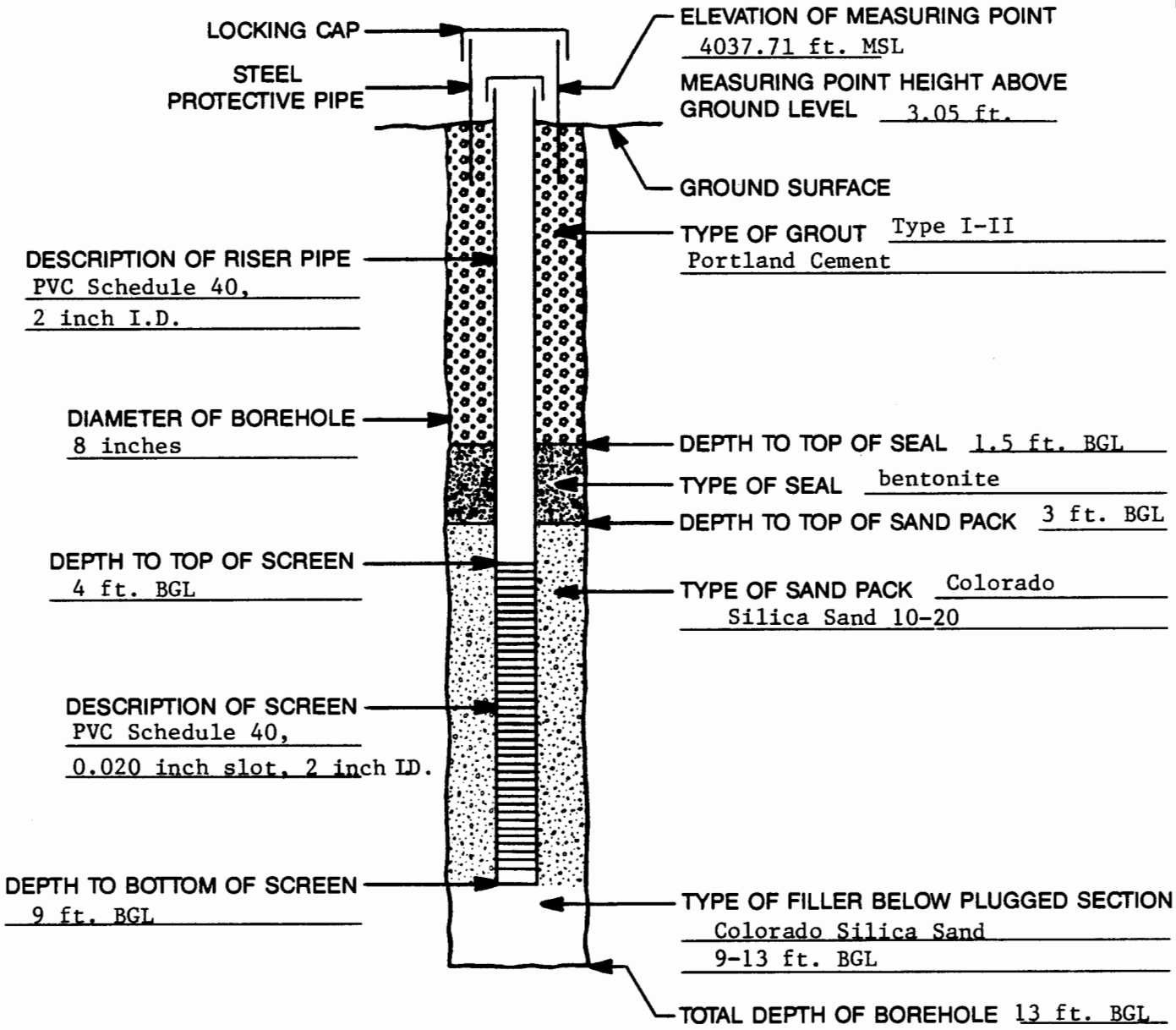


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 544342.8579, y = 664406.4341
DATE COMPLETED 20 August 1987
SUPERVISED BY Gary Henderson
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

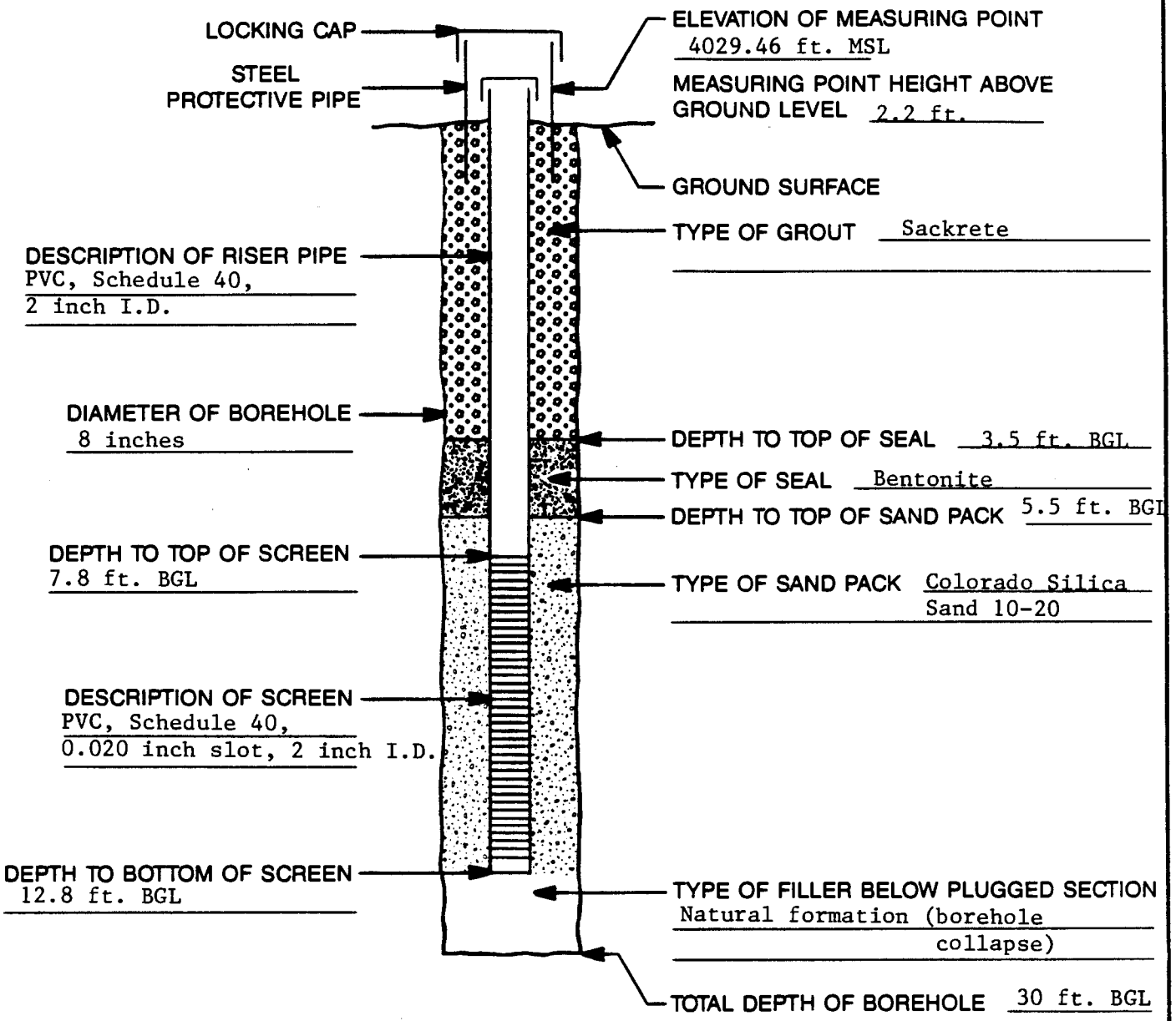
WELL NO. S-15
AQUIFER Shallow
DEPTH TO WATER 1 ft. BGL



WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 537775.8562, y = 659637.6125
DATE COMPLETED 3 October 1987
SUPERVISED BY Gary Henderson
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. S-16
AQUIFER Shallow
DEPTH TO WATER 7 ft. BGL

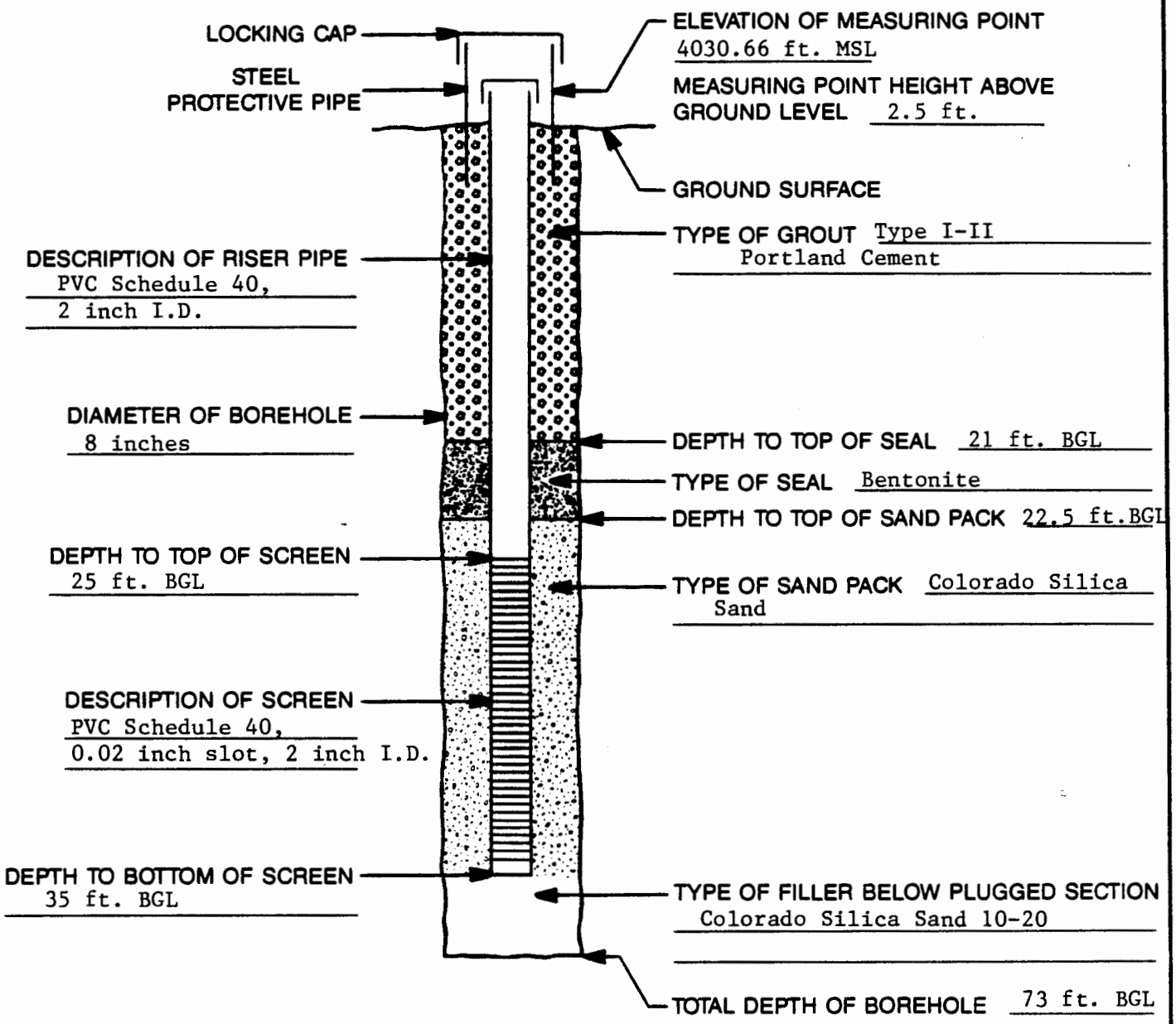


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, NM
COORDINATES x = 540864.6750, y = 663846.2849
DATE COMPLETED 23 September 1987
SUPERVISED BY Heidi Tomich
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

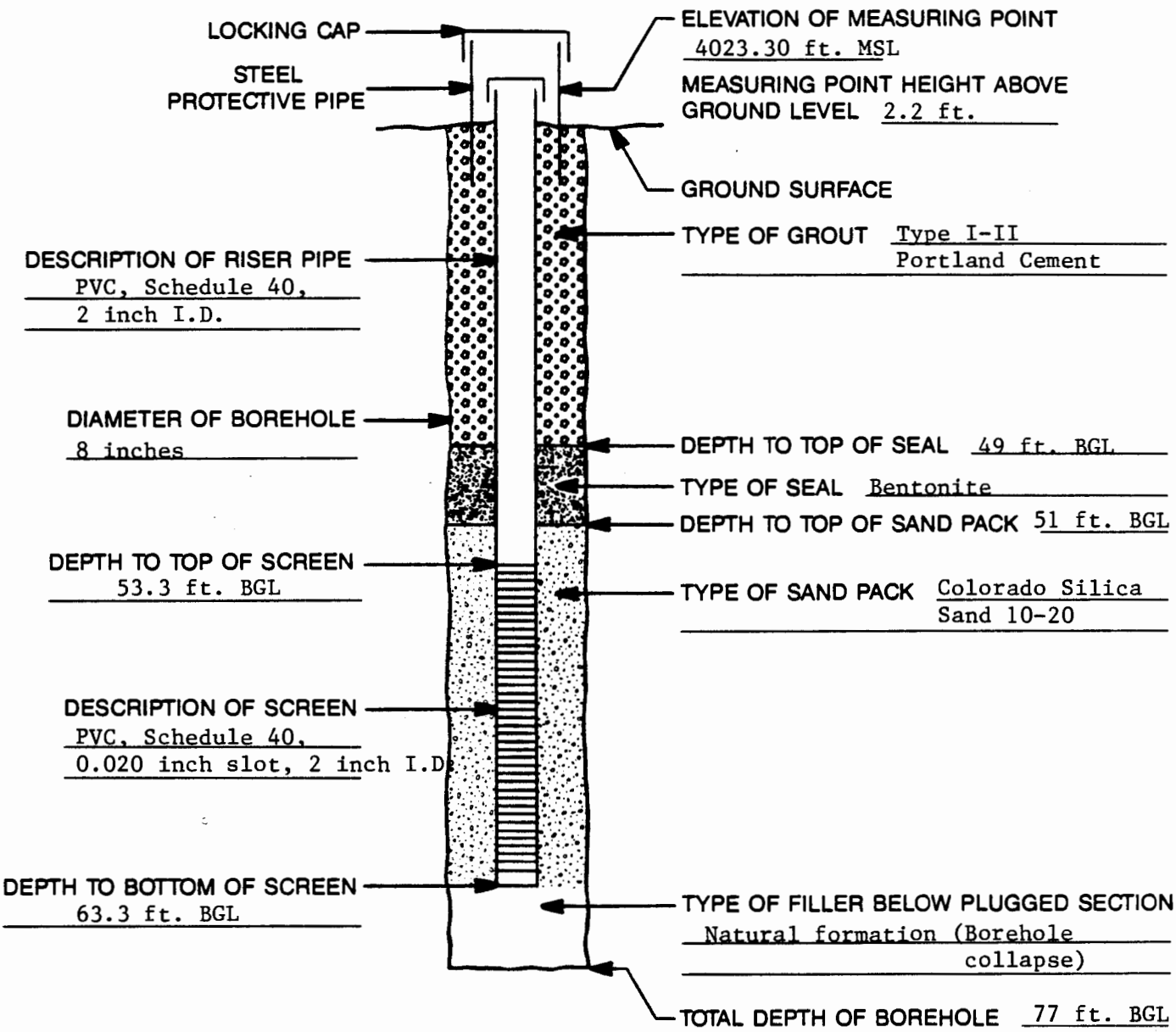
WELL NO. D-1
AQUIFER Deep
DEPTH TO WATER 4.45 ft. BGL



WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 542460.0840, y = 658545.0017
DATE COMPLETED 1 October 1987
SUPERVISED BY Gary Henderson
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

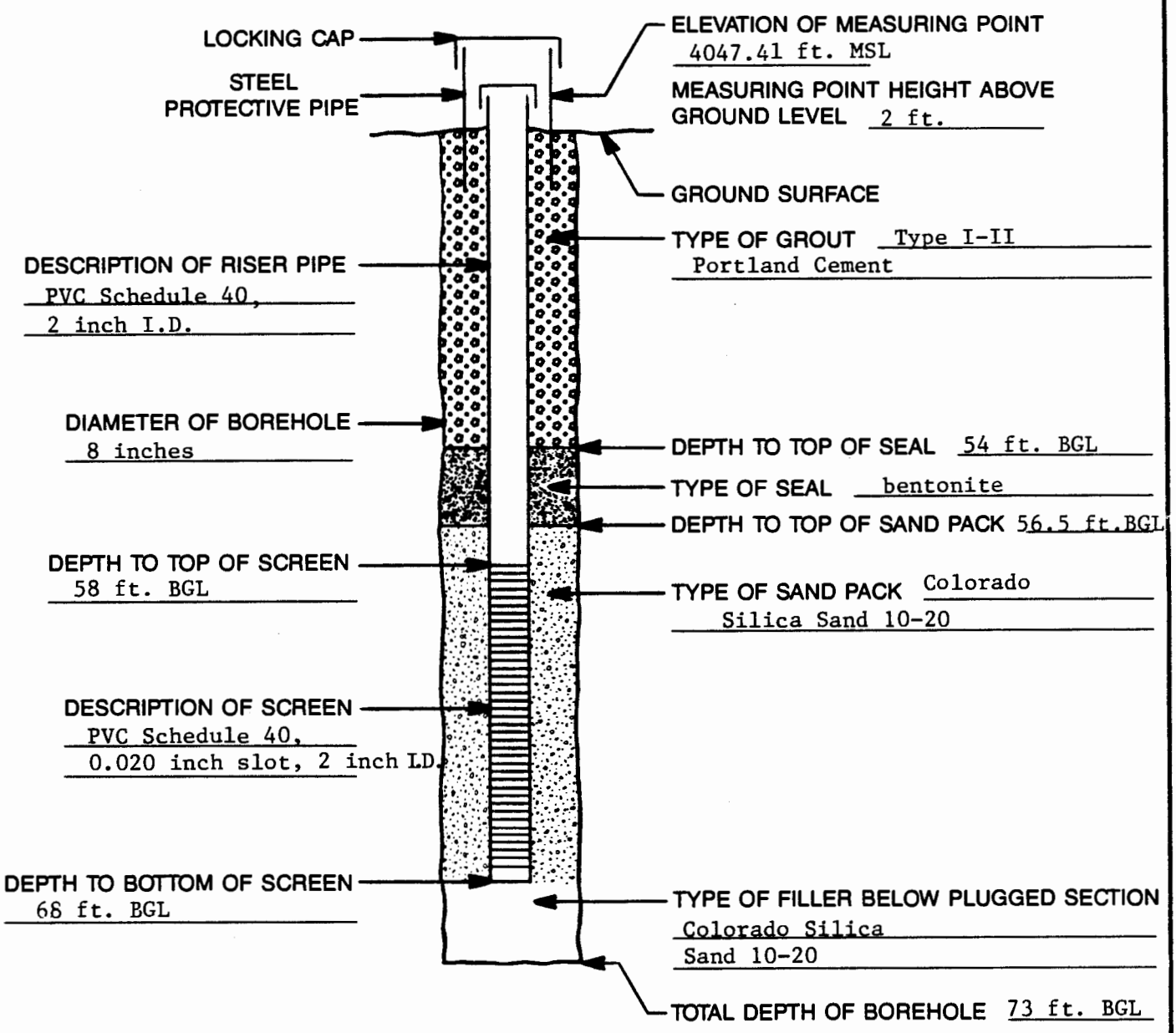
WELL NO. D-2
AQUIFER Deep
DEPTH TO WATER ~5 ft. BGL



WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 547567.4360, y = 665970.8721
DATE COMPLETED 8 August 1987
SUPERVISED BY Toby Walters/Wendy Rozacky
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. D-3
AQUIFER Deep
DEPTH TO WATER 4 ft. BGL

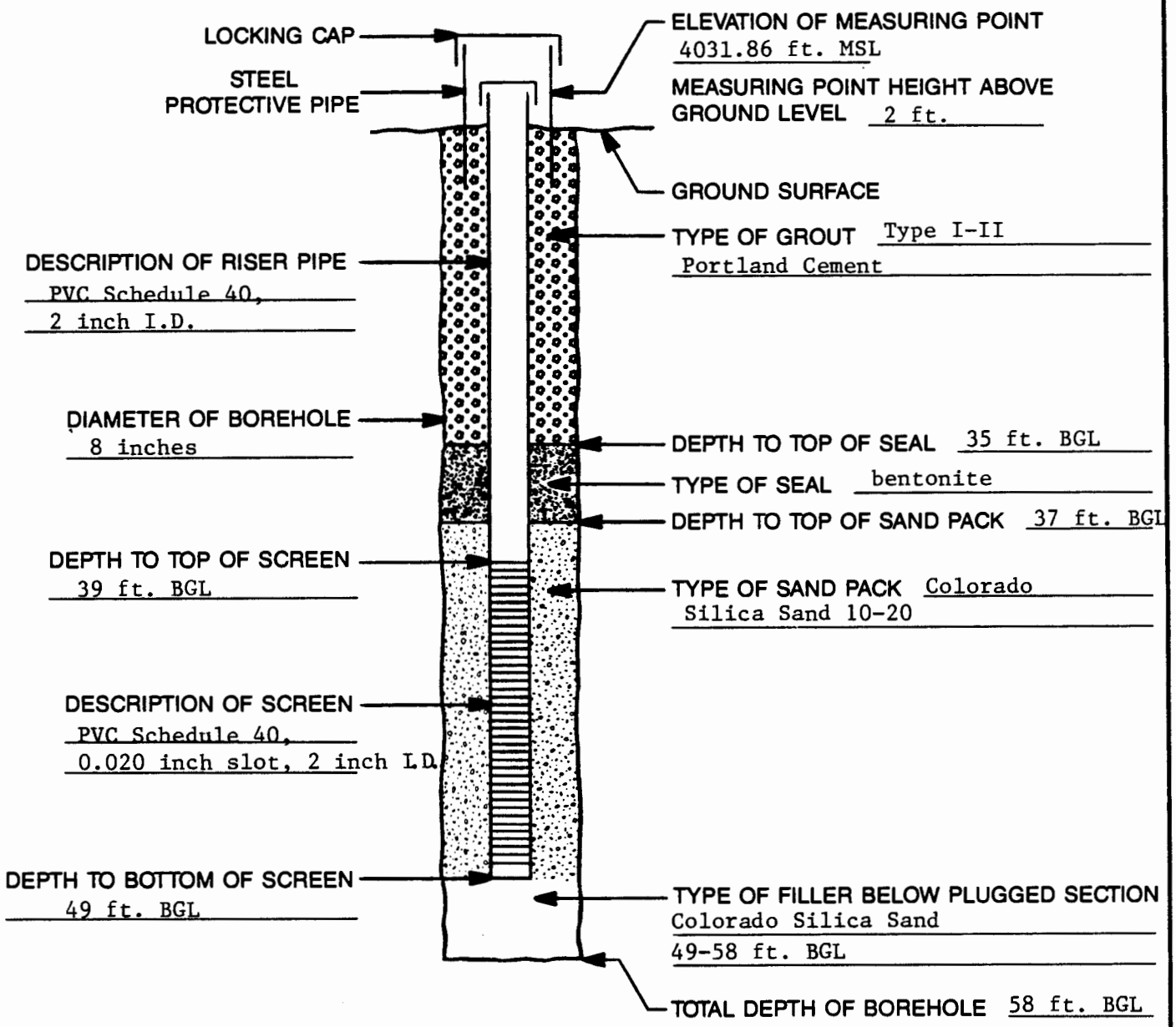


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 544323.0769, y = 661959.6260
DATE COMPLETED 23 August 1987
SUPERVISED BY Gary Henderson
DRILLER Kingsley/Winnek Inc.
DRILLING METHOD Hollow stem auger

WELL NO. D-4
AQUIFER Deep
DEPTH TO WATER 8 ft. BGL

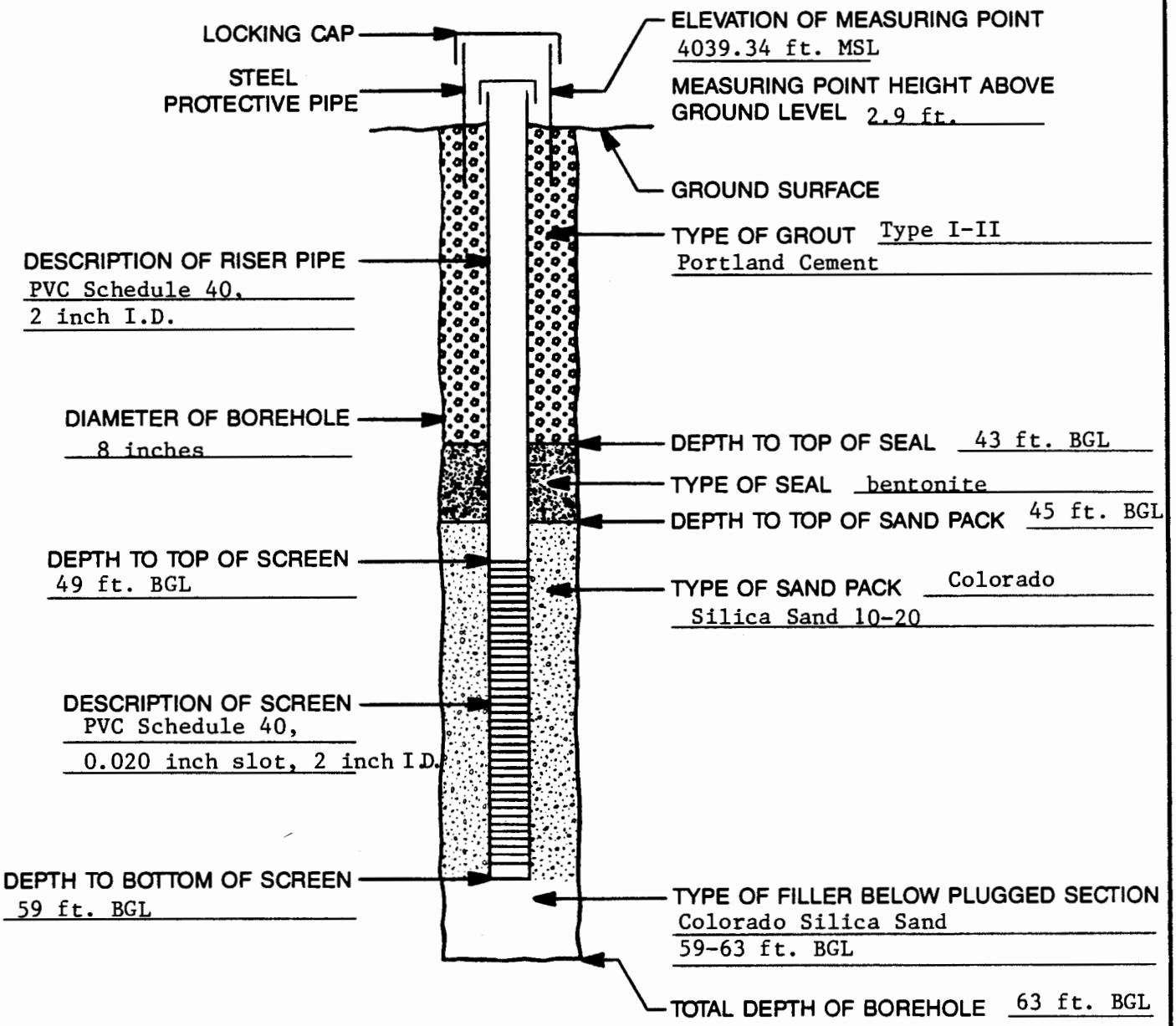


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 544355.8010, y = 664707.9622
DATE COMPLETED 20 August 1987
SUPERVISED BY Gary Henderson
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. D-5
AQUIFER Deep
DEPTH TO WATER 1 ft. BGL

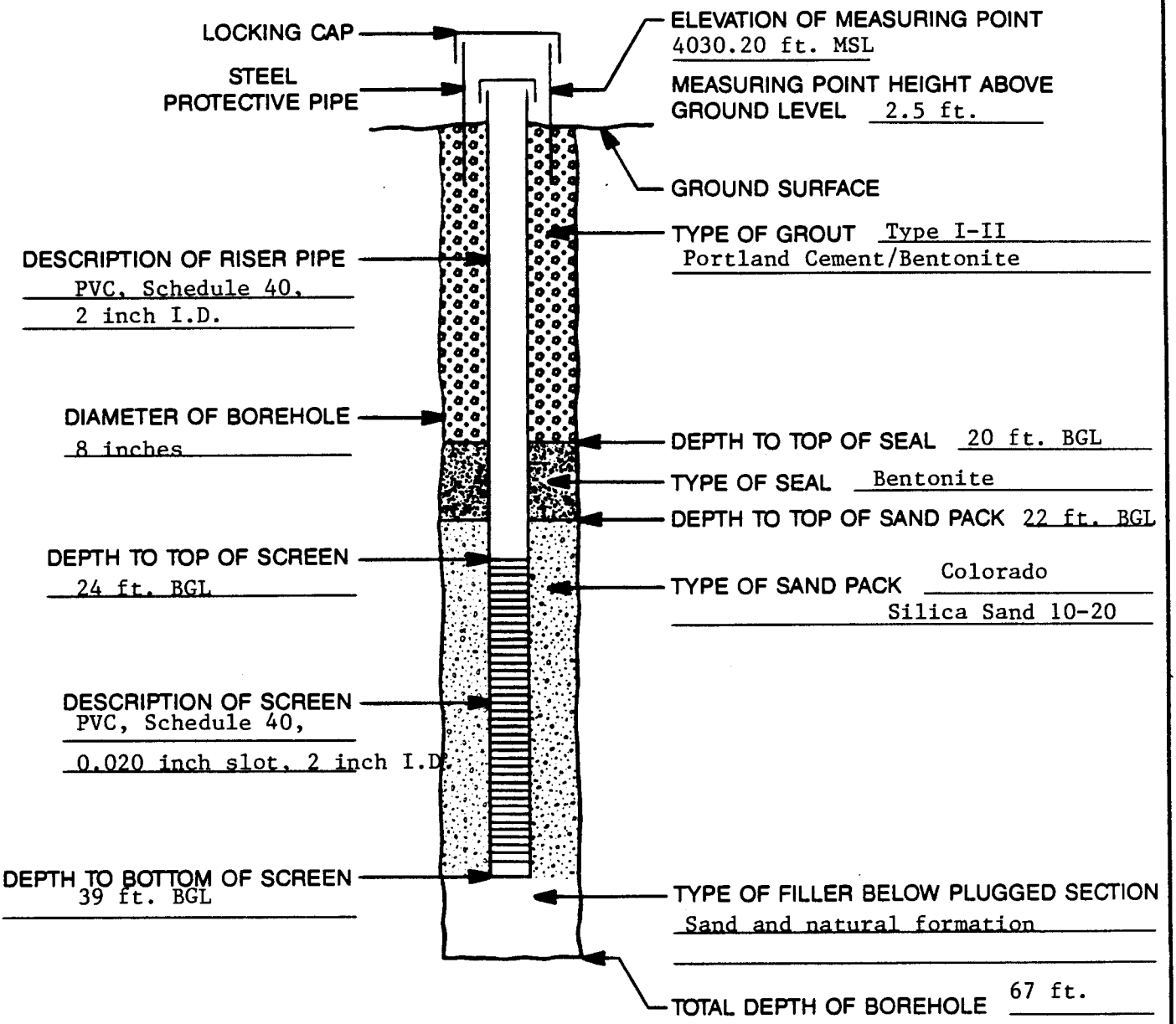


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 537661.0452, y = 659274.1448
DATE COMPLETED 6 October 1987
SUPERVISED BY Gary Henderson
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. D-6
AQUIFER Deep
DEPTH TO WATER 8 ft. BGL

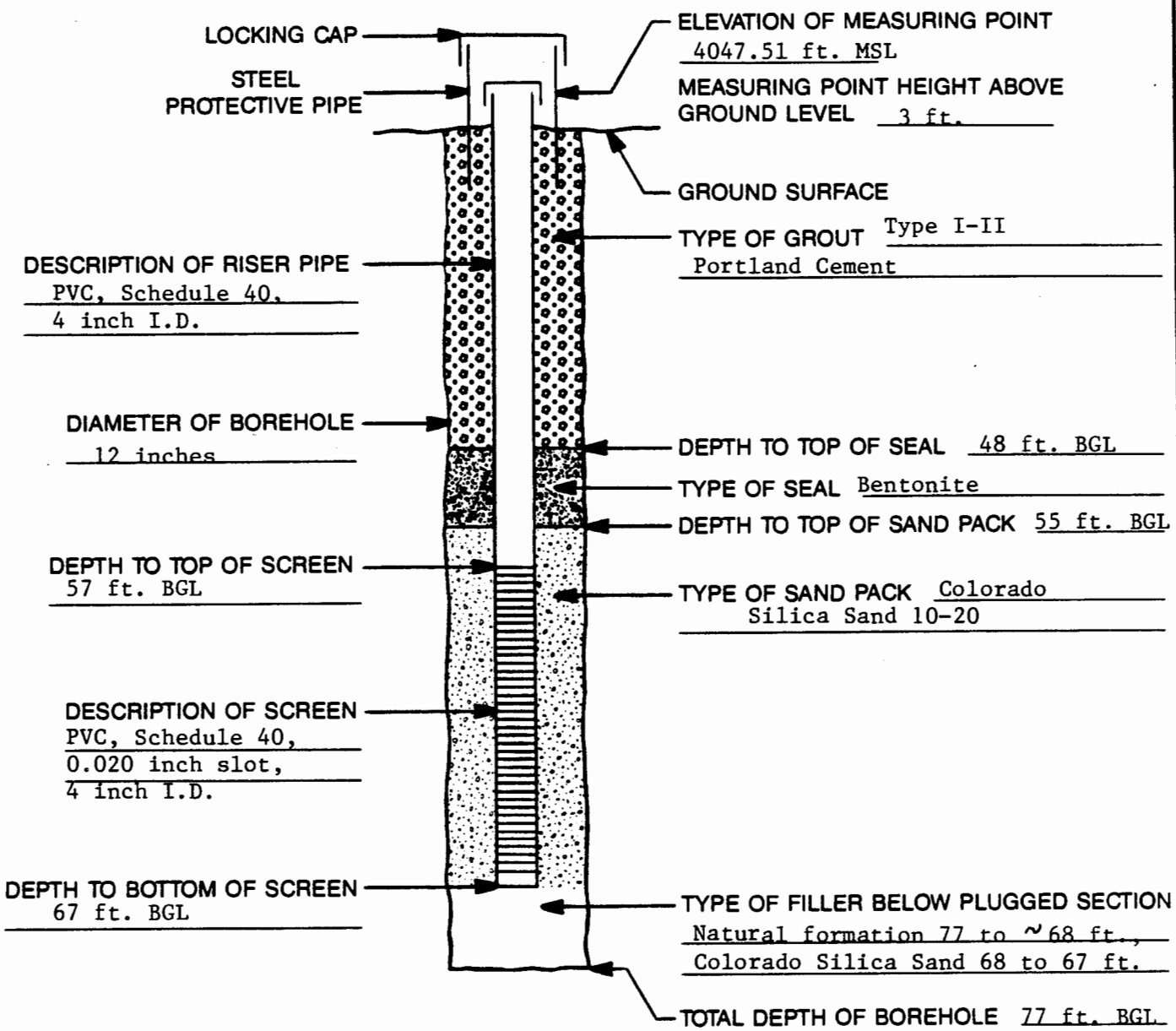


D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 547500.0391, y = 666007.6208
DATE COMPLETED 17 October 1987
SUPERVISED BY Wendy Rozacky
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. P-1
AQUIFER Deep
DEPTH TO WATER 4 ft. BGL



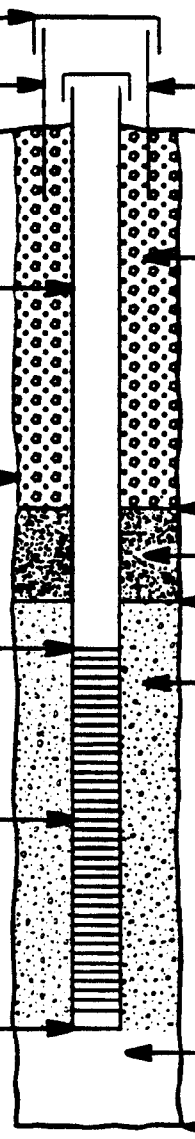
NOTE: While pulling out augers, borehole collapsed from 55 to 50 ft. BGL above sand pack. Bentonite seal is from 50 to 48 ft. BGL.

D87 - 1240A

WELL CONSTRUCTION SCHEMATIC

PROJECT Holloman AFB Hydrogeologic Investigation
SITE Holloman AFB, New Mexico
COORDINATES x = 544350.0620, y = 661861.4221
DATE COMPLETED 15 October 1987
SUPERVISED BY Wendy Rozacky
DRILLER Kingsley/Winnek, Inc.
DRILLING METHOD Hollow stem auger

WELL NO. P-2
AQUIFER Deep
DEPTH TO WATER 7 ft. BGL



D87 - 1240A

APPENDIX C

SOIL CHARACTERIZATION RESULTS
HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

HOLLOMAN AIR FORCE BASE

10/29/87

Boring Number	Depth (feet)	Soil Description (Unified Soil Classification)	Content (%)	LL (%)	PI (%)	Percent Passing No. 4	No. 10	No. 40	No. 200
P-1	57-59	Light brown silty sand (SM)	19.7	Non-Plastic		100.0	100.0	98.4	34.0
P-2	42-44	Reddish brown silty sand (SM)	20.9	Non-Plastic		100.0	100.0	98.9	25.0

Frank E. Barak C.E.T.

HOLLOMAN AIR FORCE BASE

Boring Number	Depth (feet)	Soil Description (Unified Soil Classification)	Content (%)	LL (%)	PI (%)	Percent Passing No. 4	No. 10	No. 40	No. 200
D-1	28-30	Gray to light brown clayey sand (SC)	26	24	12	100.0	100.0	94.4	49.9
D-1	38.75-40	Light brown & reddish brown sandy clay (CL)	26	36	20	97.9	95.2	93.5	79.8
S-5	8-10	Light brown sandy silt (ML)	35	20	NP	100.0	100.0	96.9	52.4
S-5	13-15	Reddish brown silty clay (CL)	27	42	16	99.6	98.6	92.4	78.5
S-6	8-10	Light brown sandy clay (CL)	40	27	8	100.0	98.7	96.6	69.6
S-6	45-47	Reddish brown sandy clay (CL)	31	36	18	100.0	99.7	95.1	69.9
S-8	18-19	Light brown sandy clay (CL)	38	32	9	100.0	97.6	94.6	57.4
S-8	19-21	Light brown to reddish brown sandy clay (CL)	33	33	14	92.8	88.8	83.4	66.1
S-11	13-14.5	Light brown sandy clay (CL)	34	31	13	99.2	98.3	92.6	70.2
S-11	17-19	Reddish brown silty sand with calcide or gypsum fragments (SM)	28	38	19	96.6	88.1	77.2	45.7

Boring Number	Depth (feet)	Soil Description (Unified Soil Classification)	Content (%)	LL (%)	PI (%)	Percent Passing No. 4	No. 10	No. 40	No. 200
D-3	63-63.9	Reddish brown & gray clayey sand (SC)	25	29	10	100	100	99	48
D-3	68-70	Gray sandy clay (CH)	30	52	30	100	100	99	69
D-4	43-44	Reddish brown silty sand (SM)	20	Non-Plastic		99	99	78	13
D-4	56-58	Light reddish brown & gray sandy clay (CL)	24	43	24	100	97	96	51
D-5	53-54.5	Reddish brown silty clayey sand (SC-SM)	21	25	7	100	100	97	39
S-1	11-12	Light reddish brown silty sand (SM)	28	39	5	88	79	68	38
S-1	13-15	Light gray clayey sand (SC)	16	48	24	93	79	68	40
S-2	9-11	Light reddish brown sandy silt (ML)	39	Non-Plastic		100	99	81	64
S-2	23-25	Reddish brown sandy clay (CL)	21	33	15	95	78	67	52
S-3	3-5	Light reddish brown silty sand (SM)	22	Non-Plastic		98	96	91	33
S-3	10-12	Light gray sandy clay (CL)	17	37	15	97	88	73	59
S-4	8-10	Light reddish brown & gray silty sand with gravel (SM)	34	Non-Plastic		86	70	60	27
S-4	18-20	Reddish brown sandy clay (CL)	28	39	19	89	80	74	65
S-12	3-5	Light reddish brown silty sand (SM)	16	Non-Plastic		100	98	92	37
S-12	10-12	Reddish brown sandy clay (CL)	18	38	12	95	84	72	54
S-15	4-5	Light brown & gray silty sand (SM)	17	Non-Plastic		100	99	91	33
S-15	10-12	Reddish brown sandy clay (CL)	16	31	15	87	81	77	56

Boring Number	Depth (feet)	Soil Description (Unified Soil Classification)	Content (%)	LL (%)	PI (%)	Percent Passing No. 4	No. 10	No. 40	No. 200
D-2	52-54	Reddish brown sand with silt (ML)	21	Non-Plastic		100.0	100.0	99.9	74.5
D-2	67-69	Light gray and reddish brown clayey find sand (CH)	28.1	50	33	100.0	100.0	100.0	80.5
D-6	24-26	Light brown clay (CL)	27.9	48	27	100.0	100.0	98.4	90.8
D-6	32-34	Light brown clayey fine sand (SC)	26.9	25	8	98.4	97.7	82.9	19.9
D-6	67-68.3	Light brown clayey sand (SC)	22.0	Non-Plastic		100.0	100.0	97.5	19.3
S-7	17-19	Light brown silty clay with calcicide or gypsum nodules (CL)	29.2	41	22	99.0	92.5	85.9	67.1
S-9*	12-14	Light brown clayey silt with a cementatious product (--)	14.0	Not Obtainable		98.7	96.8	92.1	44.8
S-9	24-26	Gray clay (CL)	34.1	41	25	100.0	100.0	100.0	89.4
S-10**	12-24	Light brown clayey silt with a cementatious product (--)	33.9	Not Obtainable		100.0	98.2	93.7	69.8
S-10	27-29	Light brown, yellow and gray silty clay (CH)	41.7	55	33	100.0	100.0	100.0	95.0
S-16***	12-14	Light brown clayey silt with a cementatious product (--)	36.6	Not Obtainable		100.0	98.9	86.3	43.3
S-16	32-33.5	Yellowish brown clayey sand (CL)	30.8	36	20	100.0	100.0	98.9	64.8

* Sample S-9 (12-14′) has a cementatious product that causes sample to set-up before Atterberg Limit could be performed. Three individual attempts were made. Gradation results are questionable.

** Sample S-10 (12-14′) has the same results as S-9, but not as severe. Result is still questionable.

*** Sample S-16 (12-14′) is the same as S-9 and S-10. Sample went from 12 blows liquid limit to below plastic limit in less than 2 minutes. Gradation results are still questionable.

APPENDIX D

SURVEYED LOCATIONS FOR PIEZOMETERS INSTALLED DURING HYDROGEOLOGIC INVESTIGATION HOLLOMAN AFB, NEW MEXICO

DANIEL ENGINEERING COMPANY
REGISTERED PROFESSIONAL ENGINEERS
AND LAND SURVEYORS
Phone (505) 437-0340 • 1015 Oregon • P. O. Box 493
ALAMOGORDO, NEW MEXICO 88310

October 30,1987

RADIAN CORPORATION
COORDINATES FOR MONITORING WELLS AT HOLLOMAN AFB, NEW MEXICO
STATE PLANE COORDINATE SYSTEM

WELL DESIGNATION	ELEVATIONS GROUND	ELEVATIONS CASING	STATE PLANE COORDINATES NORTH	STATE PLANE COORDINATES EAST
S-3	4040.93	4042.66	666310.2590	544339.4419
D-3	4045.48	4047.41	665970.8721	547567.4360
S-12	4046.01	4048.31	665999.0471	547576.0190
P-1	4045.09	4047.51	666007.6208	547500.0391
S-1	4038.99	4041.72	664038.3872	547227.8560
D-5	4036.86	4039.34	664707.9622	544355.8010
S-15	4034.86	4037.71	664406.4341	544342.8579
D-1	4028.34	4030.66	663846.2849	540864.6750
S-5	4031.32	4033.47	662360.6421	543989.3052
S-13	4030.05	4032.34	661961.1260	544352.8779
S-14	4030.20	4032.43	661960.5151	544338.7419
D-4	4030.19	4031.86	661959.6260	544323.0769
P-2	4030.25	4032.11	661861.4221	544350.0620
S-4	4031.49	4034.46	662213.6641	544926.5640
S-2	4037.99	4040.56	662911.0500	547271.0679
S-11	4025.17	4027.23	660788.5884	541772.1089
D-2	4021.37	4023.30	658545.0017	542460.0840
S-10	4027.85	4030.00	657713.5806	539544.9966
S-9	4018.42	4020.67	655436.2842	537626.7751
S-16	4027.46	4029.46	659637.6125	537775.8562
D-6	4027.98	4030.20	659274.1448	537661.0452
S-8	4031.02	4033.15	660347.1843	539393.4084
S-7	4028.22	4030.24	662546.2710	538199.1724
S-6	4029.44	4031.52	663611.0007	539431.6543

APPENDIX E

LITHOLOGIC LOGS OF BOREHOLE DATA COLLECTED DURING HYDROGEOLOGIC INVESTIGATION HOLLOMAN AFB, NEW MEXICO

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 1 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: S-1
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 17 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 6; ST = shelby tube; Grab 2
11. ELEVATION GROUND WATER: 4034.92 ft MSL (11/17/87)
12. DATE HOLE STARTED: 8/10/87 COMPLETED: 8/11/87
13. ELEVATION TOP OF HOLE: 4038.99 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			2, 3, 4, 7	SS	Silt: dark brown to light brown to tan, minor gypsum, moist	ML	
3			8,15,22,35	SS	Silt: tan, some gypsum, dry	ML	OVA = 2.5/2.5 ppm at 3 ft.
5			10,18,22,30	SS	Silt: tan to light reddish-brown, with gypsum, dry	ML	
7				Grab	Silt: sandy, wet	SM	
8			20,43,68,	SS	Silt: greenish-tan, with gypsum, dry	ML	
11		S-1(11-12)		Grab	Sand: light reddish-brown, silty, wet	SC	
13		S-1(13-15)	15,20,12,10	SS	Clay and sand: clay, silty, greenish-tan, abundant gypsum crystals, very moist to wet with interbedded sand, light gray, clayey	CL/SC	OVA = 3.0/2.5 ppm at 15 ft.
15				SS	Sand: light brown to dark reddish-brown, quartzose, fine- to medium- to coarse-grained, with gypsum crystals, at 16 ft. - abundant dark minerals, arkosic, saturated	SM	Last split spoon from 15 to 17 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 2 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: S-2
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 25 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 9; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4031.37 ft MSL (11/17/87)
12. DATE HOLE STARTED: 8/17/87 COMPLETED: 8/17/87
13. ELEVATION TOP OF HOLE: 4037.99 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			3, 4, 5,10	SS	Silt: brown, organic near top, some very fine-grained sand, trace clay, moist to dry	OL/ML	
3			5,10,15,17	SS	Silt: brown, clayey, slightly sandy, trace gypsum, trace organics, trace dark accessory minerals, moist to dry	ML	OVA = 2.5/2.5 ppm at 3 ft.
5			7,10,11,12	SS	Silt: brown, clayey, some very fine-grained sand, some gypsum, trace dark accessory minerals, trace organics, damp in places	ML	OVA = 2.5/2.5 ppm at 7 ft.
7			9,15,21,31	SS	Sand: brown, quartzose, very fine-grained, poorly sorted, silty, clayey, trace dark accessory minerals, moist	SM	OVA = 2.5/2.5 ppm at 9 ft.
9		S-2(9-11)	95,15,21,31	SS	Silt: light reddish-brown, sandy, (sand is very fine-grained), slightly clayey, some gypsum, wet to saturated	ML	
11			13,33,44,52	SS	Sand: very fine-grained, moderately well sorted, some gypsum, trace organics, more silt and clayey 12 to 13 ft.	SM	
15				SS	Sand: brown, very fine-grained, clayey, silty, moist	SC	
18				SS	Clay: white to pale greenish-tan, abundant gypsum crystals (25 to 50%), friable, damp	CL	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 2 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 9 ST = shelby tube Grab	
3. DRILLING AGENCY: Winnek Inc.			
4. HOLE NO.: S-2		11. ELEVATION GROUND WATER: 4031.37 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 8/17/87	COMPLETED: 8/17/87
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.		13. ELEVATION TOP OF HOLE: 4037.99 ft MSL	
		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 25 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
23		S-2(23-25)		SS	Clay: white to pale greenish-tan (23 to 23.25 ft.), reddish-brown, sandy, with gypsum crystals, moist (23.25 to 24.75 ft.)	CL	Last split spoon from 23 to 24.75 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 1 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: S-3
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 12 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 4; ST = shelby tube; Grab 1
11. ELEVATION GROUND WATER: 4034.60 ft MSL (11/17/87)
12. DATE HOLE STARTED: 8/5/87 COMPLETED: 8/5/87
13. ELEVATION TOP OF HOLE: 4040.93 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			3, 7,11, 9	SS	Silt: brown, with gypsum, ranging to white silty sand, very moist	ML/SM	
3		S-3(3-5)	4, 6, 8,12	SS	Sand: quartzose, very fine-grained, well sorted, light tan, silty, trace dark accessory minerals, saturated	SM	OVA = 0/0 ppm at 3 ft.
6				Grab	Sand: quartzose, very fine-grained, some clay, light tan, saturated	SC	
8			4,10,15,20	SS	Clay: light tan to reddish brown, some silt and very fine-grained sand, some gypsum crystals, saturated 8 to 9 feet, dry in places from 9 to 10 feet	CL	
10		S-3(10-12)	5,10,13,19	SS	Clay: light gray to light reddish-brown, sandy, some silt, with gypsum crystals, wet, dry in places	CL	Last split spoon from 10 to 12 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 1 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: S-4
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 20 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 6; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4025.01 ft MSL (11/17/87)
12. DATE HOLE STARTED: 8/21/87 COMPLETED: 8/21/87
13. ELEVATION TOP OF HOLE: 4031.49 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			2, 6,10, 5	SS	Silt: white to light tan, slightly clayey, some small concretions (calcarious?), moist	ML	
3			8,13,16,24	SS	Sand: brown to tan, quartzose, fine-grained, silty, slightly clayey, moist	SM	
6			15, 9, 6, 9	SS	Sand and clay: 6 to 7 ft.: sand, brown, quartzose, very fine-grained, wet; 7 to 8 ft.: clay, reddish-brown, with some sand, low to medium plasticity, moist	SP/CL	OVA = 2.4 ppm at 6 ft.
8		S-4(8-10)	25,41,49,51	SS	Sand: light reddish-brown and gray, very fine-grained, silty, clayey, some gravel, saturated	SM	Water on bit at 13 ft. OVA = 2.4/2.4 ppm at 8 ft.
13			10,21,21,18	SS	Sand: reddish-brown, very fine-grained, clayey to very clayey, silty, some gypsum crystals, less clayey and silty near bottom	SC	Water on bit at 13 ft., OVA = 2.4/2.4 ppm at 13 ft.
18		S-4(18-20)	8,10,18,19	SS	Clay: reddish-brown, sandy, with gypsum crystals, firm, plastic, moist	CL	Last split spoon from 18 to 20 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 1 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: S-5
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 17 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 5; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4023.66 ft MSL (11/17/87)
12. DATE HOLE STARTED: 9/20/87 COMPLETED: 9/21/87
13. ELEVATION TOP OF HOLE: 4031.32 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			1, 9,12,13	SS	Silt: light beige, slightly sandy, minor white weathered patches, minor dark accessory minerals, moderately cohesive, slightly moist to moist	ML	
3			16,12, 9, 9	SS	Silt and sand: 3 to 4 ft.: silt, light beige, slightly sandy, minor dark accessory minerals, moderately cohesive, moist; 4 to 5 ft.: sand, quartzose, tan, very fine-grained, very silty, minor dark accessory minerals, slightly cohesive, moist to wet (wet at very bottom)	ML/SM	
8		S-5(8-10)	36,54,36,26	SS	Silt: light brown, sandy, sand is fine-grained, slightly cohesive, wet	ML	
13		S-5(13-15)	7,13,17,17	SS	Clay: reddish-brown, slightly to moderately silty in zones, 5 to 10% gypsum crystals, moderately stiff, non-plastic, slightly moist	CL	
15			4, 5, 9,12	SS	Clay: reddish-brown, slightly silty, sandy in one 0.3' zone, minor gypsum, moderately stiff, non-plastic, slightly moist to moist	CL	Last split spoon from 15 to 17 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 3 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 12 ST = shelby tube Grab	
3. DRILLING AGENCY: Winnek Inc.			
4. HOLE NO.: S-6		11. ELEVATION GROUND WATER: 4019.31 ft MSL (11/16/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 9/23/87	COMPLETED:
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.		13. ELEVATION TOP OF HOLE: 4029.44 ft MSL	
		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 47 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			4,11,16,17	SS	Silt: light tan, slightly sandy, minor dark accessory minerals, slightly cohesive to loose, dry	ML	OVA = 0.25/0.25 ppm at 2 ft.
3			13,17,18,18	SS	Sand: light tan, very fine-grained, slightly silty, minor dark accessory minerals, loose, dry	SM	OVA = 0.0/0.0 ppm at 5 ft.
8		S-6(8-10)	22,42,50,	SS	Silt and clay: 8 to 9 ft.: silt, light tan, with very fine-grained sand and minor dark accesssory minerals, loose to slightly cohesive, moist; 9 to 9.5 ft.: clay, tan, sandy, minor dark accessory minerals, cohesive, moist to wet	ML/CL	7-inch refusal.
13			15,21,21,24	SS	Clay: tan to light reddish-brown, silty, slightly sandy to sandy at bottom, some gypsum crystals, low plasticity, very cohesive, moist	CL	OVA = 0.5/0.5 ppm at 15 ft.
18			3, 9, 7, 6	SS	Sand: quartzose, light gray, fine-grained, well sorted, slightly to moderately clayey in zones, minor dark accessory minerals, loose, wet	SC	OVA = 0.5/0.5 ppm at 20 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 3 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 12 ST = shelby tube Grab	
3. DRILLING AGENCY: Winnek Inc.			
4. HOLE NO.: S-6		11. ELEVATION GROUND WATER: 4019.31 ft MSL (11/16/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 9/23/87 COMPLETED:	
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.		13. ELEVATION TOP OF HOLE: 4029.44 ft MSL	
		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 47 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
23			17,14, 9, 6	SS	Sand: quartzose, light gray, very fine-grained, moderately clayey at bottom, minor dark accessory minerals, loose to slightly cohesive, moist to wet	SC	OVA = 0.5/0.5 ppm at 25 ft.
28			7,17,34,50	SS	Sand: quartzose, light gray, fine-grained, well sorted, moderately rounded, slightly clayey, minor dark accessory minerals, loose to slightly cohesive, moist	SC	OVA = 0.75/0.75 ppm at 28 ft.
33			19,64, ,	SS	Sand: light gray to light reddish-gray, fine-grained, slightly clayey at ~33.5 ft., minor dark accessory minerals, loose to slightly cohesive, wet to moist	SC	Refusal at ~34 ft., OVA = 1.5/1.5 ppm at 35 ft.
38			17,15,27,38	SS	Sand: reddish-brown (gray where clayey), fine- to very fine-grained, silty, clayey in thin lenses, minor dark accessory minerals, moist	SC	OVA = 2.0/2.0 ppm at 38 ft.
40			25,51, ,	SS	Silt and sand: reddish brown, slightly to moderately clayey, some gypsum crystals (~50% to 60% at 41 to 42 ft.), cohesive, moist	ML	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 3 OF 3 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 12	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab	
4. HOLE NO.: S-6		11. ELEVATION GROUND WATER: 4019.31 ft MSL (11/16/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 9/23/87	COMPLETED:
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4029.44 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 47 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
43			30,34,24,23	SS	Silt and clay: 43 to 44 ft.: silt, slightly sandy and clayey, moist; 44 to 45 ft.: clay, brownish-red, silty, minor gypsum, low plasticity, moist	ML/CL	OVA = 0.25/0.25 at 45 ft.
45		S-6(45-47)	6, 7, 9,11	SS	Clay: brownish-red, non- to slightly silty (at 45.5 to 46.5 ft.), sandy, some small gypsum crystals, low to medium plasticity, very slightly moist	CL	Last split spoon from 45 to 47 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 1 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: S-7
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 22 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
10. NO. OF SAMPLES TAKEN: SS = split spoon 5; ST = shelby tube; Grab 1
11. ELEVATION GROUND WATER: 4017.78 ft MSL (11/16/87)
12. DATE HOLE STARTED: 10/3/87 COMPLETED: 10/3/87
13. ELEVATION TOP OF HOLE: 4028.22 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			6, 6,14,22	SS	Silt: brown, trace sand (dark grains), trace whitish pockets (gypsum grains), slightly cohesive, damp	ML	
5				Grab	Silt: light tan, minor concretions, damp	ML	OVA = 2.5/2.5 ppm at 5 ft.
7			8,32,38,41	SS	Sand: quartzose, light tan, very fine-grained, silty, trace dark accessory minerals, trace gypsum, moderately to well sorted, slightly cohesive, damp	SM	
12			2, 4,17,34	SS	Clay and sand; 12 to 13.5 ft.: clay, grayish-green, zone of gypsum, soft, calcarious; 13.5 to 14 ft.: sand, quartzose, white to light tan, moderately well sorted, sub-rounded, silty, very calcareous at top, wet	CL/SM	OVA = 2.0/2.0 ppm at 12 ft.
17		S-7(17-19)	2, 4, 4, 5	SS	Clay: light tan to light grayish-green, plastic, soft to firm, silty, abundant gypsum crystals in pockets, calcareous, moist	CL	
20			2, 6,11,13	SS	Sand: quartzose, yellowish-brown, very fine- to fine-grained, 2% dark accessory minerals, some limonite staining, thin yellowish-brown clay layer interbedded	SC	Last split spoon from 20 to 22 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 1 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: S-8
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 22 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 6; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4017.97 ft MSL (11/16/87)
12. DATE HOLE STARTED: 9/24/87 COMPLETED: 9/24/87
13. ELEVATION TOP OF HOLE: 4031.02 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			3, 6, 6, 8	SS	Silt: tan, some white weathered spots, minor dark accessory minerals, loose, dry	ML	
3			4, 9,17,21	SS	Silt: tan to beige, some gypsum granules, minor dark accessory minerals, loose to slightly cohesive, dry to slightly moist	ML	OVA = 0.5/0.5 at 5 ft.
8			9,13,13,13	SS	Sand: quartzose, tannish-brown, minor white weathered areas, very fine-grained, poorly sorted, silty, minor dark accessory minerals, slightly cohesive, moist	SM	OVA = 0.75/0.75 ppm at 10 ft.
13			7,12,15,17	SS	Sand: quartzose, tannish-brown, very fine-grained, poorly sorted, silty, slightly to moderately clayey, minor dark accessory minerals, wet	SM	OVA = 0.75/0.75 ppm at 15 ft.
18		S-8(18-19)	25,35,64,	SS	Clay: light brown to greenish-gray, sandy from 18 to 19 ft., some gypsum, wet to moist	CL	OVA = 0.75/0.75 ppm at 20 ft.
20		S-8(19-21)	12,41,38,32	SS	Clay and silt: 20 to 21 ft.: clay, gray, low plasticity, moist; 21 to 22 ft.: silt: light gray to reddish-brown, sandy, slightly moist	CL/ML	Last split spoon from 20 to 22 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 2 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 7	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab 1	
4. HOLE NO.: S-9		11. ELEVATION GROUND WATER: 4010.48 ft MSL (10/18/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 10/7/87	COMPLETED: 10/7/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4018.42 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 26 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			3, 8,14,32	SS	Silt: light brown to white, some very fine-grained sand, loose to moderately cohesive at 1.5 ft., damp	ML	
5				Grab	Silt: light brown, sandy, damp	ML	
7				SS	Silt: white, sandy (very fine-grained sand), calcareous silt lenses, damp	ML	OVA = 3.2/4.0 ppm at 7 ft.
12		S-9(12-14)	6,13,16,18	SS	Silt: light gray, sandy, 2% dark accessory minerals, trace lithics, clayey, wet to saturated	ML	OVA = 3.0/3.0 ppm at 12 ft.
17			16,45,41,28	SS	Sand and silt: 17 to 18 ft.: sand, light tan, very fine- to fine-grained, wet; 18 to 19 ft.: silt, white with limonite staining, sandy, moist	SP/ML	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 2 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 7	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab 1	
4. HOLE NO.: S-9		11. ELEVATION GROUND WATER: 4010.48 ft MSL (10/18/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 10/7/87	COMPLETED: 10/7/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4018.42 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 26 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
22		S-9(22-24)	2, 2, 2, 3	SS	Clay: light tan to light grayish-green, silty, gypsum crystals in pockets, soft, plastic, moist	CL	OVA = 2.0/2.0 ppm at 22 ft.
24		S-9(24-26)	1, 1, 2, 2	SS	Clay: grayish-green, slightly silty, soft, high plasticity, moist	CH	OVA = 2.0/2.0 ppm at 24 ft., last split spoon from 24 to 26 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 2 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: S-10
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 34 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
10. NO. OF SAMPLES TAKEN: SS = split spoon 7; ST = shelby tube; Grab 2
11. ELEVATION GROUND WATER: 4016.01 ft MSL (11/16/87)
12. DATE HOLE STARTED: 10/2/87 COMPLETED: 10/2/87
13. ELEVATION TOP OF HOLE: 4027.85 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			2, 4, 6, 8	SS	Silt: light tan to light brown, roots at top, loose, dry	OL	
3				Grab	Silt: light tan to off white, damp	ML	
5				Grab	Sand: quartzose, light tan to light brown, very fine-grained, very silty, trace dark accessory minerals, some gypsum, loose, damp	SM	
12		S-10(12-14)	1, 1, 3, 4	SS	Silt: light brown, clayey, sandy, slightly cohesive, wet to saturated	ML	
17			4, 5, 6,10	SS	Sand: quartzose with trace dark accessory minerals and lithic grains, brown, very fine- to fine-grained (fine- to coarse-grained from 18.5 to 19 ft.), slightly clayey, slightly cohesive, wet to saturated	SC	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 2 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: S-10
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 34 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
10. NO. OF SAMPLES TAKEN: SS = split spoon 7; ST = shelby tube; Grab 2
11. ELEVATION GROUND WATER: 4016.01 ft MSL (11/16/87)
12. DATE HOLE STARTED: 10/2/87 COMPLETED: 10/2/87
13. ELEVATION TOP OF HOLE: 4027.85 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
22			2, 1, 2,13	SS	Sand, silt, and clay: light grayish-green, very silty,ssoft, plastic, moist to wet clay, and dark brown, sandy, clayey, moist silt, with minor brown, fine-grained sand	ML	OVA = 7.0/7.0 ppm at 22 ft. (strong exhaust from rig)
27		S-10(27-79)	1, 1, 2, 8	SS	Clay: grayish-green and orange-brown, slightly silty, soft, plastic, some gypsum crystals, moist	CH	
32			3, 4, 4, 4	SS	Clay: grayish-green, some gypsum crystals, firm to soft, plastic, moist	CL	Last split spoon from 32 to 34 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 1 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 6	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab	
4. HOLE NO.: S-11		11. ELEVATION GROUND WATER: 4016.31 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 9/20/87	COMPLETED: 9/20/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4025.17 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 19 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			1, 4, 5, 9	SS	Silt: light tan to medium brown, organic, slightly sandy near surface, slightly cohesive, minor gypsum, slightly moist	OL	
3			5, 7,10,12	SS	Silt and clay: 3 to 4 ft.: silt, brown, moderately clayey, slightly sandy, some small gypsum crystals, slightly moist; 4 to 5 ft.: clay, brown, some orange zones, very silty, slightly sandy, non-plastic, many small gypsum crystals, moist	ML/CL	
8			14,16,32,57	SS	Sand: quartzose, light reddish-brown, very fine-grained, moderately silty to very silty, minor dark accessory minerals, minor gypsum, slightly clayey, slightly cohesive, moist to wet	SM	
13		S-11(13-14.5)	14,26,19,20	SS	Clay and silt: 13 to 14.5 ft.: clay, light gray, sandy, minor gypsum, minor dark accessory minerals, wet; 14.5 to 15 ft.: silt and clay, brownish-red, abundant gypsum crystals, non-plastic, slightly to moderately cohesive, moist	CL/ML	
17		S-11(17-19)	13,18,15,13	SS	Sand: reddish-brown, silty, 10-20% gypsum crystals, dry to slightly moist	SM	Last split spoon from 17 to 19 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 1 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: S-12
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 12 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 4; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4040.75 ft MSL (11/17/87)
12. DATE HOLE STARTED: 8/10/87 COMPLETED: 8/11/87
13. ELEVATION TOP OF HOLE: 4046.01 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			2, 3,11,11	SS	Silt: tan, minor very fine-grained sand, well sorted, wet to saturated	ML	
3		S-12(3-5)	3, 4, 4, 4	SS	Sand: tan, very fine-grained, some silt, well sorted, trace dark accessory minerals, wet to saturated	SM	OVA = 2.5/2.5 ppm at 5 ft.
8			13,28,28,40	SS	Silt and silty clay: reddish-brown, minor sand, some gypsum crystals, dry to moist	ML/CL	
10		S-12(10-12)	11,24,22,38	SS	Clay: reddish-brown, sandy, some silt, abundant gypsum, dry	CL	Last split spoon from 10 to 12 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 1 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 5	
3. DRILLING AGENCY: Winnek, Inc.		ST = shelby tube Grab	
4. HOLE NO.: S-13		11. ELEVATION GROUND WATER: 4023.41 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 9/1/87	COMPLETED: 9/1/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4030.05 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 20 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			2, 4, 8,10	SS	Silt: tan, some very fine-grained sand, moist	ML	
3			7,11,19,20	SS	Sand: tan, quartzose, very fine-grained, silty, very moist, becoming slightly coarser grained, less silty and very wet with depth	SM/SP	
8		S-13(8-10)	24,40,63,	SS	Sand: tan, quartzose, fine-grained, trace dark accessory minerals, saturated	SP	
13			9,18,29,27	SS	Sand and gypsum: 13 to 15 ft.: fine-grained sand, tan, trace dark accessory minerals, wet; 14 to 15 ft.: white gypsum crystals (70 to 80 %) with tan, sandy clay matrix, slightly moist	SP/SC	
18		S-13(18-20)	13,22,31,34	SS	Sand: light brown, very fine-grained, clayey, some gypsum crystals, some silt, dry to slightly moist	SC	Last split spoon from 18 to 20 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 2 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek, Inc.
4. HOLE NO.: S-14
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 35 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 6; ST = shelby tube; Grab 1
11. ELEVATION GROUND WATER: 4023.66 ft MSL (11/17/87)
12. DATE HOLE STARTED: 9/2/87 COMPLETED: 9/3/87
13. ELEVATION TOP OF HOLE: 4030.20 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0				Grab	Silt and sand: 0 to 8 ft.: dry silt from 0 to 5 ft., wet sand from 5 to 8 ft.	ML/SP	
8			14,22,42,50	SS	Sand: brown, quartzose, very fine-grained, silty, trace dark accessory minerals, saturated	SM	
13			11,15,17,19	SS	Sand and gypsum crystals: 13 to 14 ft.: quartzose sand, brown, clayey, silty, some gypsum crystals, moist; 14 to 15 ft.: white gypsum crystals with light gray clay matrix, saturated	SC	
18			12,16,21,28	SS	Sand: brown, very fine- to fine-grained, clayey near top, some gypsum crystals, trace dark accessory minerals, moist	SP	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 2 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek, Inc.
4. HOLE NO.: S-14
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 35 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 6; ST = shelby tube; Grab 1
11. ELEVATION GROUND WATER: 4023.66 ft MSL (11/17/87)
12. DATE HOLE STARTED: 9/2/87 COMPLETED: 9/3/87
13. ELEVATION TOP OF HOLE: 4030.20 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
23			44,17,22,23	SS	Sand and clay: brown, quartzose, sand, very fine-grained, silty, clayey, abundant gypsum crystals, wet; 2 in. layer of gypsum crystals and 2 in. layer of reddish-brown moist sandy clay with gypsum crystals at bottom of spoon	SM/CL	Recovery of 15 inches
28		S-14(29-30)	9,10,11,12	SS	Clay: 28 to 29 ft.: light green with some gypsum crystals, silty, trace very fine-grained sand, slightly moist; 29 to 30 ft.: reddish-brown, some silt, some gypsum crystals, moderate plasticity, firm, dry to slightly moist	CL	
33			5,13,15,19	SS	Clay: reddish-brown, silty, low plasticity, trace very fine-grained sand, gypsum crystals from 34 to 35 ft., moist	CL	Last split spoon from 33 to 35 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 1 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 5	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab	
4. HOLE NO.: S-15		11. ELEVATION GROUND WATER: 4032.96 ft MSL (11/18/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 8/20/87	COMPLETED: 8/20/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4034.86 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 15 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			1, 1, 2, 3	SS	Silt: dark brown to light tan, with some white areas, clayey, some very fine-grained sand, some fine roots, black stained spot at ~13 in., moist to saturated	ML	
3		S-15(4-5)	3, 7,19,25	SS	Silt and sand: 3 to 4 ft.: silt, light tan, clayey, wet; 4 to 5 ft.: sand, tan to yellow, some limonite staining, silty, some clay, very wet	ML/SM	OVA = 2.4/2.4 ppm at 5 ft.
8			14,16,20,19	SS	Clay: reddish-brown, sandy, silty, low to medium plasticity, moist	CL	
10		S-15(10-12)	3, 5, 5, 8	SS	Clay: reddish-brown, silty, with sand pockets, low to medium plasticity, firm to soft, minor gypsum crystals, moist	CL	
13			5, 6, 7, 9	SS	Clay: reddish-brown, silty, with sand pockets, some gypsum crystals, soft to firm, highly plastic, moist	CH	OVA = 3.5 ppm at 15 ft., last split spoon from 13 to 15 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 2 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: S-16
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 34 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
10. NO. OF SAMPLES TAKEN: SS = split spoon 7; ST = shelby tube; Grab 1
11. ELEVATION GROUND WATER: 4018.33 ft MSL (11/16/87)
12. DATE HOLE STARTED: 10/3/87 COMPLETED: 10/3/87
13. ELEVATION TOP OF HOLE: 4027.46 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0				SS	Silt: light tan to brown, slightly sandy, slightly cohesive, slightly calcareous in small pockets, damp	ML	
5				Grab	Silt: light tan, sandy, damp	ML	
7			7,10,14,13	SS	Sand: quartzose, brown with reddish-orange stains, very fine-grained, silty, trace dark accessory minerals, moderately well sorted, sub-rounded, minor dark stains on sand grains, wet to saturated	SM	OVA = 2.6/2.6 ppm at 7 ft., slightly stale odor 7 to 9 ft.
12		S-16(12-14)	17,29,34,37	SS	Silt: light brown, with sand, very fine- to fine-grained, moderately well sorted, sub-rounded, 3% dark accessory minerals, trace lithic grains, very slightly cohesive, wet to saturated	ML	
17			10,20,25,39	SS	Sand: quartzose, light tan to brown, very fine- to fine-grained, sub-rounded, moderately well to well sorted, clayey in upper 0.5 ft. and lower 1.5 ft., 5% dark accessory minerals, wet to saturated	SC	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 2 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 7	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab 1	
4. HOLE NO.: S-16		11. ELEVATION GROUND WATER: 4018.33 ft MSL (11/16/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 10/3/87	COMPLETED: 10/3/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4027.46 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 34 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
22			3, 3, 2, 5	SS	Sand: brown to grayish-green, fine- to very fine-grained, moderately well sorted, silty in places, 5% dark accessory minerals, trace clay, wet	SM	OVA = 3.5/3.5 ppm at 22 ft.
27			18,35,30,34	SS	Sand: quartzose, brown to grayish-green, medium- to fine-grained, lithic grains commom, 10% dark accessory minerals, very clayey last 0.2 ft., loose, wet	SC	
32		S-16(32-33.5)	1, 1, 4, 8	SS	Sand and clay: interbedded sand and clay, sand is brown, fine- to medium-grained, wet; clay is grayish-green, silty, with pockets of black carbonaceous material at 33 ft, moist	SP/CL	Last split spoon from 32 to 34 ft.

DRILLING LOG | RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM | SHEET 1 OF 4 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION	8. DATUM FOR ELEVATION SHOWN: sea level
	9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
2. LOCATION: HOLLOMAN AFB, NM	10. NO. OF SAMPLES TAKEN: SS = split spoon 16
3. DRILLING AGENCY: Winnek Inc.	ST = shelby tube Grab
4. HOLE NO.: D-1	11. ELEVATION GROUND WATER: 4021.72 ft MSL (11/17/87)
5. NAME OF DRILLER: Bob Kingsley	12. DATE HOLE |STARTED: 9/18/87 |COMPLETED: 9/20/87
6. DIRECTION OF HOLE:	13. ELEVATION TOP OF HOLE: 4028.34 ft MSL
X VERTICAL INCLINED DEG. FROM VERT.	14. SIGNATURE OF INSPECTOR:
7. TOTAL DEPTH OF HOLE: 75 ft BGL	

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			1, 3, 6,17	SS	Sand: quartzose, brown, reddish tinge, fine-grained, moderately silty, damp	SM	OVA = 1.5/1.5 ppm at 2 ft.
3			8, 8, 8, 9	SS	Silt: tan, sandy, some gypsum, moist	ML	OVA = 1.5/1.5 ppm at 5 ft.
8			22,47,24,26	SS	Silt and sand: 8 to 9.5 ft.: silt, tannish-gray, sandy, slightly clayey, damp to wet; 9.5 to 10 ft.: sand, light gray, very fine-grained, slightly silty, wet	ML/SM	OVA = 1.5/1.5 ppm at 10 ft.
13			18,32,29,30	SS	Sand: quartzose, light tannish-gray, many red oxidized zones, very fine-grained, slightly silty, some zones of gypsum crystals, minor dark accessory minerals, moist	SM	OVA = 1.5/1.5 ppm at 15 ft.
18			4,19,17,18	SS	Silt and clay: 18 to 19 ft.: silt, light tan, very clayey, slightly sandy, moderately cohesive, moist; 19 to 20 ft.: clay, light reddish-brown, very silty, slightly sandy, moderately stiff, not plastic, moist	ML/CL	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 4 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-1
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 75 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 16; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4021.72 ft MSL (11/17/87)
12. DATE HOLE STARTED: 9/18/87 COMPLETED: 9/20/87
13. ELEVATION TOP OF HOLE: 4028.34 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
23			7,21,20,26	SS	Sand: quartzose, light greenish-gray, very fine-grained, moderately to well rounded, very silty, moderately clayey, moderately cohesive, wet	SM	OVA = 2.0/2.0 ppm at 25 ft.
28		D-1(28-30)	10,13,22,36	SS	Sand: quartzose, light greenish-gray, very fine-grained, very silty, slightly clayey (to very clayey at 29 ft.), slightly cohesive, moist	SC	
33			18,33,39,61	SS	Sand: quartzose, light gray, very fine-grained, slightly clayey to clayey, slightly cohesive to cohesive, some gypsum crystals, minor dark accessory minerals, wet to damp	SC	
38		D-1(38-40)	22,28,25,34	SS	Silt and clay: 38 to 38.75 ft.: silt, reddish-brown, clayey, slightly sandy, cohesive, with orange-tan oxidized sandy zones; 38.75 to 40 ft.: clay, brownish-red to greenish-gray, sandy, trace gypsum crystals, stiff, very low to low plasticity, moist	ML/CL	OVA = 0.5/0.5 ppm at 38 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 3 OF 4 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 16	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab	
4. HOLE NO.: D-1		11. ELEVATION GROUND WATER: 4021.72 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 9/18/87	COMPLETED: 9/20/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4028.34 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 75 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
43			27,20,18,20	SS	Clay: greenish-gray to brownish-red, moderately to slightly sandy, slightly silty, some gypsum crystals, moderately stiff, low to medium plasticity, damp to moist	CL	
48			15,15,15,24	SS	Clay: brownish-red, slightly sandy, slightly silty, some gypsum crystals, low to medium plasticity, soft to moderately stiff, damp to moist	CL	
53			5, 5, 8,12	SS	Silt: brownish-red, clayey, very sandy, minor gypsum, low to medium plasticity, wet to damp	ML	OVA = 2.5/2.5 ppm at 55 ft.
58			6, 9,11,15	SS	Silt: brownish-red, slightly clayey (some very clayey zones), slightly sandy, minor dark accessory minerals, low to medium plasticity, cohesive, damp	ML	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 4 OF 4 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-1
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 75 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 16; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4021.72 ft MSL (11/17/87)
12. DATE HOLE STARTED: 9/18/87 COMPLETED: 9/20/87
13. ELEVATION TOP OF HOLE: 4028.34 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
63			7, 8, 9,15	SS	Silt: reddish-brown, clayey (some very clayey zones), slightly sandy, minor dark accessory minerals, low to medium plasticity, very cohesive, damp	ML	
68			10,12,12,17	SS	Silt: reddish-brown, clayey (some very clayey zones), slightly sandy, minor dark accessory minerals, very cohesive, damp	ML	
73			12,14,16,18	SS	Clay: reddish-brown, very silty, slightly sandy, low to medium plasticity, very cohesive, damp	CL	Last split spoon from 73 to 75 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 4 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 14	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab 1	
4. HOLE NO.: D-2		11. ELEVATION GROUND WATER: 4017.31 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 9/30/87	COMPLETED: 10/1/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4021.37 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 77 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			2, 6, 6, 9	SS	Sand: quartzose, off white to light tan to brown, very fine-grained, rounded, very silty, clayey at 1 ft., slightly damp	SM	OVA = 1.6/1.6 ppm at 2 ft.
2			4, 6, 6, 9	SS	Silt: reddish-brown to light tan to light green with some limonite staining, very clayey, trace gypsum grains, slightly damp to moist	ML	
7			22,28,31,17	SS	Sand: quartzose, fine- to very fine-grained, subrounded to rounded, slightly silty, 2% dark accessory grains, slightly cohesive, wet to saturated	SM	
12			2, 2, 6, 9	SS	Clay: reddish-brown, silty, soft to stiff, some gypsum crystals, slightly mosit	CL	
17			2, 3, 3, 9	SS	Sand and clay: 17 to 18 ft.: sand, brown, fine- to coarse grained, poorly sorted, some lithic fragments, saturated; 18 to 19 ft.: clay, reddish-brown to grayish-green, silty, some gypsum crystals, slightly moist	SP/CL	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 4 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 14	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab 1	
4. HOLE NO.: D-2		11. ELEVATION GROUND WATER: 4017.31 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 9/30/87	COMPLETED: 10/1/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4021.37 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 77 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
21				Grab	Sand, fine- to medium-grained, saturated		
22			2, 3, 4, 8	SS	Silt: grayish-green to reddish-brown, sandy, clayey, abundant gypsum at botttom, moist	ML	
27			22,34,56,	SS	Sand: quartzose and lithic, brown, fine- to medium-grained (very fine- to fine-grained last 12 inches), moderately well sorted, 10% dark accessory minerals, trace gypsum grains, wet to moist	SP	18 inches recovery
32			4, 7, 8,10	SS	Sand and clay: 32 to 32.3 ft.: sand, quartzose, grayish-green, very fine- to fine-grained, slightly clayey, moist; 32.3 to 34 ft.: clay, grayish-green, very silty, some gypsum crystals, soft to stiff, moist	SC/CL	
37			3, 5, 4, 6	SS	Clay: grayish-green, silty, some soft spots, mostly firm and plastic, pockets of gypsum crystals, moist	CL	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 3 OF 4 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-2
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 77 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
10. NO. OF SAMPLES TAKEN: SS = split spoon 14; ST = shelby tube; Grab 1
11. ELEVATION GROUND WATER: 4017.31 ft MSL (11/17/87)
12. DATE HOLE STARTED: 9/30/87 COMPLETED: 10/1/87
13. ELEVATION TOP OF HOLE: 4021.37 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
42			8, 8, 8, 9	SS	Clay: grayish-green to reddish-brown, slightly silty, some gypsum crystals, stiff to soft	CL	
52		D-2(52-54)	8, 7,17,19	SS	Sand, silt, and clay: reddish-brown to brown sand, quartzose, very fine-grained, silty, with 0.5 ft. layer of reddish-brown stiff clay, sand is wet	ML	
57			7, 8,14,12	SS	Sand and clay: interbedded sand and clay, sand is brown, very fine-grained, silty, loose, wet; clay is reddish-brown, soft to firm, slightly moist	SC	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 4 OF 4 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 14	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab 1	
4. HOLE NO.: D-2		11. ELEVATION GROUND WATER: 4017.31 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 9/30/87	COMPLETED: 10/1/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4021.37 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 77 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
62			7, 8,14,12	SS	Sand and clay: 62 to 63 ft.: sand, quartzose and lithic, very fine-grained, black and green accessory grains, poor to moderately sorted, wet to moist, gredes to silty clay ; 63 to 64 ft.: clay, reddish-brown, stiff	SP/CL	
67		D-2(67-69)	7, 6,10,12	SS	Clay: grayish-green to green to blue-green with thin white streaks throughout, silty, very stiff, moist where silty, damp where very stiff	CL	
76				Grab	Clay: blueish-green		Clay about 1 ft. up from base of bit.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 4 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 15	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab 5	
4. HOLE NO.: D-3		11. ELEVATION GROUND WATER: 4041.47 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 8/6/87	COMPLETED: 8/8/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4045.48 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 75 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			3, 8,11, 9	SS	Silt: light tan, some sand, well sorted, slightly moist	ML	OVA = 0/0 ppm at 2 ft.
2				Grab	Same as above moist to wet	ML	
3			4, 7, 7,10	SS	Sand: quartzose, tan, medium- to fine-grained, well-sorted, sub-angular to sub-rounded, trace dark accessory mineral, moist to saturated	SP	
5				Grab	Sand: quartzose, tan, fine-grained, sub-angular to sub-rounded	SP	
8			7,16,22,29	SS	Clay: reddish-brown to light greenish-gray, abundant gypsum crystals (over 60%), moist to dry	CL	OVA = 2.5/2.5 ppm at 10 ft.
13			6,86,16,15	SS		CL	
15				Grab	Same as above	CL	
18			45,10,15,13	SS	No return, hard zone, cuttings are slightly sandy		OVA = 2.5/2.5 ppm at 18 ft.
20			8,12,15,15	SS	Clay: reddish-brown, some gypsum (10-20%), in "pods", silty, plastic, cohesive, moist	CH	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 4 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-3
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 75 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 15; ST = shelby tube; Grab 5
11. ELEVATION GROUND WATER: 4041.47 ft MSL (11/17/87)
12. DATE HOLE STARTED: 8/6/87 COMPLETED: 8/8/87
13. ELEVATION TOP OF HOLE: 4045.48 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
23			11,15,19,18	SS	Silt: greenish-gray, clayey, with some gypsum crystals, some very fine-grained sand at 24-25 feet, moist	ML	
25				Grab	Same as above (25 to 28 feet)	ML	
28			1,16,20,23	SS	Clay: reddish-brown to greenish-gray, gypsum crystals (crystals up to 1.5 cm), silty, moist	CL	
30				Grab	Clay: light brown, silty, some sand, significant increase in water at 32 feet	CL	
33			9,13,15,20	SS	Clay: reddish-brown, silty, trace very fine-grained sand, some gypsum crystals, poorly plastic, dry to moist	CL	OVA = 2.5/2.5 ppm at 35 ft.
38			9,12,14,18	SS	Clay: reddish-brown, silty, with gypsum crystals, poorly plastic, dry to moist	CL	OVA = 2.5/2.5 at 40 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 3 OF 4 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 15	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab 5	
4. HOLE NO.: D-3		11. ELEVATION GROUND WATER: 4041.47 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 8/6/87	COMPLETED: 8/8/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4045.48 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 75 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
48			4,12,13,13	SS	Clay: reddish-brown, to mottled green, minor silt, plastic, dry to slightly moist, saturated very fine-grained sand layer 2 cm thick at ~49 feet	CL	
53			6,13,17,20	SS	Silt: reddish-brown, clayey, minor gypsum crystals, minor greenish-gray clay	ML	OVA = 3.0/3.0 ppm at 55 ft.
58		D-3(58-60)	14,24,28,45	SS	Silt and sand: greenish-gray to reddish-brown silt, with some fine-grained sand, moist; also a layer of sand, grayish-green, very fine-grained, saturated	SM	21.5 inches recovery

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 4 OF 4 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 15	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab 5	
4. HOLE NO.: D-3		11. ELEVATION GROUND WATER: 4041.47 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 8/6/87	COMPLETED: 8/8/87
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.		13. ELEVATION TOP OF HOLE: 4045.48 ft MSL	
7. TOTAL DEPTH OF HOLE: 75 ft BGL		14. SIGNATURE OF INSPECTOR:	

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
63		D-3(63-64)	15,40,50,	SS	Silt and sand: grayish-green silt, clayey, wet; grayish-green to tan sand, some silt, well sorted, trace dark accessory minerals, saturated	ML/SC	OVA = 4.0/4.0 ppm at 63.9 ft.
68		D-3(68-70)	9,12,13,31	SS	Clay: grayish-green, with interbedded thin layers of silty very fine-grained saturated sand	CH	OVA = 4.0/4.0 ppm at 70 ft.
73			34,27,22,22	SS	Clay: grayish-green, silty, plastic, moist, with thin layers of fine-grained, silty sand	CL	OVA = 5.0/5.0 ppm at 75 ft., last split spoon 73 to 75 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 3 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 13 ST = shelby tube Grab	
3. DRILLING AGENCY: Winnek Inc.			
4. HOLE NO.: D-4		11. ELEVATION GROUND WATER: 4024.39 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 8/22/87	COMPLETED: 8/23/87
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.		13. ELEVATION TOP OF HOLE: 4030.19 ft MSL	
		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 58 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0				SS	Silt: brown, slightly clayey, moist	ML	OVA = 2.4/2.4 ppm at 3 ft.
3			7,13, 9, 9	SS	Sand: brownish-tan, very fine-grained grading to fine-grained at ~ 4 ft., moderately well sorted, moist to very wet		OVA = 2.2 at 3 ft.
8			14,48,77,	SS	Sand: brown, quartzose, fine-grained to very fine-grained, trace gypsum grains, trace dark accessory minerals, wet	SP	Free water on split spoon, OVA = 2.2/2.2 ppm at 8 ft.
13			4,11,16,16	SS	Sand: 13 to 14 ft.: sand, brown to yellow-brown, clayey, very wet; 14 to 15 ft.: clayey sand, white to pale green, very clayey, some gypsum grains, dry	SC	OVA = 2.2/2.2 ppm at 13 ft.
18			9,18,26,26	SS	Clay and sand: sandy clay, reddish-brown to light tan, silty, very fine-grained sand, with gypsum crystals, grading into clayey sand, off-white to brown, very fine-grained, with gypsum crystals	SC	Recovery of 16 inches

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 3 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-4
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 58 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 13; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4024.39 ft MSL (11/17/87)
12. DATE HOLE STARTED: 8/22/87 COMPLETED: 8/23/87
13. ELEVATION TOP OF HOLE: 4030.19 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
23			5, 6,16,13	SS	Sand: brown, quartzose, moderately to poorly sorted, slightly clayey to clayey, gypsum crystals in "pockets", very wet	SC	
28			7, 7, 7, 7	SS	Clay and silt: 28 to 29.75 ft.: clay, light tan to pale greenish-tan to reddish-brown, abundant gypsum crystals, firm, plastic, moist; 29.75 to 30 ft.: clayey silt, plastic, wet	CL/ML	OVA = 0.5/0.5. ppm at 28 ft.
33			9,14,16,16	SS	Clay and sand: clay, light greenish-gray to reddish brown, some sand and silt, some gypsum crystals, with interbedded (6 in. layer) of very fine-grained reddish-brown sand, clayey, wet	ML	
38			6,11,14,12	SS	Clay and sand: 38 to 39 ft.: clay, reddish-brown, slightly silty, trace gypsum, stiff, plastic, moist; 39 to 40 ft.: sand, reddish-brown, quartzose, very fine-grained, wet to moist	CL/SM	OVA = 1.8/1.8 ppm at 38 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 3 OF 3 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 13	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab	
4. HOLE NO.: D-4		11. ELEVATION GROUND WATER: 4024.39 ft MSL (11/17/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 8/22/87	COMPLETED: 8/23/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4030.19 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 58 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
43		D-4(43-44,44-45)	7,14,22,17	SS	Sand: brown, quartzose, fine to medium-grained, moderately well sorted, 30% lithics, feldspar, and dark accessory grains, wet with interbedded reddish-brown clay seams, clay is silty and plastic	SM/SC	OVA = 1.8/1.8 ppm at 43 ft.
48			9,16,14,14	SS	Sand: brown, quartzose, very fine-grained, moderately well sorted, silty and clayey in places with interbedded reddish-brown clay, clay is slightly silty, plastic and moist	SC	
53			9,21,21,23	SS	Sand and clay: interbedded brown, very fine-grained, wet sand and reddish-brown, stiff, plastic, clay	SC-SM	
56		D-4(56-58)		grab	Clay: grayish-green, silty, plastic	CL	Last split spoon from 56 to 58 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 4 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-5
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 65 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 15; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4032.07 ft MSL (11/18/87)
12. DATE HOLE STARTED: 8/18/87 COMPLETED: 8/20/87
13. ELEVATION TOP OF HOLE: 4036.86 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			4, 4, 3, 3	SS	Silt: 0 to 1 ft.: brown to tan, moist, organics, moist ; 1 to 2 ft.: light tan to white, saturated	OL/ML	OVA = 3.0/2.5 ppm at 2 ft.
3			2,12,11, 4	SS	Silt and sand: sandy silt (3 to 4 ft.) to silty sand (4 to 5 ft.). Sand is light brownish-tan, moderately well sorted, with minor dark accessory minerals, trace brown clay	SM	OVA = 2.5/2.5 ppm at 5 ft.
8			12,15,27,38	SS	Sand: brown, very fine-grained, silty, white to light tan, very moist to moist	SM	OVA = 3.0/2.5 ppm at 10 ft.
13			9,11,19,22	SS	Sand and clay: 13 to 14 ft.: sand, light tan to brown, saturated; 14 to 15 ft: clay, reddish-brown to off-white, with gypsum crystals, firm to friable	SP/CL	OVA = 2.5/2.5 at 13 ft.
18			12,21,25,34	SS	Sand: brown to light tan to reddish-brown, quartzose, very fine-grained, poorly sorted, clayey, silty, minor gypsum, trace dark accessory minerals	SC	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 4 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-5
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 65 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 15; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4032.07 ft MSL (11/18/87)
12. DATE HOLE STARTED: 8/18/87 COMPLETED: 8/20/87
13. ELEVATION TOP OF HOLE: 4036.86 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
23			10,14,18,28	SS	Clay: reddish-brown, silty, small white patches scattered throughout, gypsum crystals (23 to 23.25 ft.), stiff, moderately to slightly plastic, slightly moist	CL	OVA = 3.5/2.5 ppm at 25 ft.
28			9, 8,17,25	SS	Clay: reddish-brown, silty, highly plastic, soft to firm 28 to 29 ft., stiff 29 to 30 ft., minor white silty clay in "pockets", some gypsum crystals, moist	CL	
33			9, 9,53,	SS	Clay: light green, trace limonite staining, slightly silty, scattered gypsum crystals in "pockets", firm, plastic, slightly moist	CL	
38			8,13,19,20	SS	Clay: light green, trace limonite staining, slightly silty, scattered pockets of gypsum crystals, firm, plastic, moist	CL	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 3 OF 4 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-5
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 65 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 15; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4032.07 ft MSL (11/18/87)
12. DATE HOLE STARTED: 8/18/87 COMPLETED: 8/20/87
13. ELEVATION TOP OF HOLE: 4036.86 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
43			6,10,21,71	SS	Sand and clay: 43 to 44.75 ft.: sand, brown, quartzose, very fine-grained, moderately to well sorted, saturated; 44.75 to 45 feet, clay, reddish-brown, with large gypsum crystals, stiff, moist	SP/CL	
48			6, 7,10,30	SS	Clay and sand: 48 to 49.7 feet: clay, reddish-brown with grayish-green pockets, silty, stiff, moist; 49.7 to 50 ft.: sand, grayish-green, quartzose, very fine-grained, silty, slightly clayey, moist	CL/SM	
53		D-5(53-54.5)	8,22,28,22	SS		SC/SM	
55			7,13,35,50	SS	Sand: light grayish-green to reddish-brown to brown, very fine-grained, slightly clayey, some silt, some dark accessory minerals, moist to wet	SP/SM	
58			12,20,47,67	SS	Sand: brown, quartzose, very fine-grained, some lithics (5%), trace bladed gypsum crystals, clayey near bottom, wet	SP/SC	OVA = 2.2/2.2 at 60 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 4 OF 4 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-5
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 65 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-50
10. NO. OF SAMPLES TAKEN: SS = split spoon 15; ST = shelby tube; Grab
11. ELEVATION GROUND WATER: 4032.07 ft MSL (11/18/87)
12. DATE HOLE STARTED: 8/18/87 COMPLETED: 8/20/87
13. ELEVATION TOP OF HOLE: 4036.86 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
63			8,33,50,	SS	Sand: brownish-yellow to light gray, quartzose, very fine-grained, poorly to moderately well sorted, sub-rounded, slightly clayey, some dark accessory minerals (5%), wet to saturated	SP	Recovery of 21 inches. Last split spoon from 63 to 64.7 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 4 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 16	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab 1	
4. HOLE NO.: D-6		11. ELEVATION GROUND WATER: 4018.45 ft MSL (11/16/87)	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 10/5/87	COMPLETED: 10/6/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: 4027.98 ft MSL	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 68 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			5,19,15,15	SS	Silt: light tan, loose, slightly damp	ML	
5				Grab	Sand: quartzose, very fine-grained, silty, damp	SM	
7			7,11,12, 9	SS	Sand: quartzose, light tan with limonite staining, very fine-grained, moderately well sorted, sub-angular to sub-rounded, 1% dark accessory minerals, moist, wet last 0.5 ft.	SP	OVA = 2.6/2.6 ppm at 7 ft.
12			17,70, ,	SS	Sand and silt: upper 8 inches: sand, quartzose, light tan to brown, very fine-grained, wet; lower 8 inches: silt, sandy, hard, wet	SP/ML	Recovery of 16 inches.
15			10,17,23,32	SS	Sand and silt: sand, quartzose, brown, very fine-grained, silty, wet, grading into silt, brown, sandy, moist, at base of sample	SP/ML	OVA = 2.6/2.6 ppm at 15 ft.
17			10,17,13,17	SS	Sand: quartzose, brown to light tan, very fine- to fine-grained, moderately well sorted, sub-angular to sub-rounded, silty, 3% dark accesssory minerals, trace lithic grains, wet to saturated	SM	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 4 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-6
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 68 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
10. NO. OF SAMPLES TAKEN: SS = split spoon 16; ST = shelby tube; Grab 1
11. ELEVATION GROUND WATER: 4018.45 ft MSL (11/16/87)
12. DATE HOLE STARTED: 10/5/87 COMPLETED: 10/6/87
13. ELEVATION TOP OF HOLE: 4027.98 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
22			6, 3, 4, 3	SS	Sand and clay: 22 to 22.6 ft.: sand, light grayish-green, very fine- to fine-grained, wet; 22.6 to 24 ft.: clay, grayish-green, some gypsum, moist	SP/CL	
24		D-6(24-26)	2, 2, 3, 5	SS	Clay: reddish-brown, scattered gypsum crystals in pockets, soft to firm, plastic, moist	CL	OVA = 2.6/2.6 ppm at 24 ft.
27			3, 4,10,11	SS	Clay and sand: top 9 inches: clay, reddish-brown, soft to firm, plastic, slightly silty, moist; last 9 inches: sand, quartzose, brown, very fine-grained, moderately well sorted, very silty, slightly clayey, slightly cohesive, wet to moist	CL/SM	Recovery of 18 inches.
32		D-6(32-34)	4, 9, 4, 7	SS	Sand: brown to light tan, very fine- to coarse-grained, some lithics and dark accessory minerals, poor to moderately well sorted, upper 6 inches and bottom 6 inches are clayey, moist to wet	SP/SC	Recovery of 24 inches.
37			32,22,35,32	SS	Sand: quartzose, brown, very fine- to fine-grained, moderately well sorted, 2% dark accessory minerals, trace lithics, trace feldspar, slightly cohesive, wet	SP	OVA = 2.2/2.2 ppm at 37 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 3 OF 4 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-6
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 68 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
10. NO. OF SAMPLES TAKEN: SS = split spoon 16; ST = shelby tube; Grab 1
11. ELEVATION GROUND WATER: 4018.45 ft MSL (11/16/87)
12. DATE HOLE STARTED: 10/5/87 COMPLETED: 10/6/87
13. ELEVATION TOP OF HOLE: 4027.98 ft MSL
14. SIGNATURE OF INSPECTOR:

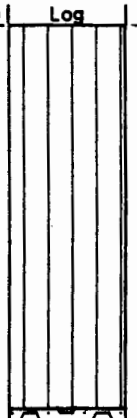
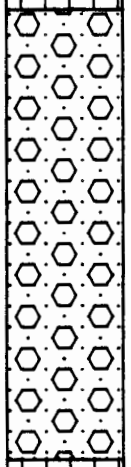
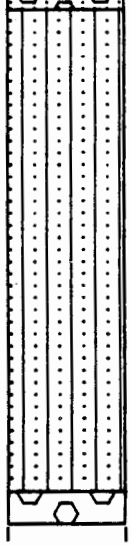
Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
42			15,13,18,14	SS	Sand: brown to reddish-brown, very fine- to fine-grained, slightly clayey in places, 2% dark accessory minerals, trace gypsum grains, some calcareous spots, wet, very wet at base (soupy)	SC	
47			15,20,18,26	SS	Sand: quartzose, brown, very fine- to fine-grained, silty, trace gypsum grains, trace dark accessory minerals, trace lithics, very slightly clayey, moderately cohesive, moist	SM	
52			15,22,22,28	SS	Sand: quartzose, brown, very fine- to fine-grained, silty, trace gysum, dark accessory minerals and lithics, very slightly clayey, very moist	SM	Recovery of 19 inches.
57			8, 7, 7, 9	SS	Sand: quartzose, brown, very fine- to fine-grained, slightly clayey (2 inch clay layer at 57.5 ft.), clay is reddish-brown, with gypsum crystals in pockets and lenses, clay is moist	SC	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 4 OF 4 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: D-6
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 68 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
10. NO. OF SAMPLES TAKEN: SS = split spoon 16; ST = shelby tube; Grab 1
11. ELEVATION GROUND WATER: 4018.45 ft MSL (11/16/87)
12. DATE HOLE STARTED: 10/5/87 COMPLETED: 10/6/87
13. ELEVATION TOP OF HOLE: 4027.98 ft MSL
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
62			10,11,11,14	SS	Sand: quartzose, brwon, very fine- to fine-grained, slightly clayey, trace gypsum crystals in pockets and lenses, moderately well sorted, sub-angular to sub-rounded, wet	SC	
67		D-6(67-68.3)	22,32,50,	SS	Sand: quartzose, brown, very fine- to fine-grained, moderately well sorted, clayey, moderately cohesive, 1% dark accessory minerals, trace lithics, wet	SC	Split spoon refusal at 68.3 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 1 OF 2 SHEETS
1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION		8. DATUM FOR ELEVATION SHOWN: sea level	
		9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
2. LOCATION: HOLLOMAN AFB, NM		10. NO. OF SAMPLES TAKEN: SS = split spoon 6	
3. DRILLING AGENCY: Winnek Inc.		ST = shelby tube Grab 0	
4. HOLE NO.: B-1		11. ELEVATION GROUND WATER: -	
5. NAME OF DRILLER: Bob Kingsley		12. DATE HOLE STARTED: 10/7/87	COMPLETED: 10/7/87
6. DIRECTION OF HOLE:		13. ELEVATION TOP OF HOLE: -	
X VERTICAL INCLINED DEG. FROM VERT.		14. SIGNATURE OF INSPECTOR:	
7. TOTAL DEPTH OF HOLE: 30 ft BGL			

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
0			5,17,27,	SS	Silt: light tan to brown, roots, loose to slightly cohesive, dry	OL	
5				Grab	Sandy silt and silt with calcareous concretions		
7			50,47, ,	SS	Sandstone and sand: reddish to yellowish-brown sandstone, moderately indurated, fine- to medium-grained at top with lesser indurated, fine-grained, silty sand at base, dry	?/SP	OVA = 2.5/2.5 at 7 ft., recovery of 8 inches.
17			50, , ,	SS	Silty sand and sandy silt, damp	SM/ML	Recovery of 3 inches, OVA = 2.2/2.2 ppm at 17 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: HOLLOMAN AFB, NM	SHEET 2 OF 2 SHEETS

1. PROJECT: HOLLOMAN AFB, HYDROGEOLOGIC INVESTIGATION
2. LOCATION: HOLLOMAN AFB, NM
3. DRILLING AGENCY: Winnek Inc.
4. HOLE NO.: B-1
5. NAME OF DRILLER: Bob Kingsley
6. DIRECTION OF HOLE: X VERTICAL INCLINED DEG. FROM VERT.
7. TOTAL DEPTH OF HOLE: 30 ft BGL
8. DATUM FOR ELEVATION SHOWN: sea level
9. MANUAFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
10. NO. OF SAMPLES TAKEN: SS = split spoon 6; ST = shelby tube; Grab 0
11. ELEVATION GROUND WATER: -
12. DATE HOLE STARTED: 10/7/87 COMPLETED: 10/7/87
13. ELEVATION TOP OF HOLE: -
14. SIGNATURE OF INSPECTOR:

Depth (Ft.)	Graphic Log	Sample ID	Blow Counts/ 6 in.	Type of Sample	Stratigraphy	Soil Class	Remarks
22			50, , ,	SS	Sandstone: quartzose, moderately to slighly indurated, very fine- to fine-grained, limonite staining, dry to damp		Recovery of 3 inches. OVA = 2.4/2.4 ppm at 24 ft.
27			50, , ,	SS	Sandstone and sand: quartzose, yellow-orange, limonitic, black staining around grains, very fine- to fine-grained, slightly to moderately indurated		Recovery of 3 inches, slow drilling from 22 to 27 ft., OVA = 2.2
30							Auger refusal at 30 ft.

Hole No.

DRILLING LOG	DIVISION	INSTALLATION Holloman AFB, NM	SHEET 1 OF 4 SHEETS

1. PROJECT Holloman AFB, NM Hydrogeologic Investigation	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Holloman AFB, NM	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Winnek Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL Mobile Drill 8-61
4. HOLE NO. (As shown on drawing title and file number) P-1	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER Bob Kingsley	14. TOTAL NUMBER CORE BOXES
	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.	16. DATE HOLE — STARTED 10/17/87 — COMPLETED 10/17/87
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 77 ft BGL	19. SIGNATURE OF INSPECTOR Wendy Rozacky

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		Light brown clay			
	2		Clayey sand			
	5		Sandy clay			
	12		Clay medium reddish-brown, silty, moist			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT | HOLE NO.

Hole No.

DRILLING LOG	DIVISION	INSTALLATION Holloman AFB, NM	SHEET 2 OF 4 SHEETS

1. PROJECT Holloman AFB, NM Hydrogeologic Investigation	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Holloman AFB, NM	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Winnek Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL Mobile Drill 8-61
4. HOLE NO. (As shown on drawing title and file number) P-1	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED: — UNDISTURBED:
5. NAME OF DRILLER Bob Kingsley	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 10/17/87 — COMPLETED 10/17/87
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 77 ft BGL	19. SIGNATURE OF INSPECTOR Wendy Rozacky

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	21		Silt: tan, very clayey, sandy, soup then back into clay to very fine grain clayey sand			
	24		Clayey, dry, more cohesive			
	35		Return is still clay, very fine sand and silt, wet			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT | HOLE NO.

Hole No.

DRILLING LOG	DIVISION	INSTALLATION Holloman AFB, NM	SHEET 3 OF 4 SHEETS

1. PROJECT Holloman AFB, NM Hydrogeologic Investigation	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Holloman AFB, NM	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Winnek Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL Mobile Drill 8-61
4. HOLE NO. (As shown on drawing title and file number)	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER Bob Kingsley	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 10/17/87 — COMPLETED 10/17/87
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 77 ft BGL	19. SIGNATURE OF INSPECTOR Wendy Rozacky

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	50		No return			
	53		Return is clay, very fine sand and silt, wet			
	57		Sand: quartzose medium brown, very fine-fine grain, saturated, about 3% dark accessory minerals, with thin layers (1-3 in.) of clay (brown to red-brown), sandy, moist			Blow counts: 12,21,25,30

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT HOLE NO.

Hole No.

DRILLING LOG	DIVISION	INSTALLATION Holloman AFB, NM	SHEET 4 OF 4 SHEETS

1. PROJECT Holloman AFB, NM Hydrogeologic Investigation	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Holloman AFB, NM	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Winnek Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL Mobile Drill 8-61
4. HOLE NO. (As shown on drawing title and file number) P-1	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER Bob Kingsley	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 10/17/87 — COMPLETED 10/17/87
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 77 ft BGL	19. SIGNATURE OF INSPECTOR Wendy Rozacky

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	62		Slough Next 6 in. : Sand: brown, fine grain, well sorted, minor dark accessory minerals, saturated moderately cohesive. Next 4 in.: Clay, grayish-green, plastic, cohesive, moist, some very fine grain sand. Next 4 in.: Clay, red-brown, plastic, cohesive, moist. Next 4 in.: Sand: grayish-tan, saturated, minor mafics, minor feldspar, moderately cohesive.			Blow counts: 5,29,53
	67		Clay: dark greenish-gray with black streaks at bottom. Thin layers of clayey, green-gray sand (saturated). Clay is plastic, very stiff, minor silt and minor sand			Blow counts: 3,8,63

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE NO.

Hole No.

DRILLING LOG	DIVISION	INSTALLATION Holloman AFB, NM	SHEET 1 OF 3 SHEETS

1. PROJECT Holloman AFB, NM Hydrogeologic Investigation	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Holloman AFB, NM	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Winnek Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL Mobile Drill 8-61
4. HOLE NO. (As shown on drawing title and file number) P-2	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED: — UNDISTURBED:
5. NAME OF DRILLER Bob Kingsley	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 10/14/87 — COMPLETED 10/15/87
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 62 ft BGL	19. SIGNATURE OF INSPECTOR Wendy Rozacky

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		Silt, sandy, light brown, dry			
	7		Sand: medium brown, very fine grain, saturated, some silt and clay			
	12					HNU=3.0/2.5 ppm in cuttings, probably due to exhaust from rig
	19		Clay			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT | HOLE NO.

Hole No.

DRILLING LOG	DIVISION	INSTALLATION Holloman AFB, NM	SHEET 2 OF 3 SHEETS

1. PROJECT Holloman AFB, NM Hydrogeologic Investigation	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Holloman AFB, NM	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Winnek Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL Mobile Drill 8-61
4. HOLE NO. (As shown on drawing title and file number) P-2	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED: — UNDISTURBED:
5. NAME OF DRILLER Bob Kingsley	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 10/14/87 — COMPLETED 10/15/87
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 62 ft BGL	19. SIGNATURE OF INSPECTOR Wendy Rozacky

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	37		Clay: red-brown, some silt, low-medium plasticity, moist			Blow counts: 6,6,7,10
	39		Clay: red-brown, some sand, low-medium plasticity, moist, 24 in. recovery			Blow counts: 5,6,9,12

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT HOLE NO.

Hole No.

DRILLING LOG	DIVISION	INSTALLATION Holloman AFB, NM	SHEET 3 OF 3 SHEETS

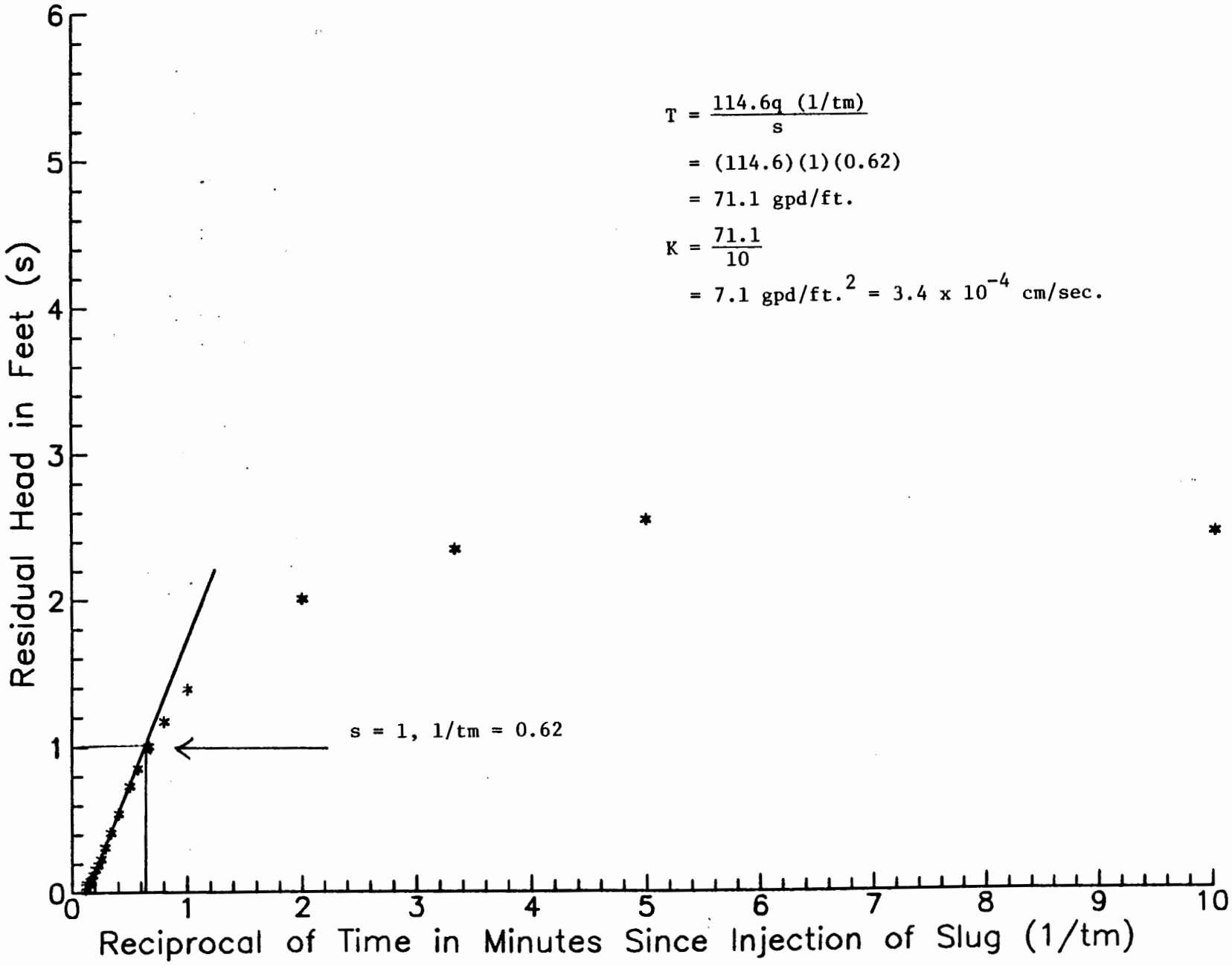
1. PROJECT Holloman AFB, NM Hydrogeologic Investigation	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Holloman AFB, NM	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY Winnek Inc.	12. MANUFACTURER'S DESIGNATION OF DRILL Mobile Drill 8-61
4. HOLE NO. (As shown on drawing title and file number) P-2	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER Bob Kingsley	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 10/14/87 — COMPLETED 10/15/87
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 62 ft BGL	19. SIGNATURE OF INSPECTOR Wendy Rozacky

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	42		Sand: quartzose, medium brown, very fine to medium grained, trace lithics, trace feldspar, trace dark accessory minerals, saturated, slightly cohesive			Blow counts: 11,20,31,54
	47		Sand and Clay: 5 in. sand, 12 in. clay, 7 in. sand Sand: fine-medium grain, medium-red brown, some clay, some mafics and lithics, saturated Clay: red brown, some sand, slightly moist			Blow counts: 5,16,15,27
	52		Sand: medium to red-brown, clayey, very fine grain, saturated, moderately cohesive			Blow counts: 10,16,13,31
	56		Green plastic clay			

APPENDIX F

SLUG TEST ANALYSES
HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

S-2.1 SLUG TEST ANALYSIS, HOLLOMAN AFB



$$T = \frac{114.6q\ (1/tm)}{s}$$

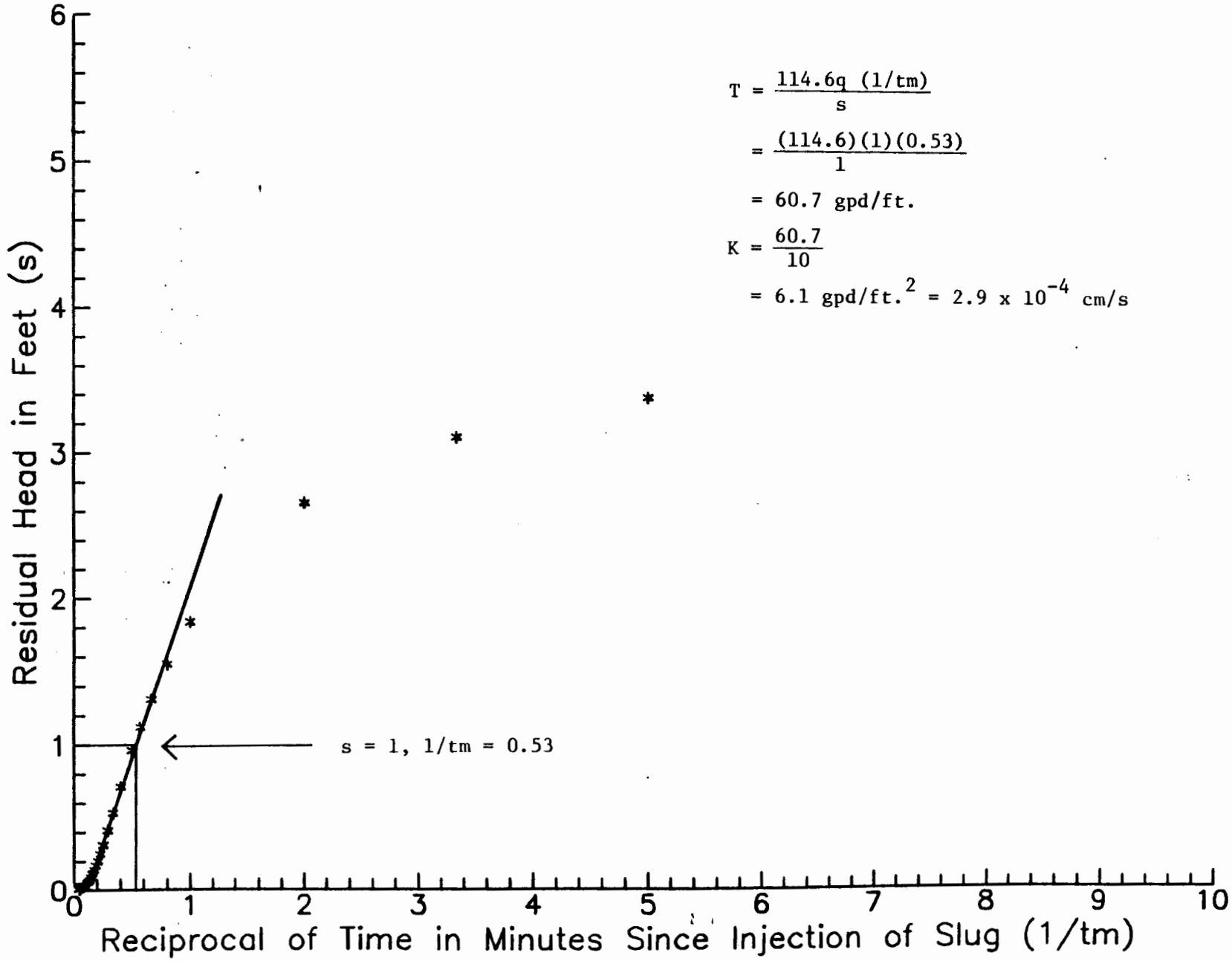
$$= (114.6)(1)(0.62)$$

$$= 71.1 \text{ gpd/ft.}$$

$$K = \frac{71.1}{10}$$

$$= 7.1 \text{ gpd/ft.}^2 = 3.4 \times 10^{-4} \text{ cm/sec.}$$

S-2.2 SLUG TEST ANALYSIS, HOLLOMAN AFB



$$T = \frac{114.6q\ (1/tm)}{s}$$

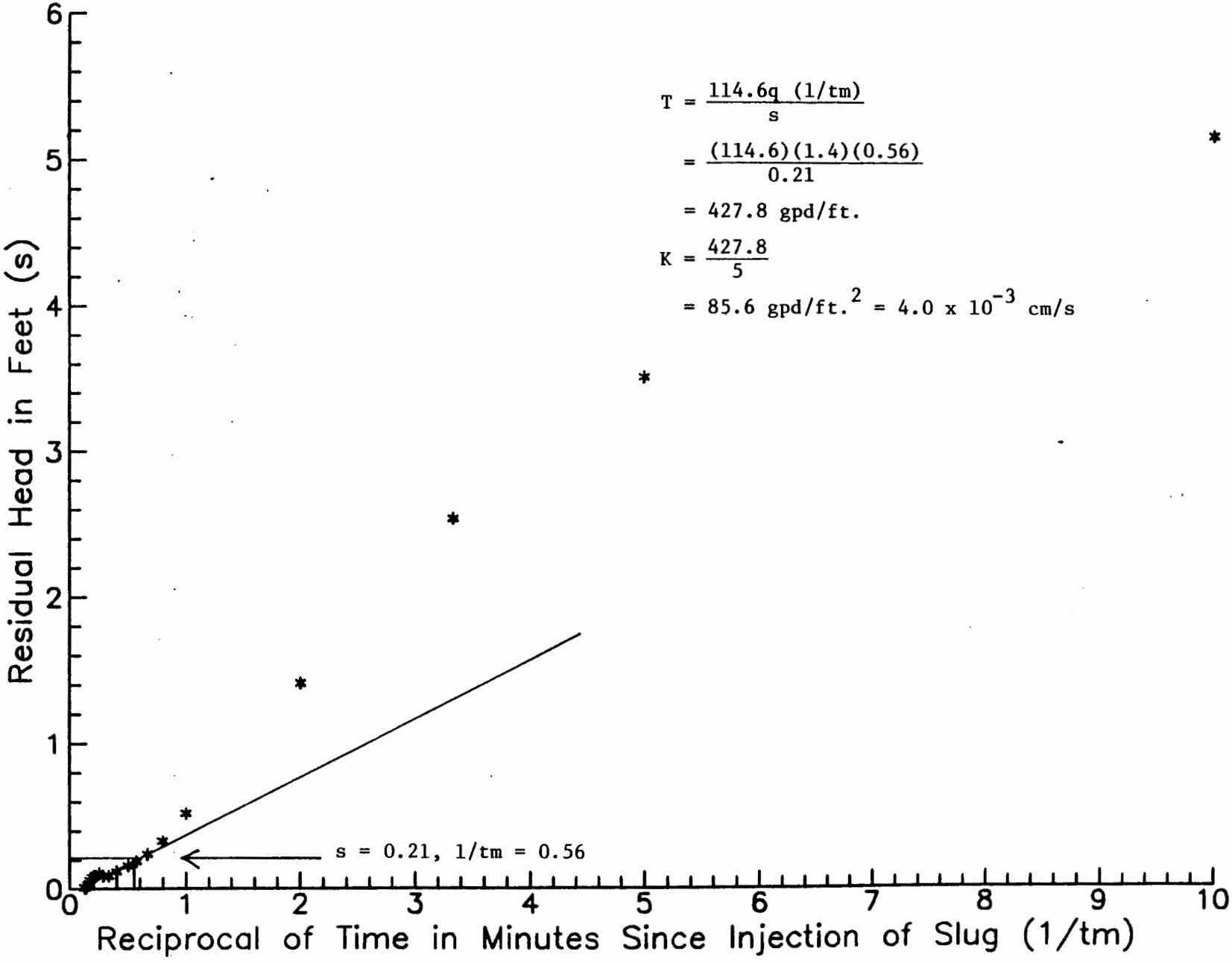
$$= \frac{(114.6)(1)(0.53)}{1}$$

$$= 60.7 \text{ gpd/ft.}$$

$$K = \frac{60.7}{10}$$

$$= 6.1 \text{ gpd/ft.}^2 = 2.9 \times 10^{-4} \text{ cm/s}$$

S-4 SLUG TEST ANALYSIS, HOLLOMAN AFB



$$T = \frac{114.6q\ (1/tm)}{s}$$

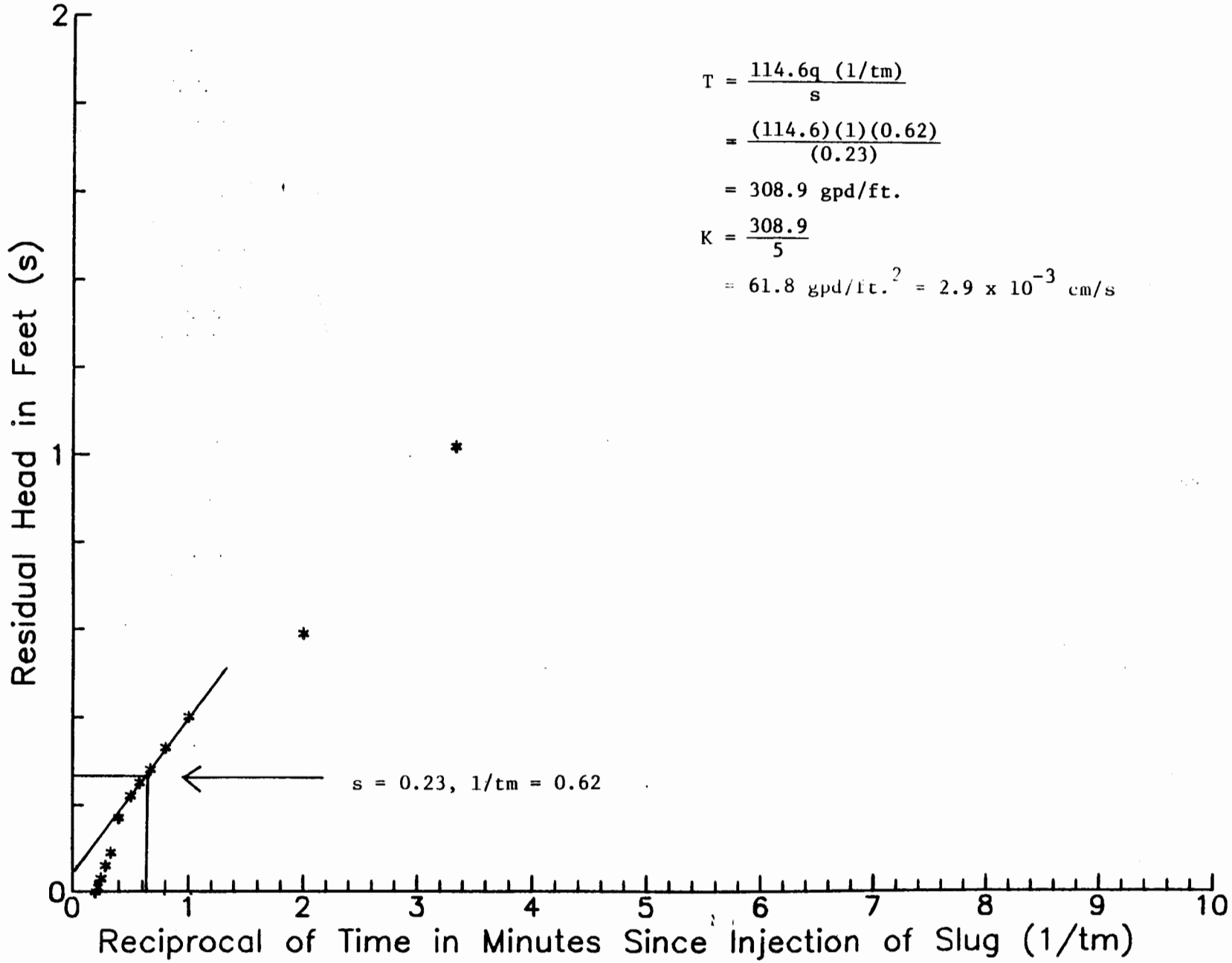
$$= \frac{(114.6)(1.4)(0.56)}{0.21}$$

$$= 427.8 \text{ gpd/ft.}$$

$$K = \frac{427.8}{5}$$

$$= 85.6 \text{ gpd/ft.}^2 = 4.0 \times 10^{-3} \text{ cm/s}$$

S-5 SLUG TEST ANALYSIS, HOLLOMAN AFB



$$T = \frac{114.6q\ (1/tm)}{s}$$

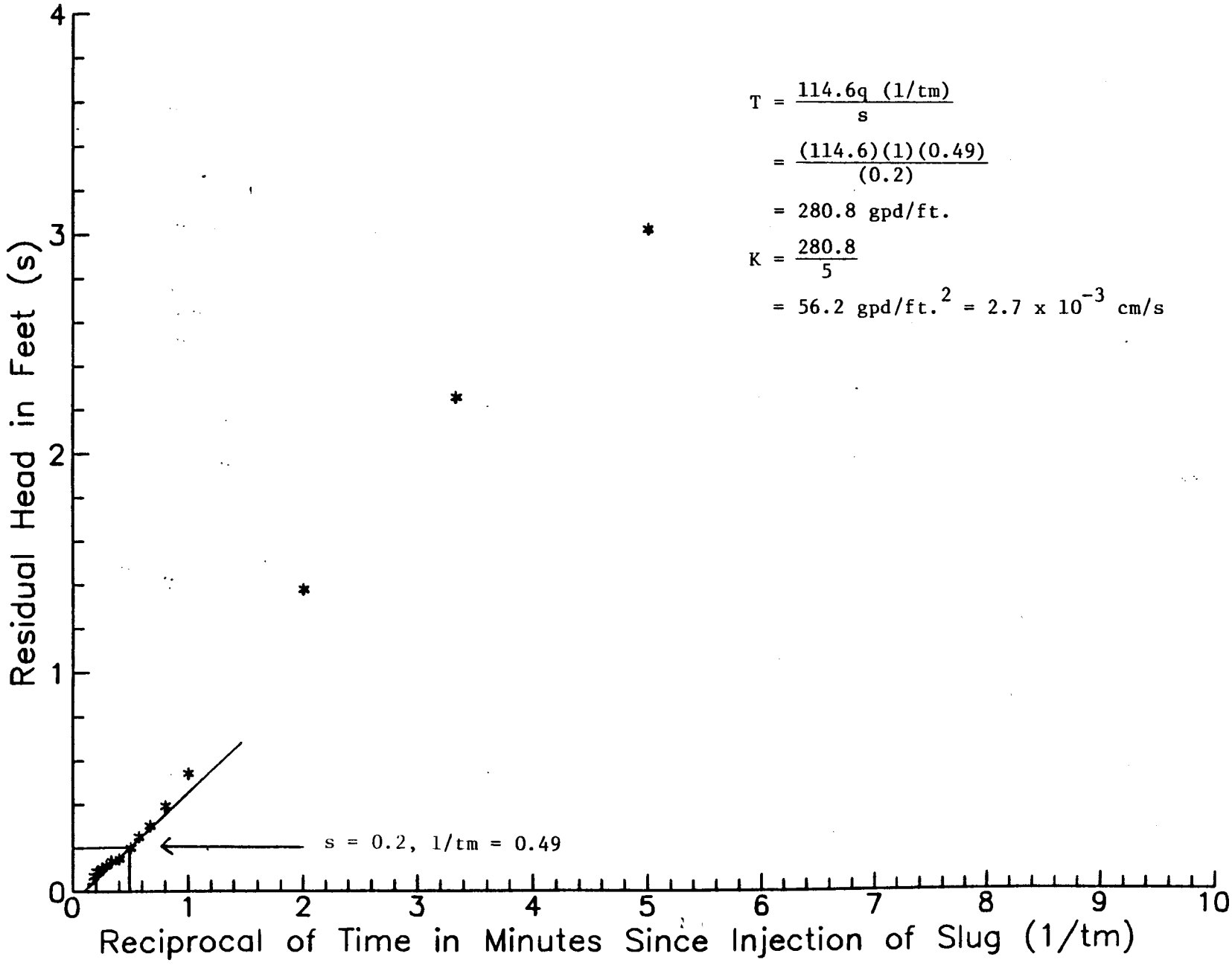
$$= \frac{(114.6)(1)(0.62)}{(0.23)}$$

$$= 308.9 \text{ gpd/ft.}$$

$$K = \frac{308.9}{5}$$

$$= 61.8 \text{ gpd/ft.}^2 = 2.9 \times 10^{-3} \text{ cm/s}$$

S-8 SLUG TEST ANALYSIS, HOLLOMAN AFB



$$T = \frac{114.6q\ (1/tm)}{s}$$

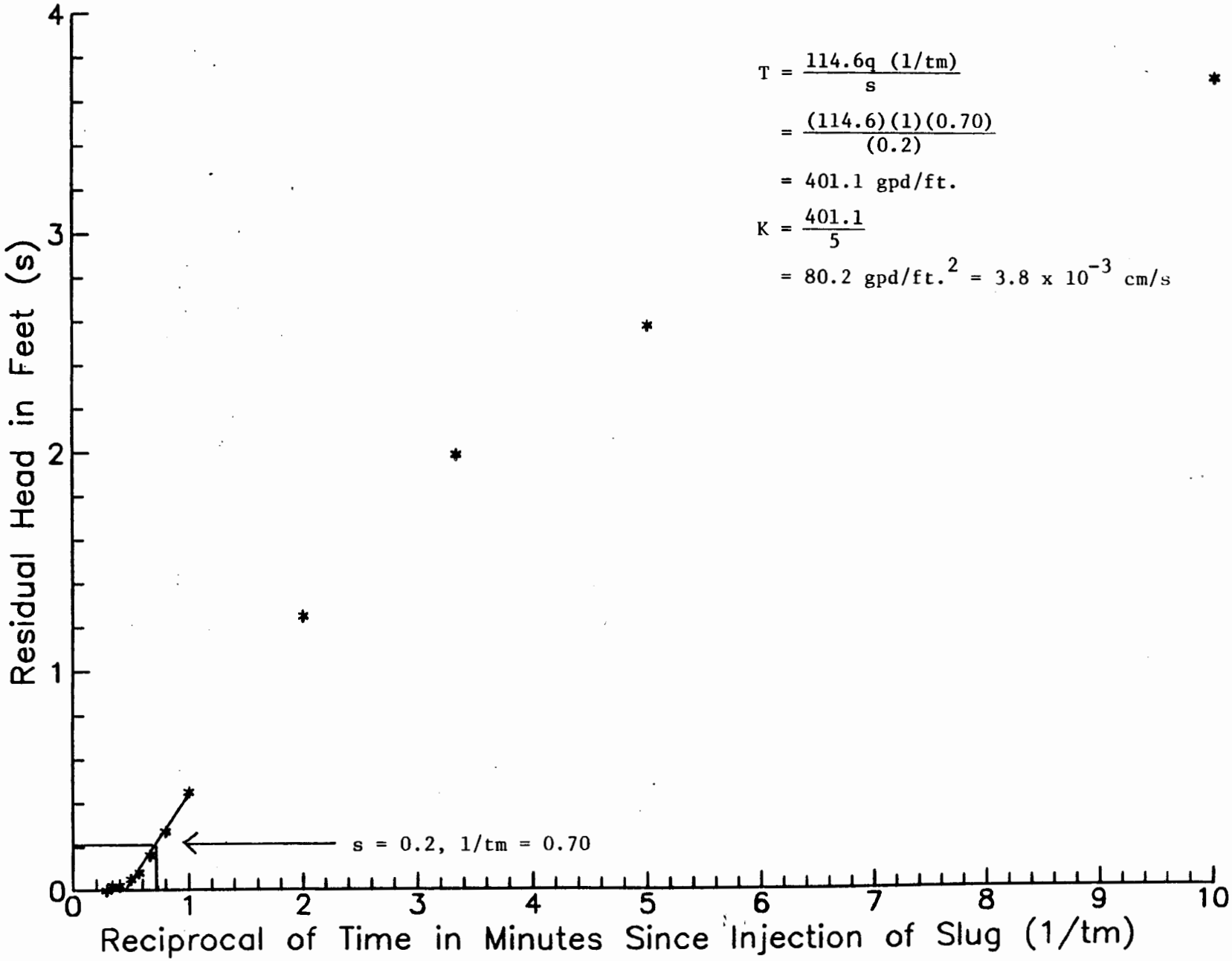
$$= \frac{(114.6)(1)(0.49)}{(0.2)}$$

$$= 280.8 \text{ gpd/ft.}$$

$$K = \frac{280.8}{5}$$

$$= 56.2 \text{ gpd/ft.}^2 = 2.7 \times 10^{-3} \text{ cm/s}$$

S-11 SLUG TEST ANALYSIS, HOLLOMAN AFB



$$T = \frac{114.6q\ (1/tm)}{s}$$

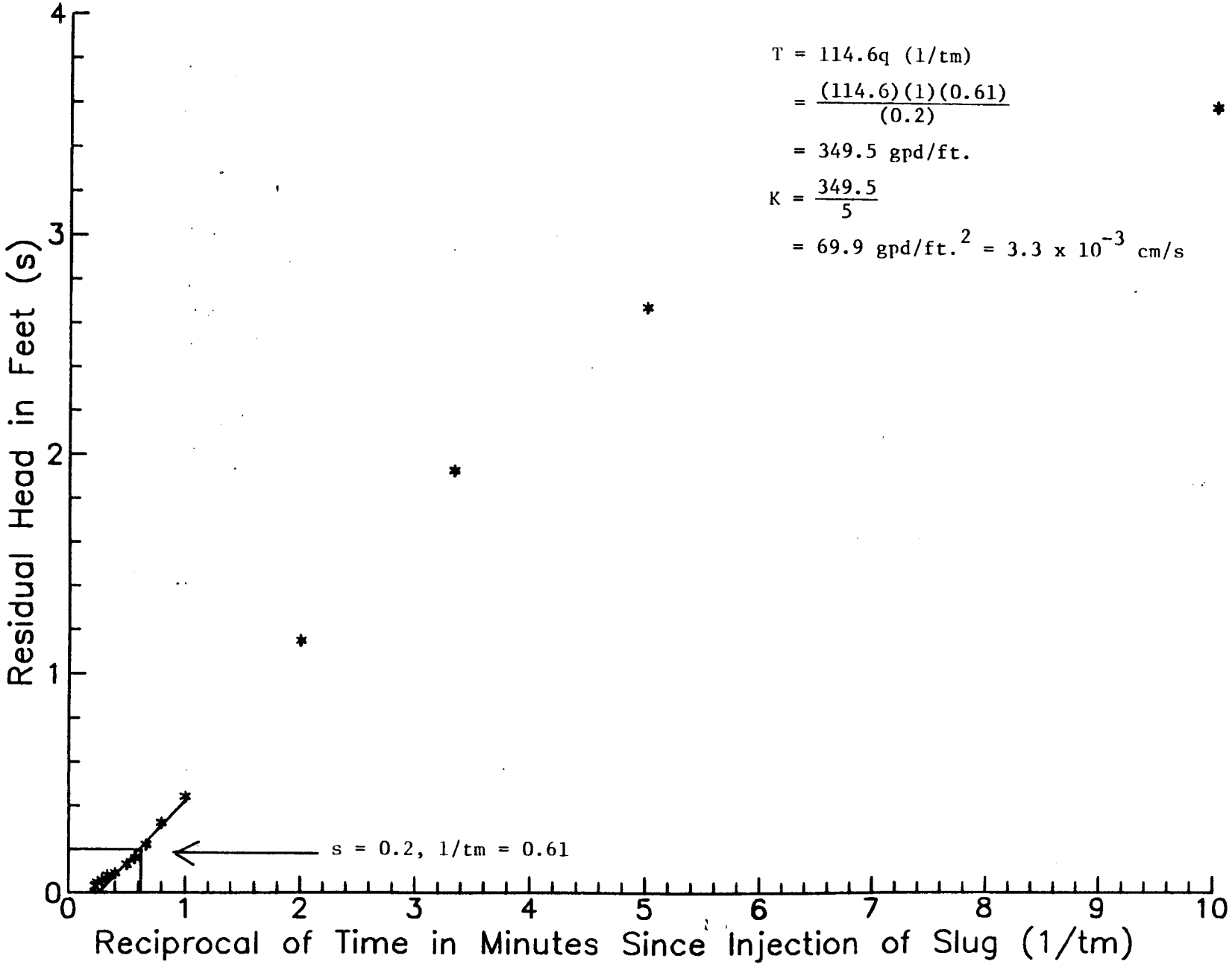
$$= \frac{(114.6)(1)(0.70)}{(0.2)}$$

$$= 401.1 \text{ gpd/ft.}$$

$$K = \frac{401.1}{5}$$

$$= 80.2 \text{ gpd/ft.}^2 = 3.8 \times 10^{-3} \text{ cm/s}$$

S-15 SLUG TEST ANALYSIS, HOLLOMAN AFB



$$T = 114.6q \ (1/tm)$$

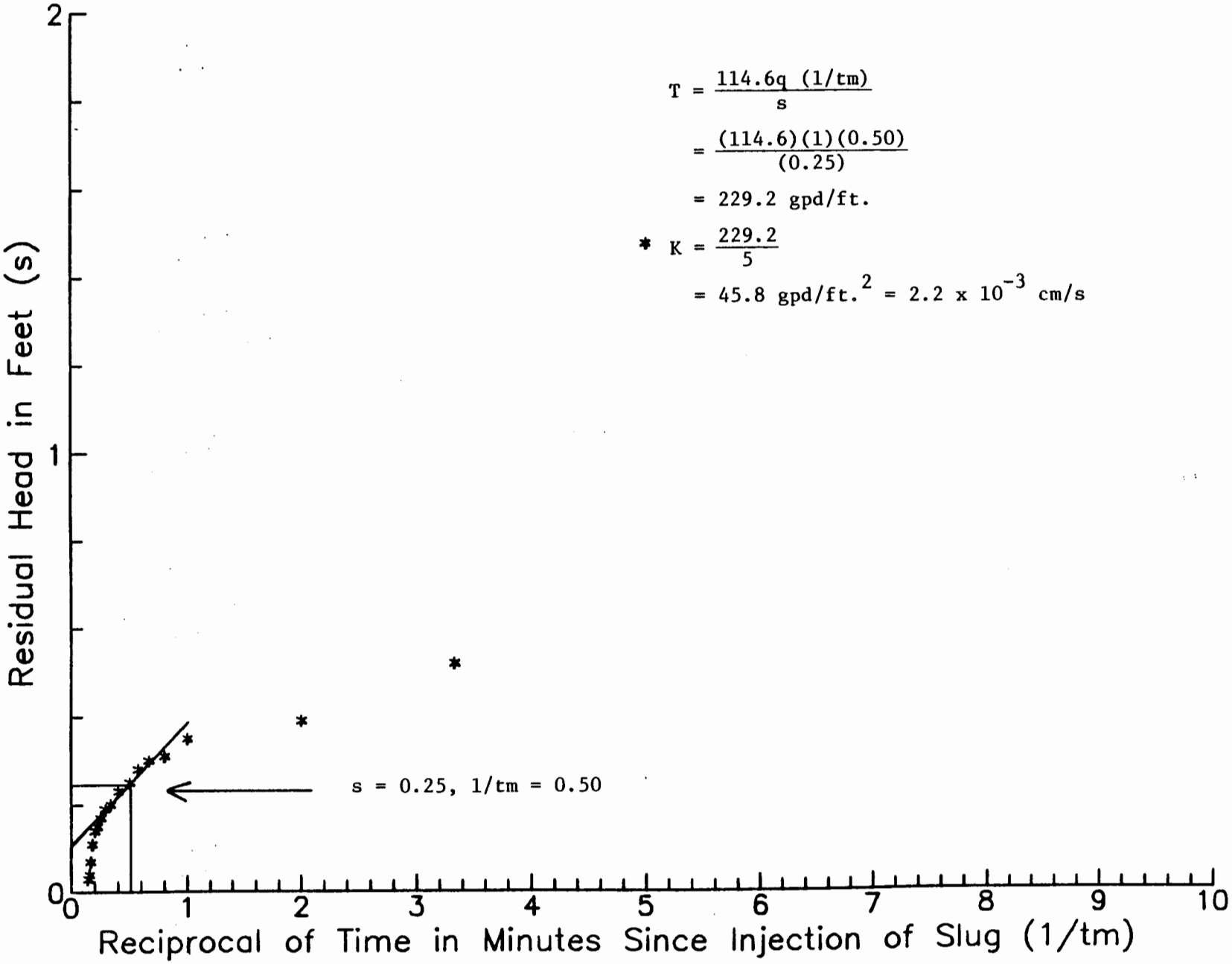
$$= \frac{(114.6)(1)(0.61)}{(0.2)}$$

$$= 349.5 \text{ gpd/ft.}$$

$$K = \frac{349.5}{5}$$

$$= 69.9 \text{ gpd/ft.}^2 = 3.3 \times 10^{-3} \text{ cm/s}$$

S-16 SLUG TEST ANALYSIS, HOLLOMAN AFB



$$T = \frac{114.6q\ (1/tm)}{s}$$

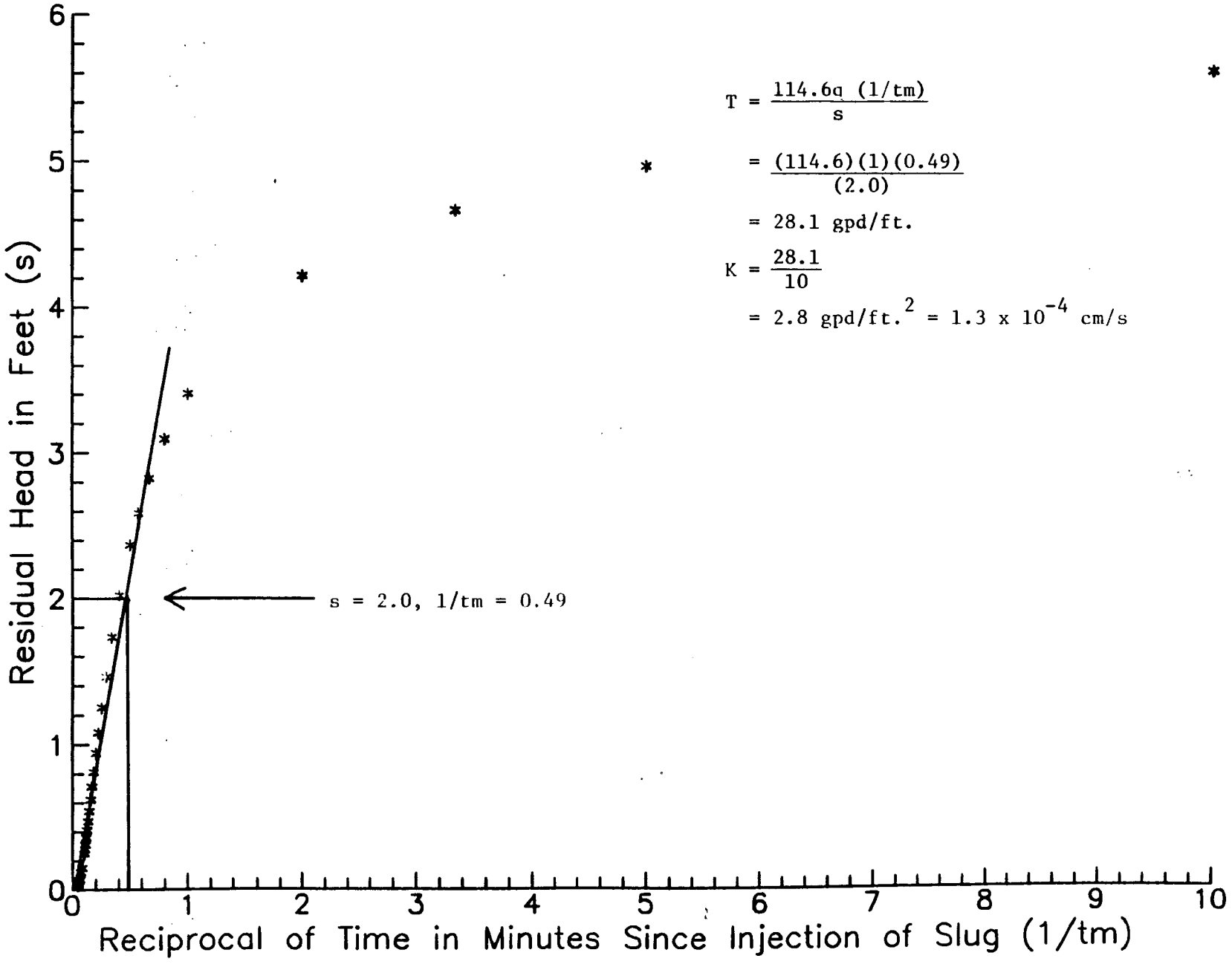
$$= \frac{(114.6)(1)(0.50)}{(0.25)}$$

$$= 229.2 \text{ gpd/ft.}$$

$$* \quad K = \frac{229.2}{5}$$

$$= 45.8 \text{ gpd/ft.}^2 = 2.2 \times 10^{-3} \text{ cm/s}$$

D-2 SLUG TEST ANALYSIS, HOLLOMAN AFB



$$T = \frac{114.6q\ (1/tm)}{s}$$

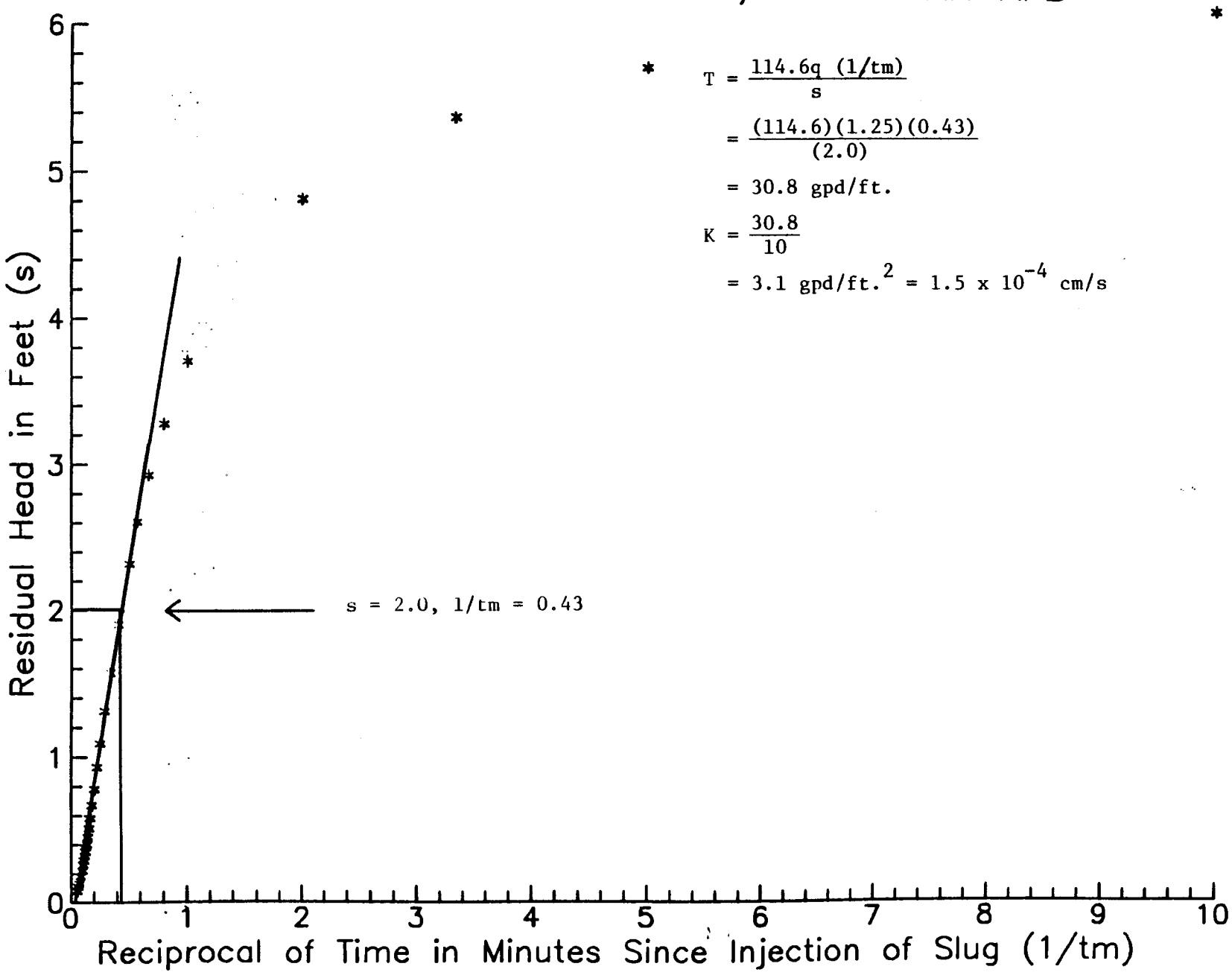
$$= \frac{(114.6)(1)(0.49)}{(2.0)}$$

$$= 28.1 \text{ gpd/ft.}$$

$$K = \frac{28.1}{10}$$

$$= 2.8 \text{ gpd/ft.}^2 = 1.3 \times 10^{-4} \text{ cm/s}$$

D-5 SLUG TEST ANALYSIS, HOLLOMAN AFB



$$T = \frac{114.6q\ (1/tm)}{s}$$

$$= \frac{(114.6)(1.25)(0.43)}{(2.0)}$$

$$= 30.8 \text{ gpd/ft.}$$

$$K = \frac{30.8}{10}$$

$$= 3.1 \text{ gpd/ft.}^2 = 1.5 \times 10^{-4} \text{ cm/s}$$

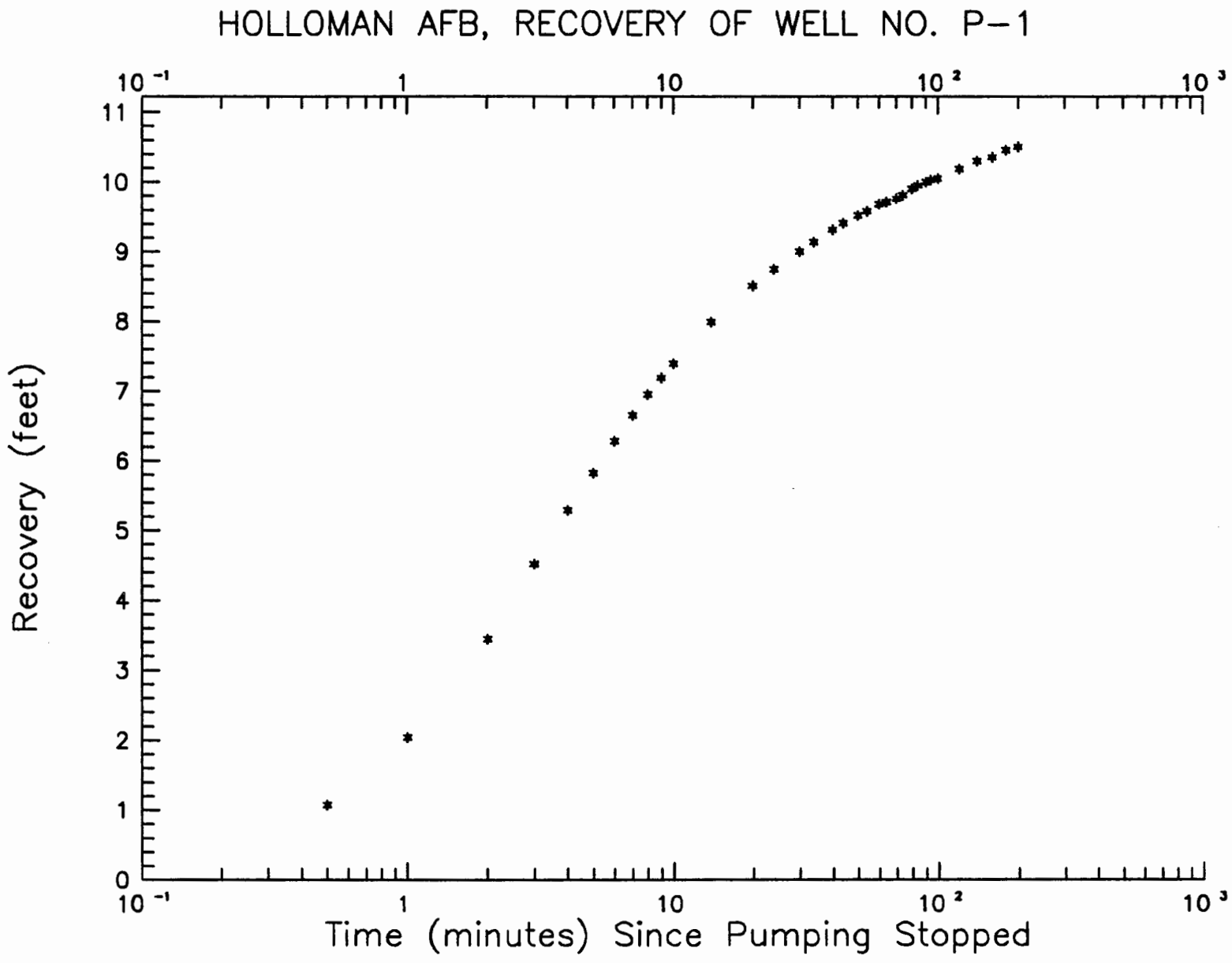
APPENDIX G

RAW PUMP TEST DATA FROM HYDROGEOLOGIC INVESTIGATION HOLLOMAN AFB, NEW MEXICO

UPGRADIENT PUMP TEST RESULTS
COLLECTED 4 NOVEMBER, 1987
FROM WELLS P-1, S-12, AND D-3

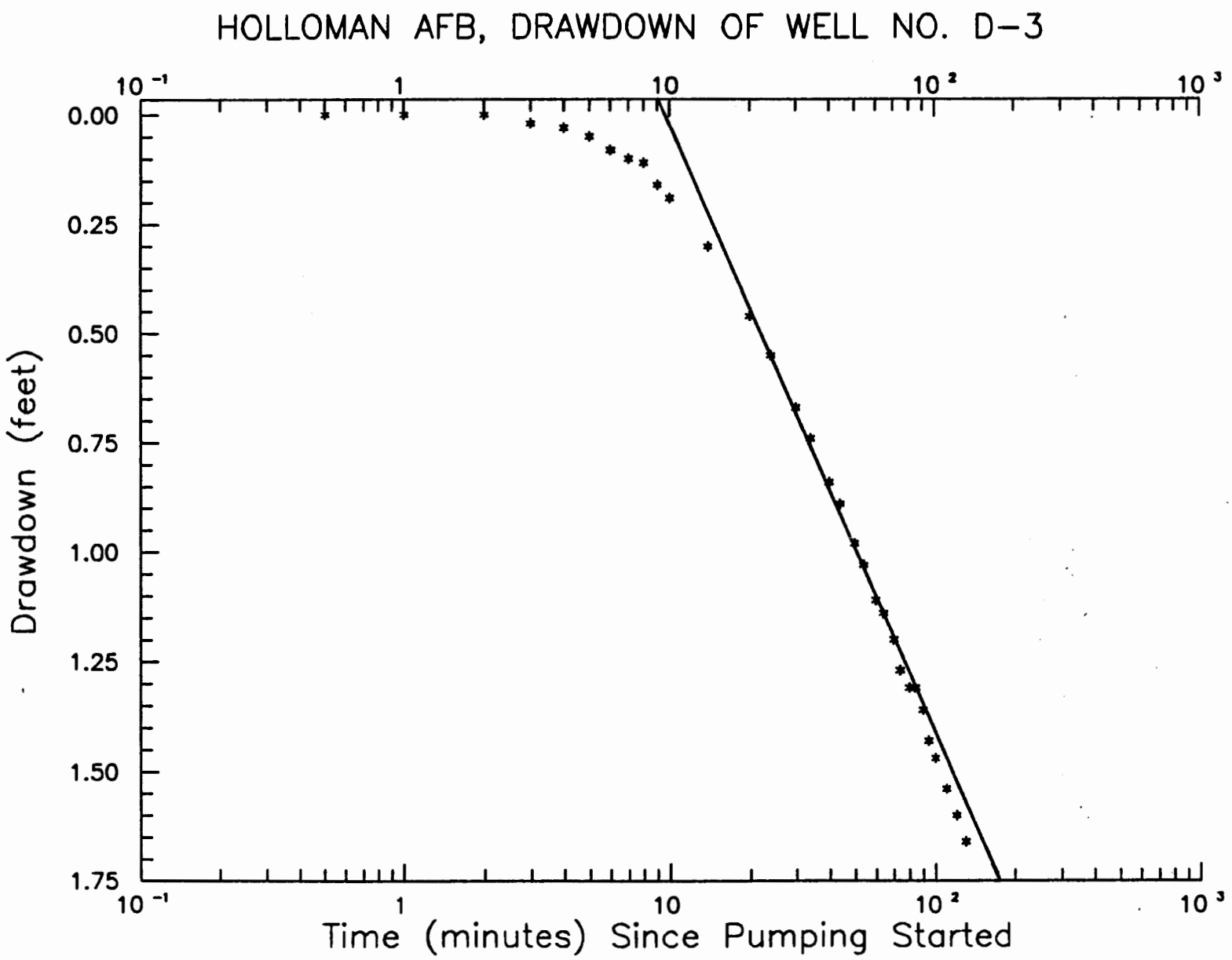
HOLLOMAN RECOVERY TEST FOR
WELL NO. P-1

MINUTES	RECOVERY MEASUREMENT	WATER LEVEL
0.0	0.00	4041.10
0.5	1.08	4042.18
1.0	2.04	4043.14
2.0	3.45	4044.55
3.0	4.52	4045.62
4.0	5.29	4046.39
5.0	5.83	4046.93
6.0	6.28	4047.38
7.0	6.66	4047.76
8.0	6.95	4048.05
9.0	7.19	4048.29
10.0	7.39	4048.49
14.0	7.99	4049.09
20.0	8.31	4049.61
24.0	8.75	4049.85
30.0	9.01	4050.11
34.0	9.14	4050.24
40.0	9.31	4050.41
44.0	9.41	4050.51
50.0	9.52	4050.62
54.0	9.58	4050.68
60.0	9.68	4050.78
64.0	9.71	4050.81
70.0	9.76	4050.86
74.0	9.81	4050.91
80.0	9.90	4051.00
84.0	9.95	4051.05
90.0	10.00	4051.10
94.0	10.03	4051.13
100.0	10.05	4051.15
120.0	10.18	4051.28
140.0	10.30	4051.40
160.0	10.35	4051.45
180.0	10.45	4051.55
200.0	10.50	4051.60


HOLLOMAN AFB, RECOVERY OF WELL NO. P-1
Recovery (feet)
Time (minutes) Since Pumping Stopped
0
1
2
3
4
5
6
7
8
9
10
11
10^{-1}
1
10
10^{2}
10^{3}

HOLLOMAN DRAWDOWN TEST FOR
WELL NO. D-3

MINUTES	DRAWDOWN MEASUREMENT	WATER LEVEL
0.0	0.00	4041.36
0.5	0.00	4041.36
1.0	0.00	4041.36
2.0	0.00	4041.36
3.0	0.02	4041.34
4.0	0.03	4041.33
5.0	0.05	4041.31
6.0	0.08	4041.28
7.0	0.10	4041.26
8.0	0.11	4041.25
9.0	0.16	4041.20
10.0	0.19	4041.17
14.0	0.30	4041.06
20.0	0.46	4040.90
24.0	0.55	4040.81
30.0	0.67	4040.69
34.0	0.74	4040.62
40.0	0.84	4040.52
44.0	0.89	4040.47
50.0	0.98	4040.38
54.0	1.03	4040.33
60.0	1.11	4040.25
64.0	1.14	4040.22
70.0	1.20	4040.16
74.0	1.27	4040.09
80.0	1.31	4040.05
84.0	1.31	4040.05
90.0	1.36	4040.00
94.0	1.43	4039.93
100.0	1.47	4039.89
110.0	1.54	4039.82
120.0	1.60	4039.76
130.0	1.66	4039.70


HOLLOMAN AFB, DRAWDOWN OF WELL NO. D-3
Drawdown (feet)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
10 -1
1
10
10 2
10 3
Time (minutes) Since Pumping Started

AQUIFER TEST DATA

Owner Holloman AFB Address Alamogordo [redacted] County Doña Ana State NM

Date 11/4/87 Company performing test Radian Corp. Measured by GDH, WJR, TKW

Well No. D-3 Distance from pumping well 77' Type of test pump test Test No. 2

Measuring equipment

Time Data
Pump on: Date 11/4 Time _____ (t_0)
Pump off: Date _____ Time _____ (t'_0)
Duration of aquifer test:
Pumping _____ Recovery _____

Water Level Data
Static water level 6' 3/8"
Measuring point TOC
Elevation of measuring point 4047.41

Discharge Data
How Q measured bucket/watch
Depth of pump/air line
Previous pumping? Yes ✓ No ____
Duration _____ End _____

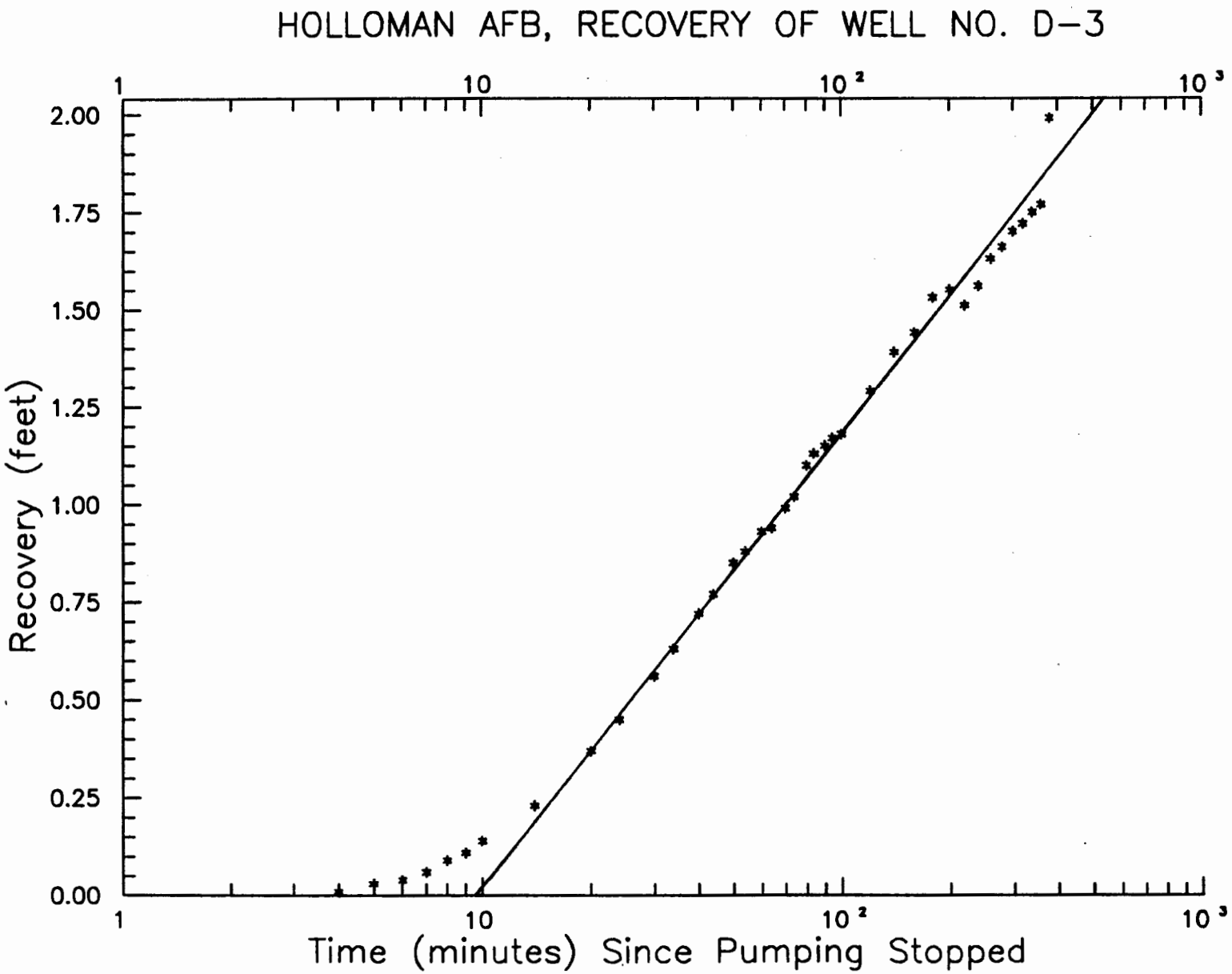
Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		
11/4	740	0				4041.38					2	gpm		start 7:39 18
	750	10				4041.17								
	800	20				4040.90					2	gpm		
	810	30				4040.69								
	820	40				4040.52								
	830	50				4040.38					2	gpm		
	840	60				4040.25								
	850	70				4040.16								
	900	80				4040.05								
	910	90				4040.00								
	920	100				4039.89					2	gpm		
	930	110				4039.82								Water Temp. 21°C
	940	120				4039.76								9:39:18
	950	130				4039.70								Last Reading 9:49:18 Pump off at ~
	1000	140												start ~~Test~~ Step 1 at 9:50.58 Last 3min 40sec.
	1010	150												
	1020	160									2	gpm		
	1030	170									2	gpm		~10:26:30 → 10:29:30 Pump off Reset etc to get back in
														Readjust pump rate to 2 gpm
														Pump off 10:40 → 10:43
														Readjust ~~2p~~ 2gpm
														10:55 generator runs smooth
														Pump off 10:56-10:59
														1134 start recovery

5-12
7'5 1/8"

HOLLOMAN RECOVERY TEST FOR
WELL NO. D-3

MINUTES	RECOVERY MEASUREMENT	WATER LEVEL
0.0	0.00	4041.38
0.5	0.00	4041.38
1.0	-0.02	4041.36
2.0	-0.02	4041.36
3.0	0.00	4041.38
4.0	0.01	4041.39
5.0	0.03	4041.41
6.0	0.04	4041.42
7.0	0.06	4041.44
8.0	0.09	4041.47
9.0	0.11	4041.49
10.0	0.14	4041.52
14.0	0.23	4041.61
20.0	0.37	4041.75
24.0	0.45	4041.83
30.0	0.56	4041.94
34.0	0.63	4042.01
40.0	0.72	4042.10
44.0	0.77	4042.15
50.0	0.85	4042.23
54.0	0.88	4042.26
60.0	0.93	4042.31
64.0	0.94	4042.32
70.0	0.99	4042.37
74.0	1.02	4042.40
80.0	1.10	4042.48
84.0	1.13	4042.51
90.0	1.15	4042.53
94.0	1.17	4042.55
100.0	1.18	4042.56
120.0	1.29	4042.67
140.0	1.39	4042.77
160.0	1.44	4042.82
180.0	1.53	4042.91
200.0	1.55	4042.93
220.0	1.51	4042.89
240.0	1.56	4042.94
260.0	1.63	4043.01
280.0	1.66	4043.04
300.0	1.70	4043.08
320.0	1.72	4043.10
340.0	1.75	4043.13
360.0	1.77	4043.15
380.0	1.99	4043.37


HOLLOMAN AFB, RECOVERY OF WELL NO. D-3
Recovery (feet)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1
10
10 ²
10 ³
Time (minutes) Since Pumping Stopped

AQUIFER TEST DATA

Owner _____ Address _____ County _____ State _____

'e _____ Company performing test _____ Measured by _____

Well No. D-3 Distance from pumping well 77' Type of test recovery test Test No. _____

Measuring equipment Pressure Transducer

Time Data
Pump on: Date _____ Time _____ (t_0)
Pump off: Date _____ Time _____ (t'_0)
Duration of aquifer test:
Pumping _____ Recovery _____

Water Level Data
Static water level _____
Measuring point _____
Elevation of measuring point _____

Discharge Data
How Q measured _____
Depth of pump/air line _____
Previous pumping? Yes ____ No ____
Duration _____ End _____

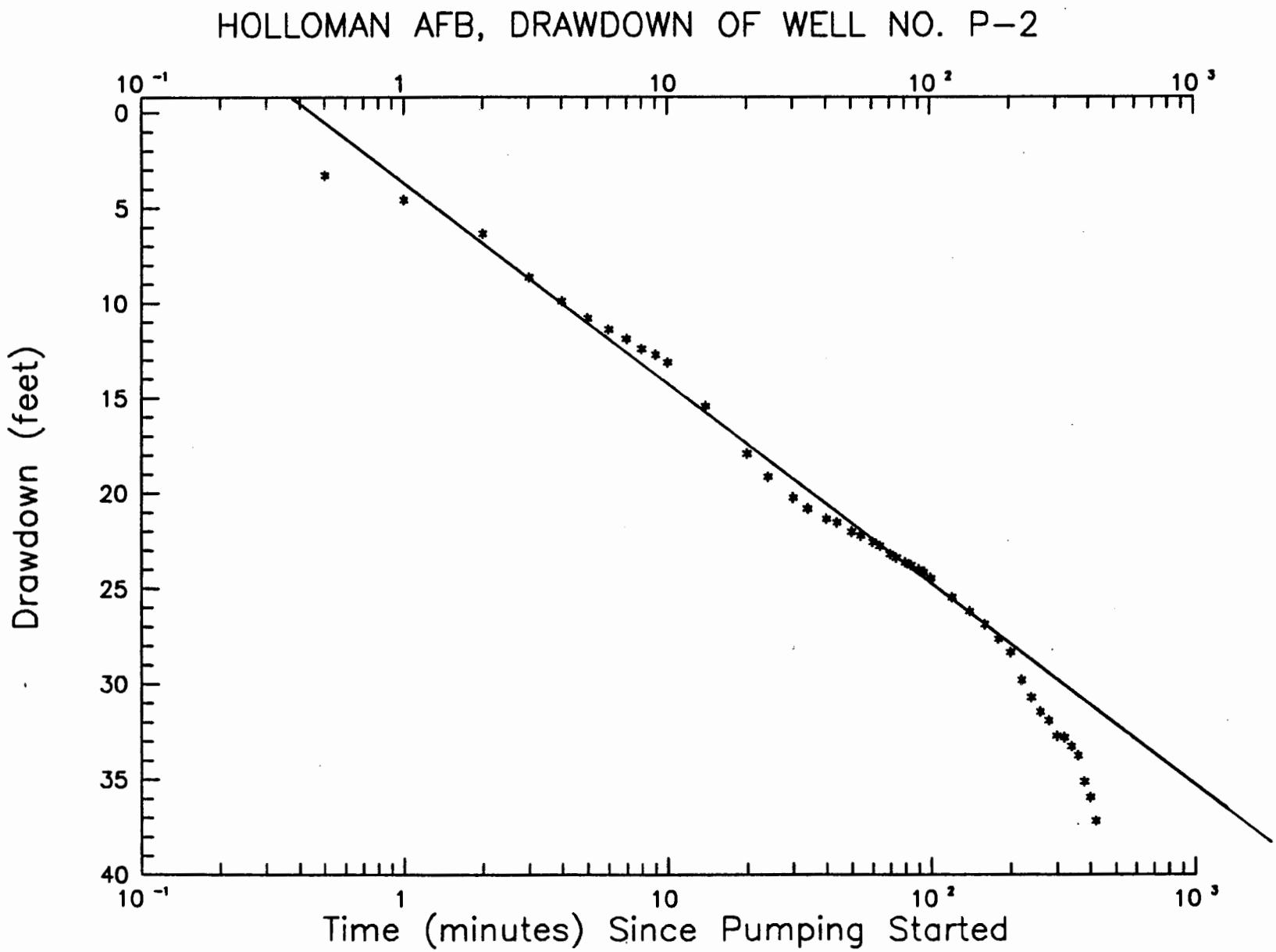
Comments on factors affecting test data: 4041.38 Data logger; 4041.56 12 min

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		
11/4	1134		0			4041.38						0		began recovery test
	1142		12			4041.50								
	1154		24			4041.83								
			36			4042.04								
			48			4042.20								
	1241		60			4042.31								
			72			4042.39								
			130			4042.67								
			140			4042.77								
			150			4042.77								
			160			4042.82								
			170			4042.85								
			180			4042.91								
			190			4042.89								
			200			4042.93								
			210			4042.88								
			220			4042.89								
			230			4042.91								
			240			4042.94								
			250			4042.97								
			260			4043.01								
			270											
			280			4043.04								
			290											
			300			4043.08								
			320			4043.10								
			340			4043.13								
			360			4043.15								

DOWNGRADIENT PUMP TEST RESULTS
COLLECTED 5 NOVEMBER, 1987
FROM WELLS P-2, D-4, S-13, AND S-14

HOLLOMAN DRAWDOWN TEST FOR
WELL NO. P-2

MINUTES	DRAWDOWN MEASUREMENT	WATER LEVEL
0.0	0.00	4023.86
0.5	3.27	4020.59
1.0	4.57	4019.29
2.0	6.34	4017.52
3.0	8.63	4015.23
4.0	9.89	4013.97
5.0	10.80	4013.06
6.0	11.38	4012.48
7.0	11.89	4011.97
8.0	12.41	4011.45
9.0	12.73	4011.13
10.0	13.13	4010.73
14.0	15.43	4008.43
20.0	17.93	4005.93
24.0	19.14	4004.72
30.0	20.23	4003.63
34.0	20.82	4003.04
40.0	21.35	4002.51
44.0	21.54	4002.32
50.0	22.04	4001.82
54.0	22.24	4001.62
60.0	22.58	4001.28
64.0	22.79	4001.07
70.0	23.22	4000.64
74.0	23.39	4000.47
80.0	23.65	4000.21
84.0	23.79	4000.07
90.0	24.02	3999.84
94.0	24.16	3999.70
100.0	24.48	3999.38
120.0	25.49	3998.37
140.0	26.21	3997.65
160.0	26.89	3996.97
180.0	27.66	3996.20
200.0	28.35	3995.51
220.0	29.80	3994.06
240.0	30.71	3993.15
260.0	31.46	3992.40
280.0	31.91	3991.95
300.0	32.73	3991.13
320.0	32.81	3991.05
340.0	33.27	3990.59
360.0	33.75	3990.11
380.0	35.11	3988.75
400.0	35.94	3987.92
420.0	37.17	3986.69


HOLLOMAN AFB, DRAWDOWN OF WELL NO. P-2
Drawdown (feet)
Time (minutes) Since Pumping Started
0
5
10
15
20
25
30
35
40
10 -1
1
10
10 2
10 3

HOLLOMAN RECOVERY TEST FOR
WELL NO. P-2

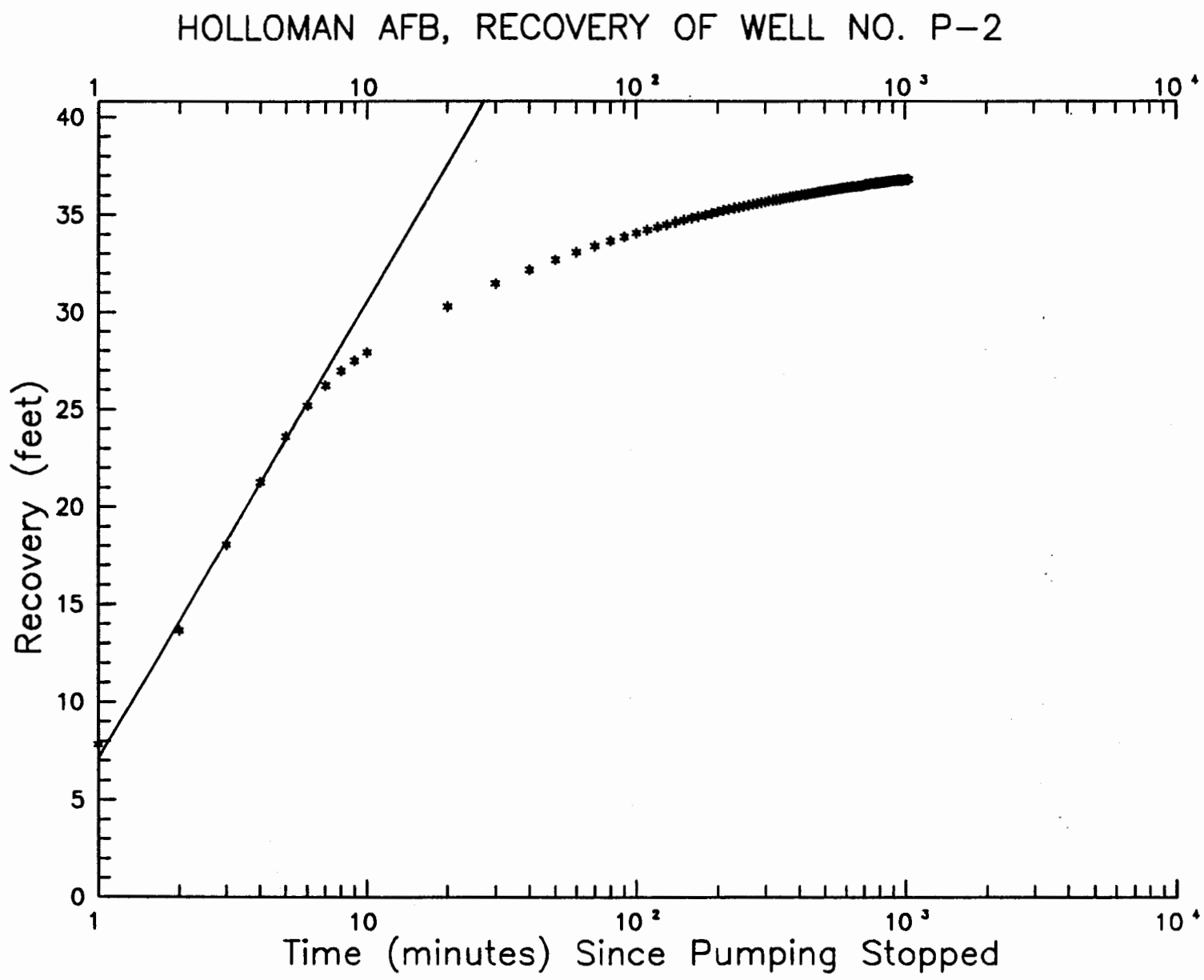
MINUTES	RECOVERY MEASUREMENT	WATER LEVEL
0	0.00	3987.06
1	7.84	3994.90
2	13.65	4000.71
3	18.06	4005.12
4	21.25	4008.31
5	23.59	4010.65
6	25.18	4012.24
7	26.21	4013.27
8	26.96	4014.02
9	27.49	4014.55
10	27.92	4014.98
20	30.30	4017.36
30	31.48	4018.54
40	32.18	4019.24
50	32.70	4019.76
60	33.10	4020.16
70	33.40	4020.46
80	33.66	4020.72
90	33.88	4020.94
100	34.07	4021.13
110	34.23	4021.29
120	34.37	4021.43
130	34.50	4021.56
140	34.63	4021.69
150	34.74	4021.80
160	34.84	4021.90
170	34.92	4021.98
180	35.00	4022.06
190	35.08	4022.14
200	35.16	4022.22
210	35.22	4022.28
220	35.29	4022.35
230	35.35	4022.41
240	35.40	4022.46
250	35.45	4022.51
260	35.49	4022.55
270	35.54	4022.60
280	35.59	4022.65
290	35.64	4022.70
300	35.67	4022.73
310	35.72	4022.78
320	35.75	4022.81
330	35.78	4022.84
340	35.81	4022.87
350	35.84	4022.90
360	35.88	4022.94
370	35.91	4022.97
380	35.94	4023.00
390	35.97	4023.03
400	35.99	4023.05
410	36.02	4023.08
420	36.04	4023.10
430	36.07	4023.13
440	36.08	4023.14

HOLLOMAN RECOVERY TEST FOR
WELL NO. P-2

MINUTES	RECOVERY MEASUREMENT	WATER LEVEL
450	36.12	4023.18
460	36.13	4023.19
470	36.15	4023.21
480	36.18	4023.24
490	36.20	4023.26
500	36.21	4023.27
510	36.24	4023.30
520	36.26	4023.32
530	36.28	4023.34
540	36.29	4023.35
550	36.31	4023.37
560	36.32	4023.38
570	36.34	4023.40
580	36.36	4023.42
590	36.37	4023.43
600	36.39	4023.45
610	36.40	4023.46
620	36.42	4023.48
630	36.44	4023.50
640	36.45	4023.51
650	36.45	4023.51
660	36.47	4023.53
670	36.48	4023.54
680	36.48	4023.54
690	36.50	4023.56
700	36.53	4023.59
710	36.55	4023.61
720	36.56	4023.62
730	36.56	4023.62
740	36.58	4023.64
750	36.60	4023.66
760	36.60	4023.66
770	36.61	4023.67
780	36.63	4023.69
790	36.64	4023.70
800	36.64	4023.70
810	36.66	4023.72
820	36.68	4023.74
830	36.68	4023.74
840	36.68	4023.74
850	36.69	4023.75
860	36.71	4023.77
870	36.71	4023.77
880	36.72	4023.78
890	36.72	4023.78
900	36.74	4023.80
910	36.74	4023.80
920	36.74	4023.80
930	36.76	4023.82
940	36.77	4023.83
950	36.77	4023.83
960	36.77	4023.83
970	36.77	4023.83
980	36.79	4023.85

HOLLOMAN RECOVERY TEST FOR
WELL NO. P-2

MINUTES	RECOVERY MEASUREMENT	WATER LEVEL
990	36.79	4023.85
100	36.80	4023.86
1010	36.80	4023.86
1020	36.80	4023.86
1030	36.80	4023.86


HOLLOMAN AFB, RECOVERY OF WELL NO. P-2
Recovery (feet)
Time (minutes) Since Pumping Stopped
0
5
10
15
20
25
30
35
40
1
10
10 ²
10 ³
10 ⁴

AQUIFER TEST DATA

Owner Holloman AFB Address Alamogordo, NM County _____ State _____

e 11/5/87 Company performing test Radian Corp. Measured by WJR, TKW, GDH

Well No. P-2 Distance from pumping well NA Type of test Pump test - Test No. 1

Measuring equipment Hermit 2000 Environmental Data Logger with pressure transducers

Time Data
Pump on: Date 11/5 Time 755 (t_0)
Pump off: Date 11/5 Time 1455 (t'_0)
Duration of aquifer test:
Pumping 7 hrs Recovery _____

Water Level Data
Static water level 4024.38
Measuring point TOC
Elevation of measuring point _____

Discharge Data
How Q measured Bucket/stopwatch
Depth of pump/air line _____
Previous pumping? Yes X No _____
Duration 20 min End 1200 11/4/87

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	t' Water level	Water level change s or s'	WL	Discharge measurement	Rate		Comments
11/5/87	755	0		5gpm		4023.86	0	200		3995.51		28.35		Raining - light
		1				4019.29	4.57	210		3994.71		29.15		
		2				4017.52	6.34	220		3994.06		29.80		
		3				4015.23	8.63	230		3993.47		30.39		
		4				4013.97	9.89	240		3993.15		30.71	5 gpm	
	0800	5				4013.06	10.80	250		3992.89		30.97		
		6				4012.48	11.38	260		3992.40		31.46		
		7				4011.97	11.89	270		3992.24		31.62		
		8				4011.45	12.41	280		3991.95		31.91		
		9				4011.13	12.73	290		3991.55		32.31		
	0805	10				4010.73	13.13	300		3991.13		32.73		
		20				4005.93	17.93	310		3990.54		33.32		
		30				4003.63	20.23	320		3991.05		32.81		
		40				4002.51	21.35	330		3990.62		33.24		
		50				4001.82	22.04	340		3990.59		33.27		
	0855	60		5gpm		4001.28	22.58	350		3990.46		33.40		Not raining
		70				4000.64	23.22	360		3990.11		33.75	5 gpm	
		80				4000.21	23.65	370		3989.34		34.52		
		90				3999.84	24.02	380		3988.75		35.11		
		100				3999.38	24.48	390		3988.16		35.70		
		110				3999.14	24.72	400		3987.92		35.94		
	0955	120				3998.37	25.49	410		3987.36		36.50		
		130				3997.92	25.94	420		3986.69		37.17		
		140				3997.65	26.21							
		150				3997.30	26.56							
		160				3996.97	26.89							
		170				3996.39	27.49							
	1055	180				3996.20	27.66							
		190				3996.04	27.82							

AQUIFER TEST DATA

Owner _____ Address _____ County _____ State _____

'e _____ Company performing test _____ Measured by _____

Well No. P-2 Distancè from pumping well _____ Type of test _____ Test No. _____

Measuring equipment _____

Time Data
Pump on: Date _____ Time _____ (t_0)
Pump off: Date _____ Time _____ (t'_0)
Duration of aquifer test:
Pumping _____ Recovery _____

Water Level Data
Static water level _____
Measuring point _____
Elevation of measuring point _____

Discharge Data
How Q measured _____
Depth of pump/air line _____
Previous pumping? Yes ____ No ____
Duration _____ End _____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		
11/5/87	1455		0			3987.	06							
			1			3994.	90							
			2			4000.	71							
			3			4005.	12							
			4			4008.	31							
			5			4010.	65							
			6			4012.	24							
			7			4013.	27							
			8			4014.	02							
			9			4014.	55							
			10			4014.	98							
			20			4017.	36							
			30			4018.	54							
			40			4019.	34							
			50			4019.	76							
			60			4020.	16							
			70			4020.	46							
			80			4020.	72							
			90			4020.	94							
			100			4021.	13							
			110			4021.	29							
			120			4021.	43							
			130			4021.	56							
			140			4021.	69							
			150			4021.	80							
			160			4021.	90							
			170			4021.	98							
			180			4022.	06							
			190			4022.	14							

AQUIFER TEST DATA

Owner _____ Address _____ County _____ State _____

Date _____ Company performing test _____ Measured by _____

No. P-2 Distance from pumping well _____ Type of test _____ Test No. _____

Measuring equipment _____

Time Data
Pump on: Date _____ Time _____ (t_1)
Pump off: Date _____ Time _____ (t_1')
Duration of aquifer test:
Pumping _____ Recovery _____

Water Level Data
Static water level _____
Measuring point _____
Elevation of measuring point _____

Discharge Data
How Q measured _____
Depth of pump/air line _____
Previous pumping? Yes ____ No ____
Duration _____ End _____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		
			200			4022.	22							
			210			4022.	28							
			220			4022	35							
			230			4022.	41							
			240			4022.	46							
			250			4022.	51							
			260			4022.	55							
			270			4022.	60							
			280			4022.	65							
			290			4022.	70							
			300			4022.	73							
			310			4022.	78							
			320			4022.	81							
			330			4022.	84							
			340			4022.	87							
			350			4022.	90							
			360			4022.	94							
			370			4022.	97							
			380			4023.	00							
			390			4023.	03							
			400			4023.	05							
			410			4023.	08							
			420			4023.	10							
			430			4023.	13							
			440			4023.	14							
			450			4023.	18							
			460			4023.	19							
			470			4023.	21							
			480			4023.	24							

AQUIFER TEST DATA

Owner _____ Address _____ County _____ State _____

Date _____ Company performing test _____ Measured by _____

No. P-2 Distance from pumping well _____ Type of test _____ Test No. _____

Measuring equipment _____

Time Data
Pump on: Date _____ Time _____ (t)
Pump off: Date _____ Time _____ (t')
Duration of aquifer test:
Pumping _____ Recovery _____

Water Level Data
Static water level _____
Measuring point _____
Elevation of measuring point _____

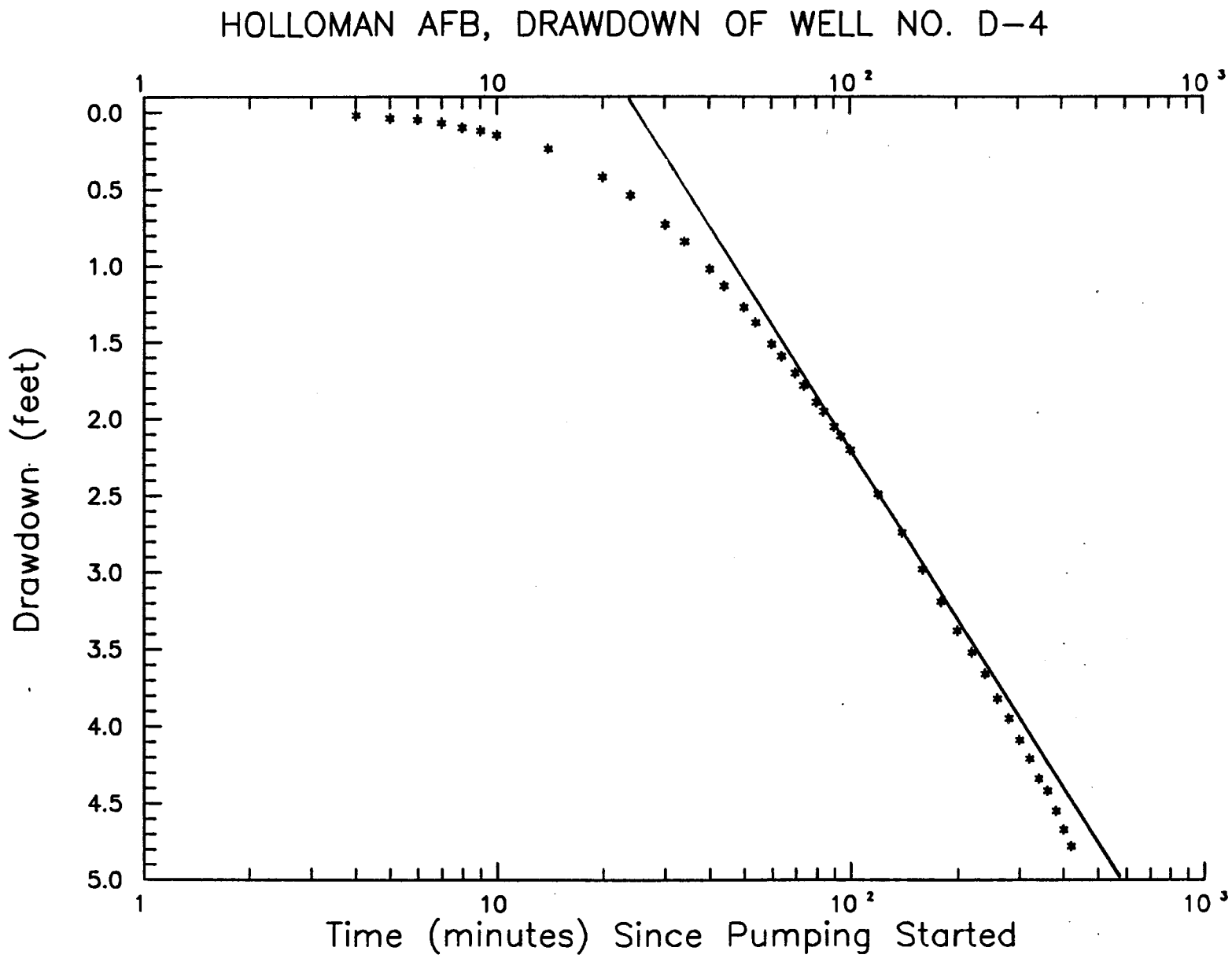
Discharge Data
How Q measured _____
Depth of pump/air line _____
Previous pumping? Yes ____ No ____
Duration _____ End _____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'	t'	Discharge measurement	W.L. Rate		
			490			4023.	26			780		4023.69		
			500			4023.	27			790		4023.70		
			510			4023.	30			800		4023.70		
			520			4023.	32			810		4023.72		
			530			4023.	34			820		4023.74		
			540			4023.	35			830		4023.74		
			550			4023.	37			840		4023.74		
			560			4023.	38			850		4023.75		
			570			4023.	40			860		4023.77		
			580			4023.	42			870		4023.77		
			590			4023.	43			880		4023.78		
			600			4023.	45			890		4023.78		
			610			4023.	46			900		4023.80		
			620			4023.	48			910		4023.80		
			630			4023.	50			920		4023.80		
			640			4023.	51			930		4023.82		
			650			4023.	51			940		4023.83		
			660			4023.	53			950		4023.83		
			670			4023.	54			960		4023.83		
			680			4023.	54			970		4023.83		
			690			4023.	56			980		4023.85		
			700			4023.	59			990		4023.85		
			710			4023.	61			1000		4023.86		
			720			4023.	62			1010		4023.86		
			730			4023.	62			1020		4023.86		
			740			4023.	64			1030		4023.86		
			750			4023.	66							
			760			4023.	66							
			770			4023	67							

HOLLOMAN DRAWDOWN TEST FOR
WELL NO. D-4

MINUTES	DRAWDOWN MEASUREMENT	WATER LEVEL
0.0	0.00	4024.36
0.5	0.00	4024.36
1.0	0.00	4024.36
2.0	0.00	4024.36
3.0	0.00	4024.36
4.0	0.02	4024.34
5.0	0.04	4024.32
6.0	0.05	4024.31
7.0	0.07	4024.29
8.0	0.10	4024.26
9.0	0.12	4024.24
10.0	0.15	4024.21
14.0	0.24	4024.12
20.0	0.42	4023.94
24.0	0.54	4023.82
30.0	0.73	4023.63
34.0	0.84	4023.52
40.0	1.02	4023.34
44.0	1.13	4023.23
50.0	1.27	4023.09
54.0	1.37	4022.99
60.0	1.51	4022.85
64.0	1.59	4022.77
70.0	1.70	4022.66
74.0	1.78	4022.58
80.0	1.89	4022.47
84.0	1.95	4022.41
90.0	2.05	4022.31
94.0	2.11	4022.25
100.0	2.20	4022.16
120.0	2.49	4021.87
140.0	2.74	4021.62
160.0	2.98	4021.38
180.0	3.19	4021.17
200.0	3.38	4020.98
220.0	3.52	4020.84
240.0	3.66	4020.70
260.0	3.82	4020.54
280.0	3.95	4020.41
300.0	4.09	4020.27
320.0	4.21	4020.15
340.0	4.34	4020.02
360.0	4.42	4019.94
380.0	4.55	4019.81
400.0	4.67	4019.69
420.0	4.78	4019.58


HOLLOMAN AFB, DRAWDOWN OF WELL NO. D-4
Drawdown (feet)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
1
10
10 ²
10 ³
Time (minutes) Since Pumping Started

AQUIFER TEST DATA

Owner HOLLOMAN AFB – ACOE Address Alamogordo County Otero State N.M.

Date 11/5/87 Company performing test Radian Corp. Measured by WJR, TKW, GDH

Well No. D-4 Distance from pumping well 102' Type of test Pump test - Test No. 1

XD-2

Measuring equipment Hermit 2000 Environmental Data Logger

Time Data
Pump on: Date 11/5 Time 0755 (t_0)
Pump off: Date 11/5 Time 1455 (t'_0)
Duration of aquifer test:
Pumping 7 hrs Recovery

Water Level Data
Static water level 4024.36
Measuring point TOC
Elevation of measuring point

Discharge Data
How Q measured Bucket/stopwatch
Depth of pump/air line
Previous pumping? Yes ✓ No
Duration 20 min End 1700 11/4/87

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		
11/5/87	755	0				4024.36			0		5	gpm		Raining - light
		1				4024.36			0					
		2				4024.36			0					
		3				4024.36			0					
		4				4024.34			0.02					
		5				4024.32			0.04					
		6				4024.31			0.05					
		7				4024.29			0.07					
		8				4024.26			0.10					
		9				4024.24			0.12					
		10				4024.21			0.15					
		20				4023.94			0.42					
		30				4023.63			0.73					
		40				4023.34			1.02					
		50				4023.09			1.27					
		60				4022.85			1.51		5	gpm		Not raining
		70				4022.66			1.70					
		80				4022.47			1.89					
		90				4022.31			2.05					
		100				4022.16			2.20					
		110				4022.01			2.35					
		120				4021.87			2.49					
		130				4021.74			2.62					
		140				4021.62			2.74					
		150				4021.49			2.87					
		[illegible]				4021.38			2.98					
		[illegible]				4021.27			3.09					
		180				4021.17			3.19					
		190				4021.08			3.28					

AQUIFER TEST DATA

Owner HOLLOMAN AFB - ACOE Address Alamogordo County Otero State N.M.

11/5/87 Company performing test Radian Corp. Measured by WJR, TKW, GDH

Well No. D-4 Distance from pumping well 102' Type of test Pump Test Test No. 1

Measuring equipment Hermit 2000 Environmental Data logger with Pressure Transducers

Time Data
Pump on: Date 0' Time 0755 (t_0)
Pump off: Date ____ Time 1455 (t'_0)
Duration of aquifer test:
Pumping 7 hrs Recovery ____

Water Level Data
Static water level 4024.36
Measuring point TOC
Elevation of measuring point ____

Discharge Data
How Q measured ____
Depth of pump/air line ____
Previous pumping? Yes ____ No ____
Duration ____ End ____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		
		200				4021.98			3.38					
		210				4020.92			3.44					
		220				4020.84			3.52					
		230				4020.78			3.58					
		240				4020.70			3.66					
		250				4020.64			3.72					
		260				4020.54			3.82					
		270				4020.51			3.85					
		280				4020.41			3.95					
		290				4020.35			4.01					
		300				4020.27			4.09					
		310				4020.19			4.17					
		320				4020.15			4.21					
		330				4020.08			4.28					
		340				4020.02			4.34					
		350				4019.99			4.37					
		360				4019.94			4.42		5	gpm		
		370				4019.86			4.50					
		380				4019.81			4.55					
		390				4019.75			4.61					
		400				4019.69			4.67					
		410				4019.64			4.72					
		420				4019.58			4.78					End Test - pumping

AQUIFER TEST DATA

Owner _____ Address _____ County _____ State _____

Date _____ Company performing test _____ Measured by _____

(2)

No. D-4 Distance from pumping well _____ Type of test _____ Test No. _____

Measuring equipment _____

Time Data

Pump on: Date _____ Time _____ (t_0)
Pump off: Date _____ Time _____ (t'_0)
Duration of aquifer test:
Pumping _____ Recovery _____

Water Level Data

Static water level _____
Measuring point _____
Elevation of measuring point _____

Discharge Data

How Q measured _____
Depth of pump/air line _____
Previous pumping? Yes ____ No ____
Duration _____ End _____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		
11/5	1455		0			4019.58								
			1			4019.56								
			2			4019.56								
			3			4019.56								
			4			4019.58								
			5			4019.56								
			6			4019.58								
			7			4019.59								
			8			4019.59								
			9			4019.65								
			10			4019.67								
			20			4019.99								
			30			4020.30								
			40			4020.57								
			50			4020.83								
			60			4021.02								
			70			4021.21								
			80			4021.36								
			90			4021.51								
			100			4021.63								
			110			4021.74								
			120			4021.85								
			130			4021.95								
			140			4022.03								
			150			4022.12								
			160			4022.19								
			170			4022.27								
			180			4022.33								
			190			4022.39								

AQUIFER TEST DATA

Owner _____ Address _____ County _____ State _____

Date _____ Company performing test _____ Measured by _____

No. D-4 Distance from pumping well _____ Type of test _____ Test No. _____

Measuring equipment _____

Time Data
Pump on: Date _____ Time _____ (t)
Pump off: Date _____ Time _____ (t')
Duration of aquifer test:
Pumping _____ Recovery _____

Water Level Data
Static water level _____
Measuring point _____
Elevation of measuring point _____

Discharge Data
How Q measured _____
Depth of pump/air line _____
Previous pumping? Yes ____ No ____
Duration _____ End _____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		
			200			4022.44								
			210			4022.50								
			220			4022.55								
			230			4022.60								
			240			4022.65								
			250			4022.68								
			260			4022.72								
			270			4022.76								
			280			4022.80								
			290			4022.84								
			300			4022.87								
			310			4022.90								
			320			4022.93								
			330			4022.96								
			340			4022.99								
			350			4023.01								
			360			4023.04								
			370			4023.07								
			380			4023.09								
			390			4023.12								
			400			4023.14								
			410			4023.17								
			420			4023.18								
			430			4023.20								
			440			4023.22								
			450			4023.25								
			460			4023.26								
			470			4023.29								
			480			4023.29								

AQUIFER TEST DATA

Owner _____ Address _____ County _____ State _____

Date _____ Company performing test _____ Measured by _____

No. D-4 Distance from pumping well _____ Type of test _____ Test No. _____

Measuring equipment _____

Time Data
Pump on: Date _____ Time _____ (t_o)
Pump off: Date _____ Time _____ (t'_o)
Duration of aquifer test:
Pumping _____ Recovery _____

Water Level Data
Static water level _____
Measuring point _____
Elevation of measuring point _____

Discharge Data
How Q measured _____
Depth of pump/air line _____
Previous pumping? Yes ____ No ____
Duration _____ End _____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		
			490			4023.31								
			500			4023.33								
			510			4023.36								
			520			4023.37								
			530			4023.39								
			540			4023.39								
			550			4023.42								
			560			4023.44								
			570			4023.45								
			580			4023.45								
			590			4023.48								
			600			4023.48								
			610			4023.50								
			620			4023.52								
			630			4023.53								
			640			4023.53								
			650			4023.55								
			660			4023.56								
			670			4023.58								
			680			4023.58								
			690			4023.60								
			700			4023.63								
			710			4023.63								
			720			4023.63								
			730			4023.64								
			740			4023.66								
			750			4023.66								
			760			4023.67								
			770			4023.69								

AQUIFER TEST DATA

Owner _____ Address _____ County _____ State _____

Date _____ Company performing test _____ Measured by _____

No. D-4 Distance from pumping well _____ Type of test _____ Test No. _____

Measuring equipment _____

Time Data
Pump on: Date _____ Time _____ (t)
Pump off: Date _____ Time _____ (t')
Duration of aquifer test:
Pumping _____ Recovery _____

Water Level Data
Static water level _____
Measuring point _____
Elevation of measuring point _____

Discharge Data
How Q measured _____
Depth of pump/air line _____
Previous pumping? Yes ____ No ____
Duration _____ End _____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		
			780			4023.71								
			790			4023.72								
			800			4023.72								
			810			4023.74								
			820			4023.74								
			830			4023.75								
			840			4023.77								
			850			4023.77								
			860			4023.79								
			870			4023.79								
			880			4023.80								
			890			4023.80								
			900			4023.82								
			910			4023.82								
			920			4023.82								
			930			4023.83								
			940			4023.85								
			950			4023.85								
			960			4023.85								
			970			4023.86								
			980			4023.86								
			990			4023.86								
			1000			4023.88								
			1010			4023.88								
			1020			4023.88								
			1030			4023.88								
			1040			4023.90								
			1050			4023.91								
			1060			4023.91								

AQUIFER TEST DATA

[redacted] County _____ Sta[redacted]

Date 11/5/87 Company performing test Radient Corp. Measured by _____

Well No. S-13 Distance from pumping well 100' Type of test Pump test Test No. 1

Measuring equipment Pressure transducer

Time Data
Pump on: Date _____ Time _____ (t_0)
Pump off: Date _____ Time _____ (t'_0)
Duration of aquifer test:
Pumping _____ Recovery _____

Water Level Data
Static water level 4023.55
Measuring point _____
Elevation of measuring point _____

Discharge Data
How Q measured _____
Depth of pump/air line _____
Previous pumping? Yes ____ No ____
Duration _____ End _____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		Comments
		0				4023.53		[illegible]	[illegible]		5	gpm		Raining - light
		1				4023.53		210	4023.	55				
		2				4023.53		220	4023.	55				
		3				4023.55		230	4023.	55				
		4				4023.55		240	4023.	55	5	gpm		
		5				4023.55		250	4023.	58				
		6				4023.55		260	4023.	53				
		7				4023.55		270	4023.	59				
		8				4023.55		280	4023.	56				
		9				4023.55		290	4023.	58				
		10				4023.55		300	4023.	56				
		20				4023.55		310	4023.	51				
		30				4023.56		320	4023.	56				
		40				4023.55		330	4023.	56				
		50				4023.56		340	4023.	55				
		60				4023.55		350	4023.	56	5	gpm		Not raining
		[illegible]				4023.56		360	4023.	58	5	gpm		Drizzling
		80				4023.55		370	4023.	55				
		90				4023.56		380	4023.	56				
		100				4023.56		390	4023.	55				Cleared up - 1100 hrs
		110				4023.56		400	4023.	56				
		120				4023.56		410	4023.	56				
		130				4023.56		420	4023.	56				
		[illegible]				4023.56								
		[illegible]				"								
		[illegible]				"								
		[illegible]				"								
		150				4023.55								
		190				[illegible]								

Observation Well S-14 Walton(1986) T&S Model

```
DATA BASE:

NUMBER OF KNOWN POINTS= 6
POINT NUMBER= 1
X (TIME)-COORDINATE OF POINT (MIN)= 2.0000D+01
Y (DRAWDOWN)-COORDINATE OF POINT (FT)= 4.0000D-02
POINT NUMBER= 2
X (TIME)-COORDINATE OF POINT (MIN)= 3.6000D+01
Y (DRAWDOWN)-COORDINATE OF POINT (FT)= 6.0000D-02
POINT NUMBER= 3
X (TIME)-COORDINATE OF POINT (MIN)= 9.5000D+01
Y (DRAWDOWN)-COORDINATE OF POINT (FT)= 6.0000D-02
POINT NUMBER= 4
X (TIME)-COORDINATE OF POINT (MIN)= 1.5500D+02
Y (DRAWDOWN)-COORDINATE OF POINT (FT)= 1.1000D-01
POINT NUMBER= 5
X (TIME)-COORDINATE OF POINT (MIN)= 1.8900D+02
Y (DRAWDOWN)-COORDINATE OF POINT (FT)= 1.7000D-01
POINT NUMBER= 6
X (TIME)-COORDINATE OF POINT (MIN)= 2.1800D+02
Y (DRAWDOWN)-COORDINATE OF POINT (FT)= 3.5000D-01
PRODUCTION WELL DISCHARGE RATE (GPM)= 5.0000D+00
DISTANCE FROM PRODUCTION WELL (FT)= 1.0400D+02

COMPUTATION RESULTS:

AQUIFER TRANSMISSIVITY (GPD/FT)=   6617.70
AQUIFER STORATIVITY (DIM)= 2.434E-03
```

Transmissivity value yields low confidence number due to fluctuations in water table OR error in water level measurement.

APPENDIX H

WELL CONSTRUCTION AND COMPLETION DETAILS FOR STAINLESS STEEL WELLS HOLLOMAN AFB, NEW MEXICO

APPENDIX H

Appendix H contains well construction information pertaining to the installation of 7 additional detection monitoring wells at Holloman AFB, New Mexico. The monitoring wells will be drilled in a manner similar to the existing piezometers installed during the hydrogeologic investigation. Specifications for well construction are derived primarily from the requirements of the Corps of Engineers which in turn conform with EPA well construction guidelines (EPA TEGD, 1986).

1.0 DRILLING TECHNIQUES

A hollow-stem auger drill rig will be used to install the wells. This method has proven satisfactory in the past because the rig operated without the use of potentially contaminating drilling fluids (water or foam). The drill rig was also easy to maneuver during the project, even during rainy days.

1.1 Borehole Drilling

During drilling operations, a Radian geologist will log the borehole from the cuttings. Drilling methods are discussed below.

Boreholes will be drilled using a Mobil Drilling hollow-stem auger rig. Each auger flight is 5 feet in length. Auger dimensions will be 12-inch outside diameter (O.D.) and 6-5/8-inch inside diameter (I.D.). Soil cuttings produced during the drilling activities will be left on site after well completion. All sites will be raked and smoothed to a pre-disturbance condition as required by Base Environmental Engineer. When the borehole reaches total depth, as determined by the supervising geologist, it will be completed as a monitor well as described in the following sections.

1.2 Decontamination Techniques

All augers will be steam cleaned, washed (ALCONOX), and rinsed following completion of the well at an area designated for decontamination activities.

2.0 MONITOR WELL CONSTRUCTION

2.1 Screen and Casing

Because the sand units are quite thin, ranging from 7 to 20 feet thick and averaging approximately 10 feet thick, 5- or 10-foot screens are proposed in order to bridge thin units of interest and detect contaminants concentrated within each unit. The rationale is that the shorter well screen will permit the sand interval of interest to be monitored.

After the site geologist determines the total depth of the well, the screen and casing will be set into the borehole. The casing will continue from the screen to approximately 2 to 3 feet above the ground surface (Figure 1).

Screen and casing for the wells will consist of 316 stainless steel 4-inch inside-diameter material. Stainless steel was selected for two reasons: 1) it is recommended by RCRA (1986), and 2) it is highly resistant to corrosion. The screen will be between 5 and 10 feet long, machine pre-slotted, with a sealed end cap. The slot size will be 0.010 inch, which was found during piezometer installation to be compatible with the grain size of sediment in the aquifer and sand pack. All joints between the screen and casing and separate casing sections will be tightly connected with flush-joint threaded couplings. No glues, lead shot, or lead wool will be used on any part of the screen or casing.

2.2 Well Plumbness and Alignment

All risers shall be set round, plumb, and true to line. If the borehole remains open, the screen and casing will be set into the well after the drill bit and auger flights have been removed. Very little deviation from vertical is anticipated during drilling because of the unconsolidated nature of the fine grained material beneath the site. For this reason, centralizers will not be used.

2.3 Sand Pack

The sand/gravel filter pack will consist of clean, bagged silica (Colorado Silica) sand of fine enough mesh size to prevent siltation of the well. Sand will be placed from the bottom of the boring to between 2 and 3 feet above the top of the screen (Figure 1).

Sand will be poured directly down the annulus between the screen and borehole. The top of the casing string will be plugged during this operation to avoid pouring sand into the well. After a calculated volume of sand has been poured down the hole, the sand pack will be tamped and measured with a weighted tape. By sounding the level of the sand in the hole, the sand above the top of the screen may be determined. Some sand will always remain in the annular space between the casing string and the borehole. Sounding the sand level with a measuring tape will detect any potential bridging that might occur.

2.4 Bentonite Seal and Grout

A bentonite seal 2 feet thick will be emplaced on top of the sand pack (Figure 1). The bentonite seal, consisting of bentonite pellets (1/4 inch), will be poured directly down between the well casing and borehole. If the bentonite bridges inside the well, the bentonite will be emplaced in the

WELL CONSTRUCTION SCHEMATIC

PROJECT: Detection Monitoring Well Installation	WELL NO.: To be assigned
SITE: Holloman AFB, NM	
COORDINATES: To be surveyed to SPCS coord.	AQUIFER: Uppermost
DATE COMPLETED: 1988	
SUPERVISED BY: Radian Corporation	DEPTH TO WATER: To be surveyed
DRILLER: Winnek Incorporated	
DRILLING METHOD: Hollow Stem Auger	

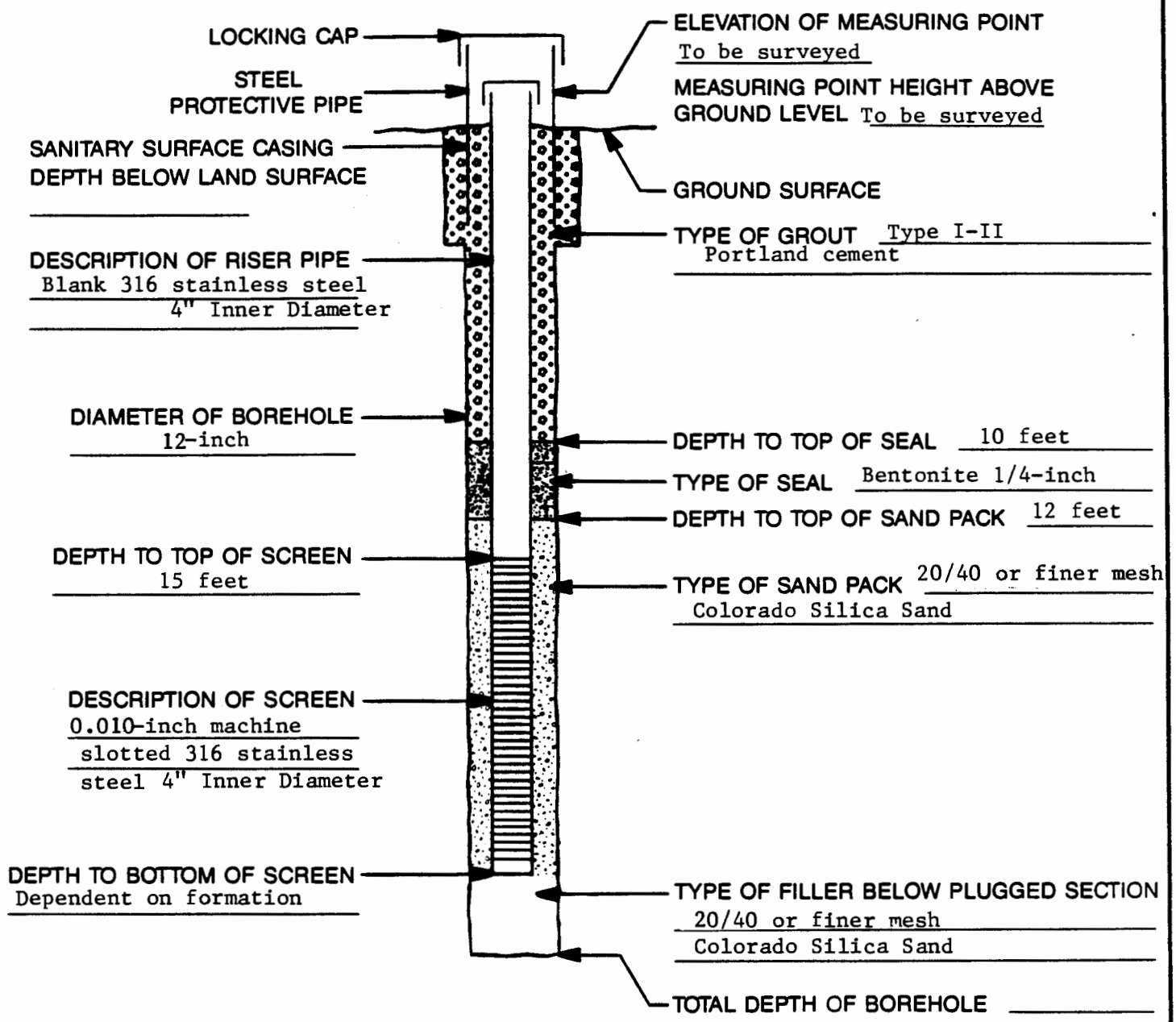


Figure 1. Example of Stainless Steel Detection Monitoring Well, Holloman AFB, New Mexico

D87 - 1240A

hole through a tremie pipe. However, experience has shown that the sediments are tight, permitting the borehole to remain open. The bentonite will be sounded and packed down with a weighted tape (as with the sand pack). The bentonite seal will be allowed to hydrate for 8 to 12 hours before grouting.

A cement grout mix will be emplaced into the hole from the top of the bentonite seal to the ground surface. The cement grout will consist of a mixture of Type 1 Portland cement (ASTM-C 150) and water. The mix will not exceed 5 1/2 gallons of clean water per bag of cement (94 lbs.). The grout mix will contain up to 3% bentonite powder by weight. The grout will be pumped under pressure through a tremie pipe to ensure positive placement of the grout. The pumping will continue until grout reaches land surface, at which time the tremie pipe will be removed.

2.5 Well Protection

If a well is temporarily left uncompleted, it will be protected with a heavy metal cover to avoid contamination of down-hole water and sediments.

Approximately 2 to 3 feet of stainless steel well casing will be left above ground after completion of the well (Figure 1). A PVC screw-joint cap will be placed on the top of the stickup casing. To protect the casing stick-up against vandalism or vehicles, a five-foot protective steel casing will be slipped over the well stick-up and anchored 2 to 3 feet into the grout (before it sets) so that the protective steel casing will extend 2 to 3 feet above land surface. The steel casing will have a locking cap and lock. A 3-foot by 3-foot by 4-inch concrete pad will be poured into a form around the protective steel casing. The concrete pad will be set at ground level and will slope away from the well casing. Three 3-inch diameter steel posts will be placed radially around the well and set into concrete (Figure 1). The posts will extend approximately 3 feet above the concrete pad and will be painted. The ground surface around the well will be sloped away from the casing. The well number will be set using a die set on the outside of the protective casing and on the well cover.

2.6 Well Construction Logs

The Radian geologist supervising the drilling procedures will prepare a log of well construction activities. Two copies with original signatures will be submitted to the Omaha District Corp of Engineers Contracting Officer within ten days of well completion. Well construction and completion logs, similar to the example in Figure 2, will be used. The following information will be included in the drilling, construction, and completion logs:

- Reference elevation for all depth measurement.
- Depth of each change of stratum.
- Thickness of each stratum.
- Identification of the material of which each stratum is composed according to the Unified Soil Classification System, or standard rock nomenclature, as necessary. Identification will also include a description of grain-size, angularity, color, and fining sequence.
- Depth interval from which each formation sample was taken.
- Depth at which groundwater is first encountered.
- Depth to the static water level and changes in static water level with well depth.
- Total depth of completed well.
- Nominal diameter of borings.
- Depth of any grouting or sealing.

Hole No.

DRILLING LOG	DIVISION	INSTALLATION	SHEET OF SHEETS

1. PROJECT	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number)	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g

Figure 2. Well Log

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PROJECT | HOLE NO.

- Amount, type, and manufacturer of all materials used in well construction.

- Depth and type of well casing.

- Description (to include length, location, diameter, slot sizes, material, and manufacturer) of well screens.

- Method of well development.

- Static water level upon completion of the well and after development.

- Drilling date or dates.

- Construction details of monitoring well as installed.

3.0 WELL DEVELOPMENT

Bailing and surging using pumps, bailers, surge blocks or a combination of these methods will be used for development of the monitor wells. Well development will proceed no sooner than 48 hours after well completion. Development will continue for a minimum of 4 hours, or until groundwater is free from sand and drill cuttings. Water from development procedures will be deposited onto land surface via a discharge hose. A photographic slide will be taken of the development water and will be sufficiently back-lit to observe the clarity of the water after the well is developed. The well depth will be rechecked before and after development to ensure that all sand and fines have been removed from the well. Well development information will be maintained as part of the record-keeping process and recorded onto a form shown in Figure 4. In addition, volumes of purged water during development activities will be calculated. All other testing methods and results compiled during field activities will be recorded in the project notebook.

4.0 DISINFECTION

Existing wells and newly installed wells will be sampled for coliform bacteria. For this reason, disinfection will take place prior to sampling. All debris and soil which could harbor and protect bacteria from disinfectants will be removed by purging prior to disinfection. Since wells were installed using steam-cleaned PVC well casing and screen, and bagged and washed sand pack, very little soil debris is expected to remain in these wells. Additionally, all previously installed wells were developed to sand-free conditions.

Disinfection procedures will consist of using methods and procedures outlined in EPA's publication 570/9-75-001 entitled, "Manual of Water Well Construction Practices (EPA, 1975)." According to Article 54 of the publication, the following proportion of chlorine is recommended for adequate disinfection. The amount of chlorine is dependent upon casing diameter and well volume.

Casing Diameter (inches)	Volume per 50 ft. (gals)	5.25% Purex, Chlorox, etc. (liquid measure)
2	8.15	1 oz.
4	32.6	4.5 oz.

Unless superseded by governmental regulation, the quantity of chlorine (Clorox) used for disinfection shall be sufficient to produce a minimum of 50 ppm available chlorine in solution when mixed with the total volume of water in the well. A 50 ppm solution will result from using the quantities of chlorine listed above.

The chlorine solution will be mixed at the site in containers and will have an aggregate volume equal to at least twice the volume of water in

the well. The solution will then be rapdily discharged into the well with a tremie pipe and surge-block. The tremie pipe will be raised and lowered to insure that the chlorine solution thoroughly flushes that portion of the casing which is above the static water level (EPA, 1975). The stock chlorine solution will be applied for a period of time not less than one hour and at a rate that will not deplete the measured amount during application. Using the surge-block and tremie pipe, the chlorine will flush the sand pack as well.

A sample of the stock chlorine solution will be analyzed in the laboratory for non-metal and metal compounds as a basis for comparison with the formation water sampled at a later date. Existing wells (installed during the Hydrogeologic Investigaiton) will be disinfected at the same time as the detection monitoring wells, to maintain consistency in disinfection procedures, equipment and personnel.

Sampling of the wells will not take place until at least 2 weeks have elapsed between chlorination and sampling. As required, the monitor wells will be purged of a minimum of 5 well-volumes until sampling. Purging will continue after 5 well-volumes have been removed until pH, conductivity and temperature have stabilized.

5.0 SURVEYING

At the completion of drilling operations, a State of New Mexico licensed and registered surveyor will determine the vertical and horizontal position of the newly installed wells. Elevations for the wells will be referenced to the 1929 National Geodetic Vertical Datum and will be referenced to the State Plane Coordinate System. Elevation and survey requirements are as follows:

- The top of ground elevation to the nearest 0.1 foot;
- The top of the well casing elevation to the nearest 0.01 foot;

- Survey points taken on the top of the well casing will be notched for future reference; and

- Horizontal coordinates will be accurate to the nearest 1.0 foot.

Wells and survey control monuments will be located on a plan map of suitable scale to accurately plot these locations as required in the Statement of Work.

APPENDIX I

ANALYTICAL REQUIREMENTS
FOR APPENDIX III AND IX ANALYSES
INCLUDING QA/QC AND INSTRUMENT METHODS
HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

1.0 INTRODUCTION

According to 40 CFR 265.90 (Subpart F), the owner or operator of a surface impoundment, landfill, or land treatment facility which is used to manage hazardous waste must implement a ground-water monitoring program capable of determining the facility's impact on the quality of ground water in the uppermost aquifer underlying the facility. The ground-water monitoring program must determine the concentration of parameters listed in Appendix III of 40 CFR 265 to characterize the suitability of the ground water as a drinking water supply as stated in 40 CFR 265.92(b)(1). Other ground water quality and contamination parameters listed in 40 CFR 265.92(b)(2) and (3) are also required to be monitored. Any values which exceed the interim primary drinking water standards must be reported to the Regional Administrator according to 40 CFR 265.94(a)(2)(i).

During the detection monitoring program (after the first year of data gathering), if a significant increase is found in any of the monitoring wells, the owner or operator must immediately sample the ground water in all of the monitoring wells for Appendix IX constituents according to 40 CFR 264.98(h)(2). The owner or operator must determine if any of the Appendix IX constituents are present and at what concentrations.

Sections 2 and 3 discuss the analytical methods and quality control criteria for the ground water indicator, contamination, and Appendix III parameters. Sections 4 through 6 discuss the analytical methods, quality control criteria, and calibration procedures for Appendix IX parameters. Section 7 discusses preventative maintenance, and Section 8 presents data analysis and reporting procedures.

2.0 ANALYTICAL METHODS AND PROCEDURES FOR GROUND WATER QUALITY INDICATORS, CONTAMINATION, AND APPENDIX III PARAMETERS

Water samples obtained from the monitoring wells will be analyzed by Radian Analytical Services (RAS). The RAS laboratory in Sacramento, California will perform the analytical work for pesticide and herbicide analysis, and the Austin, Texas laboratory will analyze for all other parameters. All chemical analyses will be performed in accordance with the protocols and guidelines established for the Contract Laboratory Program (CLP) administered by the U.S. Environmental Protection Agency (EPA).

The specific methods to be used for ground water analysis are identified in Section 2.1. Corresponding detection limits are presented in Section 2.2. The methods are described in more detail in Section 2.3, including procedures for instrument operation and interference identification.

Procedures to be used for validating the analytical methods used, such as the analysis of spiked samples, are described in Section 2.4. Section 2.5 contains a discussion of laboratory instrumentation, reagents, and standards.

2.1 Identification of Analytical Methods

Test methods for analytical procedures will be performed according to procedures in the following publications:

- SW-846, Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, U.S. EPA, Office of Solid Waste and Emergency Response, July 1982, second edition.

- EPA, Methods for Analysis of Water and Wastes, EPA Publication No. 600/4-79-020, March 1979.

- EPA, Prescribed Procedures for Measurement of Radioactivity in Drinking Water, EPA Publication No. 600/4-80-032, August 1980.

Analytical methods to be used for ground water analysis are listed in Table 2-1. Procedures required for sample preparation, such as solvent extraction and acid dissolution, are also listed. References to laboratory manuals are included.

2.2 Limits of Detection

Limits of detection are presented in Table 2-2 for the analytical parameters and methods identified in Section 2.1.

The limit of detection has been defined as the minimum concentration of a substance that can be measured with 99% confidence. Detection limits depend on the sample matrix as well as instrument capability. The ground water samples to be analyzed are expected to contain high concentrations of chloride; total filterable residue is expected to be approximately 20,000 mg/L.

2.3 Description of Analytical Methods

The analytical methods identified in Section 2.1 are described in more detail in the following paragraphs. A summarized description is given for the methods by the references shown in Table 2-1.

2.3.1 TOC Analysis Using Method 9060

Method 9060 uses a carbonaceous analyzer to measure organic carbon. This instrument converts the organic carbon in a sample to carbon dioxide by either catalytic combustion or wet chemical oxidation. The carbon dioxide formed is then either measured directly by an infrared detector or converted to methane and measured by a flame ionization detector. The amount of carbon dioxide or methane in a sample is directly proportional to the concentration of carbonaceous material in the sample. This method is most applicable to measurement of organic carbon above 1 mg/L.

TABLE 2-1. ANALYTICAL METHODS[a]

	Preparation		Analysis	
	Technique	Reference	Technique	Reference
TOC	----------	SW-846 : 9060	Carbonaceous Analyzer	SW-846 : 9060
TOX	----------	SW-846 : 9020	Microcoulometric-titration	SW-846 : 9020
Chloride, Sulfate	----------	EPA : 300.0	Ion Chromatography	EPA : 300.0
Phenols	----------	SW-846 : 9066	Colorimetric	SW-846 : 9066
Nitrate/Nitrite	Nitrate Reduction	EPA : 353.1	Colorimetric	EPA : 353.1
Fluoride	----------	EPA : 340.2	Potentiometric	EPA : 340.2
Arsenic	Acid Digestion	SW-846 : 7060	Graphite AA	SW-846 : 7060
Lead	Acid Digestion	SW-846 : 7420	Graphite AA	SW-846 : 7420
Mercury	Acid Digestion	SW-846 : 7470	Cold Vapor AA	SW-846 : 7470
Selenium	Acid Digestion	SW-846 : 7740	Graphite AA	SW-846 : 7740
Additional Metals[b]	Acid Digestion	SW-846 : 6010	ICPES	SW-846 : 6010
Pesticides[c]	Solvent Extraction	SW-846 : 3510 or 3520	GC/ECD	SW-846 : 8080
Herbicides[d]	Solvent Extraction	SW-846 : 8150	GC/ECD	SW-846 : 8150
Radium	Precipitation	EPA : 903.0	Counting	EPA[1] : 903.0
Gross Alpha and Beta	Evaporation	EPA : 900.0	Counting	EPA[1] : 900.0
Coliform Bacteria	----------	SW-846 : 9132	Membrane Filter	SW-846 : 9132

[a]Analytical Methods references include:

SW-846: Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods, 2nd and 3rd edition.

EPA: Methods for Analysis of Water and Wastes, March 1979, 600/4-79-020.

EPA[1]: Prescribed Procedures for Measurement of Radioactivity in Drinking Water, August 1980, 600/4-80-032.

[b]Additional metals include: iron, manganese, sodium, barium, cadmium, chromium, and silver.

[c]Pesticide analyses includes: endrin, lindane, methoxychlor, and toxaphene.

[d]Herbicide analyses includes: 2,4-D, and 2,4,5-TP (Silvex).

TABLE 2-2. DETECTION LIMITS FOR GROUND-WATER SAMPLES BASED ON METHODS IDENTIFIED IN TABLE 2-1

Parameter	Detection Limit	
TOC	1	mg/L
TOX	0.05	mg/L
Chloride	1	mg/L
Sulfate	1	mg/L
Phenols	0.005	mg/L
Nitrate/Nitrite	0.02	mg/L
Fluoride	0.1	mg/L
Arsenic	10	μg/L
Lead	5	μg/L
Mercury	0.2	μg/L
Selenium	5	μg/L
Iron	50	μg/L
Manganese	15	μg/L
Sodium	100	μg/L
Barium	20	μg/L
Cadmium	5	μg/L
Chromium	10	μg/L
Silver	10	μg/L
Endrin	0.01	μg/L
Lindane	0.01	μg/L
Methoxychlor	0.05	μg/L
Toxaphene	0.4	μg/L
2,4-D	0.5	μg/L
2,4,5-TP (Silvex)	0.15	μg/L
Radium	not to exceed 5	pCi/L
Gross Alpha	1	pCi/L
Gross Beta	1	pCi/L
Coliform Bacteria	<1/100	mg/L

2.3.2 TOX Analysis Using Method 9020

Method 9020 determines total organic halides (TOX) using carbon adsorption with a microcoulometric-titration detector. The method detects all organic halides containing chlorine, bromine, and iodine that are adsorbed by granular activated carbon. Fluorine-containing species are not determined by this method. This method is applicable to samples whose inorganic-halide concentration does not exceed the organic-halide concentration by more than 20,000 times.

A sample of water that has been protected against the loss of volatiles by the elimination of headspace in the sampling container, and that is free of undissolved solids, is passed through a column containing 40 mg of activated carbon. The column is washed to remove any trapped inorganic halides and is then combusted to convert the adsorbed organohalides to HX, which is trapped and titrated electrolytically using a microcoulometric detector. Operating procedures and interferences are described in Method 9020.

2.3.3 Chloride and Sulfate Analyses Using EPA Method 300.0

Method 300.0 is an ion chromatographic method applicable to the determination of certain anions in water of which chloride and sulfate are included. A small volume of sample is introduced into an ion chromatograph. The anions of interest are separated and measured, using a system comprised of a guard column, separator column, suppressor column, and conductivity detector. Operating parameters and interferences are described in the Test Method.

2.3.4 Metal Analysis Using SW-846 Method 6010

Method 6010 uses Inductively Coupled Plasma (Atomic) Emission Spectrometry (ICPES) to determine the concentration of metals in the ground water. Prior to analysis, samples are subjected to the acid digestion

procedures described in Method 6010. The following metals will be analyzed for using this method: iron, manganese, sodium, barium, cadmium, chromium, and silver.

The basis of chemical analysis by ICPES is the measurement of atomic emission by an optical spectroscopic technique. Samples are nebulized, and the aerosol that is produced is transported to the plasma torch where excitation occurs. Characteristic atomic-line emission spectra are produced by a radio frequency inductively coupled plasma. The resulting spectra are dispersed by a grating spectrometer, and the intensities of the line are multiplied by photomultiplier tubes. Inter-element correction is used for all analyses. Operating parameters and interferences are described in Method 6010.

2.3.5 Phenol Analysis Using SW-846 Method 9066

Method 9066 is an automated colorimetric analysis. The method is based on the distillation of phenol and subsequent reaction of the distillate with alkaline ferricyanide and 4-amino-antipyrine to form a red complex which is measured at 505 or 520 nm. The method is capable of measuring phenolic materials from 2 to 500 ug/L in the aqueous phase using phenol as a standard. Operating procedures and interferences are described in Method 9066.

2.3.6 Arsenic, Lead, and Selenium Analysis Using SW-846 Methods 7060, 7420, and 7740

Furnace atomic absorption spectrophotometry is used for arsenic, lead, and selenium analysis, according to the procedures outlined in EPA SW-846 Methods 7060, 7420, and 7740 respectively. Prior to analysis, acid digestion of the sample is required as described by the above methods.

Following acid digestion, an aliquot of sample is dried, charred, and atomized in a graphite furnace. Light from a metal-specific hollow

cathode lamp is passed through the resulting vapor containing ground-state atoms. The decrease in the spectral intensity across the vapor is proportional to the concentration of the metal being determined. Operating parameters and interferences are described in the respective methods.

2.3.7 Mercury Analysis Using SW-846 Method 7470

Method 7470 uses cold vapor atomic absorption to determine concentration values of mercury in ground water. Prior to analysis, acid digestion of the sample is required as described in Method 7470.

Following acid digestion, mercury is reduced to its elemental state with stannous sulfate. The mercuric vapor is then pumped through a closed system to a cell positioned in the light path of an atomic absorption spectrophotometer. The amount of light absorbed is proportional to the amount of mercury in the sample. Operating parameters and interferences are described in Method 7470.

2.3.8 Fluoride Analysis Using EPA Method 340.2

The concentration values of fluoride is determined potentiometrically using a fluoride electrode in conjunction with a standard single junction sleeve-type reference electrode and a pH meter having an expanded millivolt scale or a selective ion meter having a direct concentration scale for fluoride. The fluoride electrode consists of a lanthanum fluoride crystal across which a potential is developed by fluoride ions. This method can measure concentrations from 0.1 to 1000 mg/L. Operating parameters and interferences are described in EPA Method 340.2.

2.3.9 Nitrate/Nitrite Analysis Using EPA Method 353.1

In this method nitrate is reduced to nitrite with hydrazine sulfate and the nitrite (that was originally present plus reduced nitrate) is

determined by diazotizing with sulfanilamide and coupling with N-(1-naphthyl)-ethylenediamine dihydrochloride to form a highly colored azo dye which is measured colorimetrically. The applicable measurement range for this method is 0.01 to 10 mg/L. Operating parameters and interferences are describe in EPA Method 353.1.

2.3.10 Pesticide Analysis Using Methods 8080 and 3510 (3520)

Method 8080 is a gas chromatographic method using electron capture detection or halide-specific detection. This method is used to determine the concentration of certain organochlorine pesticides in a variety of matrices, including ground water. The pesticides to be measured include: endrin, lindane, methoxychlor, and toxaphene.

Prior to analysis, samples are extracted at a neutral pH using methylene chloride as a solvent. Ground water samples can be extracted using either Method 3510 (separatory funnel) or Method 3520 (continuous liquid-liquid extractor). Operating parameters and interferences are described in Methods 8080, 3510, and 3520.

2.3.11 Herbicide Analysis Using SW-846 Methods 8150 and 3510 (3520)

Method 8150 provides extraction, esterification, and gas chromatographic conditions for the analysis of chlorinated acid herbicides such as 2,4-D and 2,4,5-TP (Silvex). Spiked samples are used to verify the applicability of the chosen extraction technique to each new sample type. The esters are hydrolyzed with potassium hydroxide, and extraneous organic material is removed by a solvent wash. After acidification, the acids are extracted with solvent and converted to their methyl esters using diazomethane as the derivatizing agent. After excess reagent is removed, the esters are determined by gas chromatography employing an electron capture detector, microcoulometric detector, or electrolytic conductivity detector. The results

are reported as the acid equivalents. The sensitivity of Method 8150 usually depends on the level of interferences rather than on instrumental limitations.

2.3.12 Radium Analysis Using EPA Method 903.0

The radium in the ground water sample is collected by coprecipitation with barium and lead sulfate, and purified by reprecipitation from EDTA solution. Citric acid is added to the ground water sample to assure that complete interchange occurs before the first precipitation step. The final barium sulfate precipitate which includes radium-226, radium-224, and radium-223 is alpha counted to determine the total disintegration rate of the radium isotopes.

The radium activities are counted in an alpha counter where efficiency for determining radium-226 has been calibrated with a standard of known radium-226 activity. By making a correction for the ingrowth of alpha activity in radium-226 for the elapsed time after separation, one can determine radium activity in the sample. Since some daughter ingrowth can occur before the separated radium is counted, it is necessary to make activity corrections for the count rate. Operating parameters and interferences are described in Method 903.0.

2.3.13 Gross Alpha and Beta Analysis Using EPA Method 900.0

An aliquot of a preserved ground water sample is evaporated to a small volume and transferred quantitatively to a tared 2-inch stainless steel counting planchet. The sample residue is dried to constant weight, reweighed to determine dry residue weight, then counted for alpha and beta radioactivity.

Counting efficiencies for both alpha and beta particle activities are selected according to the amount of sample solids from counting efficiency

versus sample solids standard curves. Operating parameters and interferences are described in Method 900.0.

2.3.14 Coliform Bacteria Analyses Using SW-846 Method 9132

The coliform bacteria group analyzed in this procedure includes all of the organisms that produce a colony with a golden-green metallic sheen within 24 hours of inoculation.

A predetermined amount of sample is filtered through a membrane filter which retains the bacteria found in the sample. In the two-step enrichment procedure, the filters containing bacteria are placed on an absorbent pad saturated with aluryl tryptose broth and incubated at approximately 35°C for 2 hours. The filters are then transferred to an absorbent pad saturated with M-Endo media or to a dish containing M-Endo agar and incubated for another 21 hours at approximately the same temperature. Sheen colonies are then counted under magnification and reported per 100 mL of original sample.

2.4 Validation of Analytical Methods

Several procedures will be used to validate the analytical methods as they are applied to the ground water matrix. The ground water samples to be analyzed are expected to contain high concentrations of chloride, total filterable residue is expected to be approximately 20,000 mg/L.

Validation procedures fall into two categories: 1) those designed to verify that the analytical system itself is performing as well as required; and 2) those designed to verify that the analytical methods are adequate for the ground water matrix being analyzed.

System validation procedures will consist of the following:

- Analysis of method blanks,
- Calibration checks,
- Analysis of surrogate standards, and
- Analysis of standard reference materials.

The following procedures will be used to verify that the analytical methods used are adequate for the ground water matrix being analyzed:

- Duplicate analysis of samples,
- Analysis of samples spiked with a known amount of analyte, and
- Analysis using the method of standard additions, if spiked ground water samples show interferences caused by the matrix.

The validation procedures listed above will be performed at the frequencies specified in Section 3.0. Section 3.0 also contains more detailed descriptions of these validation procedures.

2.5 Laboratory Instrumentation, Reagents, and Standards

The instrumentation that will be used for the analytical methods are listed in Table 2-3.

Laboratory reagents and standards are obtained from the following suppliers:

- For inorganic analysis, spectral grade and reagent grade standards and reagents are obtained from Spex, Fisher, and Ricca. Standard reference materials are obtained from the National Bureau of Standards and the EPA Environmental Monitoring and Support Laboratory.

TABLE 2-3. INSTRUMENTATION USED FOR GROUND-WATER ANALYSES OF INDICATOR, QUALITY, AND APPENDIX III PARAMETERS

Parameter	Instrument
TOC	Dohrmann DC-80
TOX	Dohrmann DX-20
Chloride, Sulfate	Dionex Model 2110
Phenols, Nitrate/Nitrite	Technicao Autoanalyzer II Photometer
Fluoride	Ion Selective Electrode
Metals - AA (excluding Hg)	Perkin Elmer 3030 and 3030 Zeeman AA
Metals - ICPES	ARL Model 34000B
Mercury	Perkin Elmer Model 403
Pesticides and Herbicides	Varian 3700 and Varian Vista 6000 GC with dual electron capture detectors and Model 8000 auto samplers
Radium, Gross Alpha and Beta, and Coliform Bacteria	Not applicable

- For organic analysis, spectral grade and reagent grade solvents and reagents are obtained from Aldridge, Sigma, and Burdick and Jackson. Analytical standards are obtained from repositories maintained by EPA and by the National Toxicology Program administered by the National Institute of Environmental Health Sciences.

3.0 ANALYTICAL/STATISTICAL CONTROL PARAMETERS

The purpose of quality control procedures and documentation is to ensure that the analytical systems are operating within specified limits of accuracy and precision and that the conditions of control are properly documented. Results for quality control tests will also be used to estimate precision and bias associated with measurement data.

Specific measures taken to control analytical data quality include use of specific acceptance criteria for instrument calibration, QC check samples, duplicate analyses, blank samples and spiked samples. Acceptance criteria for each QC test, its required frequency, and corrective action are summarized in Table 3-1 and Table 5-1. Table 5-1 presents the criteria for metals, pesticides, herbicides, and fluoride. Table 3-1 presents the remaining parameters.

3.1 Data Quality Objectives

In formulating project-specific QA/QC strategies, Radian establishes specific objectives for measurement data quality for each measurement parameter. These objectives provide the framework for designing and effective QA/QC system which is responsive to the needs of the project.

Accuracy and precision objectives are presented in Table 3-2 and Table 5-2. Table 5-2 presents the accuracy and precision objectives for the metals, pesticides, herbicides, and fluoride analyses while Table 3-2 presents

TABLE 3-1. SUMMARY OF INTERNAL QUALITY CONTROL PROCEDURES FOR WATER SAMPLES

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Chloride/sulfate	300.0	Multipoint calibration	Daily	r $\geq$0.995	Repeat calibration
		QC check sample	Every 15 samples	$\pm$5% error	Repeat calibration
		Method blank	One per batch	None	Used to assess memory effects
		Duplicate analyses	5%	RPD $\leq$10%	1) Obtain third value, and 2) Flag data
		Matrix spike	5%	$\pm$15% error	Flag data
Total Organic	EPA 9060	Control sample	1) Following calibration 2) 10% (minumum 2) 3) Following sample analyses	Recovery between 90-110%	Repeat calibration
		Duplicate analyses	10% (minumum 1)	Relative percent difference (RPD) $\leq$20%	Repeat sample analyses
		Reagent blank	10% (minimum 1)	None	Will be used to indicate analytical contamination
SW-846 : 9020	TOX	Duplicate analyses	10%	RPD $\leq$20%	Repeat sample analyses
		Reagent blank	10%	None	Will be used to indicate analytical contamination
		Control Standard	1) 10% 2) Following sample analyses	95-105%	Repeat analyses
SW-846 : 9066	Phenol	Calibration curve	Daily prior to sample analyses	r >0.995	Repeat calibration
		QC check standard	10%	$\pm$15% error	1) Reanlyze 2) Repeat calibration 3) See lab manager
		Reagent blank	1 per batch	Recovery less than 0.02 µg/L	1) Clean instrument/equipment 2) Rerun test

(Continued)

TABLE 3-1. (Continued)

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
SW-846 : 9066 (continued)		Matrix spike	10%	±25% error	Flag data
		Matrix spike duplicate	10%	RPD ≤20%	Obtain third value
EPA : 353.1	Nitrate/Nitrite	Calibration curve	Daily prior to sample analyses	r >0.995	Repeat calibration
		QC check standard	10%	±15% error	1) Reanlyze 2) Repeat calibration 3) See lab manager
		Reagent blank	1 per batch	Recovery less than 0.02 μg/L	1) Clean instrument/equipment 2) Rerun test
		Matrix spike	10%	±25% error	Flag data
		Matrix spike duplicate	10%	RPD ≤20%	Obtain third value
EPA : 903.0	Radium	Calibration standard	Daily prior to sample analysis	Recovery between 80-120%	Repeat calibration
		Duplicates	10%	±40%	Repeat analysis
EPA : 900.0	Gross Alpha and Beta	Duplicate analysis	10%	RPD ≤40%	Repeat analyses
SW-846 : 9132	Coliform Bacteria	Sterility control	1 per batch of reagent		Repeat
		Temperature control	1 per batch	44.5 ± 0.2°C	Repeat analysis
		Calibrate thermometer	1 per year	44.5 ± 0.2°C	Replace thermometer

TABLE 3-2. ESTIMATED ACCURACY AND PRECISION OBJECTIVES

Parameter	Method	Accuracy[a]	Precision[b]
TOC	SW-846: 9060	90-110	10%
TOX	SW-846: 9020	80-120	20
Chloride, Sulfate	EPA: 300.0	90-110	10
Phenol	SW-846: 9066	85-115	15
Nitrate/Nitrite	EPA: 353.1	85-115	15
Radium	EPA: 903.0	--	--
Gross Alpha and Beta	EPA: 900.0	--	--
Coliform Bacteria	SW-846: 9132	--	--

the rest of the analyses. These values are not intended to represent data validation criteria. Rather, these values represent estimates of the magnitude of uncertainty which might be associated with the measurement data due to measurement error.

Accuracy objectives reflect recovery of target analytes spiked into actual field samples, expressed as a percentage of the amount spiked. Precision objectives reflect differences between measurements of duplicate aliquots of field samples, expressed as a percentage of the mean measured value.

3.2 Internal Quality Control Checks

Internal quality control checks are discussed in detail in Section 5.2 of this Appendix. Analytical calibration requirements are presented in the following subsections. Section 6 of this appendix discusses calibration procedures for metals, pesticides, herbicides, and fluoride.

3.2.1 Chloride and Sulfate - Method 300.0

Method 300.0 provides instructions for the determination of sulfate and chloride using ion chromatography.

A multipoint calibration curve (minimum of three points) is prepared daily by analyzing standard solutions containing the anions of interest. The calibration curve is verified by analyzing quality control check samples. A calibration curve is deemed acceptable if the correlation coefficient for the anion is greater than, or equal to 0.995 and recoveries for a QC check sample are in the range of 95 to 105 percent.

3.2.2 TOC - Method 9060

Method 9060 uses a carbonaceous analyzer to measure organic carbon.

A standard curve is set up using KHP for the expected concentration ranges of the samples to be analyzed. The calibration curve is verified by analyzing quality control check samples. The calibration curve is deemed acceptable if the QC check samples are in the range of 90 to 100 percent. The calibration is verified with an independently prepared check standard every 15 samples.

3.2.3 TOX - Method 9020

Method 9020 determines total organic halides using carbon adsorption with a microcoulometric-titration detector.

The adsorption efficiency of each newly prepared batch of carbon is checked by analyzing 100 mL of the adsorption efficiency standard, in duplicate, along with duplicates of the blank standard. The net recovery should be within 5 percent of the standard value.

The repeatability of the method background is established each day by first analyzing several nitrate-wash blank. The background is monitored between each group of eight pyrolysis determinations. The nitrate-wash blank values are obtained on single columns packed iwth 40 mg of activated carbon. It is washed with the nitrate solution and then the carbon is pyrolyzed.

Duplicate instrument-calibration standards and blank standards are pyrolyzed daily before beginning sample analysis. The net response to the calibration standars should be within 3 percent of the calibration-standard value. The instrument-calibration standard is repeated after each group of eight pyrolysis determinations and before resuming sample analysis, and after cleaning or reconditioning the titration cell or pyrolysis system.

3.2.4 Phenol - Method 9066

Method 9066 is an automated colorimetric analysis.

Phenol standards (minimum of a blank and three standards) are placed in the sampler in order of decreasing concentration. A linear standard curve is prepared by plotting peak heights of standards against concentration values. The calibration curve is verified by analyzing quality control check samples. A calibration curve is deemed acceptable if the correlation coefficient is greater than, or equal to 0.995 and recoveries for a QC check sample are within plus or minus 15 percent.

3.2.5 Nitrate/Nitrite - Method 353.1

Method 353.1 is a colorimetric analysis.

A multipoint calibration curve (minimum of three points) is prepared daily by analyzing standard solutions of nitrite. The calibration curve is verified by analyzing quality control check samples. A calibration curve is deemed acceptable if the correlation coefficient is greater than or equal to 0.995 and recoveries for a QC check sample are within plus or minus 15 percent.

3.2.6 Chloride and Sulfate Analysis - Method 300.0

Chloride and sulfate are analyzed by ion chromatography.

A multipoint calibration curve (minimum of three points) is prepared daily by analyzing standard solutions of each. The calibration curve is verified by analyzing quality control check samples. A calibration curve is deemed acceptable if the correlation coefficient is greater than or equal to 0.995 and recoveries for a QC check sample are within plus or minus 5 percent.

3.2.7 Radium, Gross Alpha and Beta, and Coliform Bacteria

Not applicable.

3.3 Corrective Action Procedures

Corrective action procedures are discussed in Section 5.3 of this Appendix.

3.4 Extended Quality Assurance Samples

Extended quality assurance of samples is discussed in Section 5.4 of this Appendix.

3.5 Schedule of Inspections and Performance Audits

Schedule of inspections and performance audits are discussed in Section 5.5 of this Appendix.

4.0 ANALYTICAL METHODS AND PROCEDURES FOR APPENDIX IX PARAMETERS

Water samples obtained from the monitoring wells will be analyzed by Radian Analytical Services (RAS). RAS laboratories in Sacramento, California will determine the following parameters: volatile organic compounds, extractable organic compounds, pesticides, and polychlorinated biphenyls. RAS laboratories in Austin, Texas will determine all other parameters. Methanol will not be determined because it is in use throughout the organic laboratories as an extraction solvent and a carrier solvent. The resulting background concentration makes accurate trace analysis of methanol impractical, if not impossible.

The specific methods to be used for groundwater analysis are identified in Section 4.1. Corresponding detection limits are presented in Section 4.2. The methods are described in more detail in Section 4.3, including procedures for instrument operation and interference identification.

Procedures to be used for validating the analytical methods used, such as the analysis of spiked samples, are described in Section 4.4. Section 4.5 contains a discussion of laboratory instrumentation, reagents, and standards.

4.1 Identification of Analytical Methods

All chemical analyses will be performed in accordance with the protocols and guidelines established for the Contract Laboratory Program (CLP) administered by the U.S. Environmental Protection Agency (EPA). With one exceptions (fluoride), all parameters will be determined according to methods published in SW-846 (Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, U.S. EPA, Office of Solid Waste and Emergency Response, July 1982, second edition), as modified for the CLP scope of work effective August 1985. Fluoride will be determined according to the method published in Methods for Analysis of Water and Wastes, U.S. EPA, March 1979, Publication No. 600/4-79-020.

Analytical methods to be used for groundwater analysis are listed in Table 4-1. Procedures required for sample preparation, such as solvent extraction and acid dissolution, are also listed. References to laboratory manuals are included.

4.2 Limits of Detection

Limits of detection are presented in Table 4-2 for the analytical parameters and methods identified in Section 4.1.

The limit of detection has been defined as the minimum concentration of a substance that can be measured with 99% confidence. Detection limits depend on the sample matrix as well as instrument capability. The groundwater samples to be analyzed are expected to contain high concentrations of chloride; total filterable residue (total dissolved solids) is expected to be approximately 20,000 mg/L.

TABLE 4-1. ANALYTICAL METHODS[a]

Parameter	Preparation		Analysis	
	Technique	Reference	Technique	Reference
Volatile Organic Compounds (including Xylene)	Purge and Trap	SW-846 : 5030	GC/MS	SW-846 : 8240
Extractable Organic Compounds (acid and base/neutral fractions)	Solvent Extraction	SW-846 : 3530	GC/MS	SW-846 : 8270
Pesticides and Polychlorinated Biphenyls	Solvent Extraction	SW-846 : 3510 or 3520	GC/ECD	SW-846 : 8080
Arsenic	Acid Digestion	SW-846 : 7060	Graphite AA	SW-846 : 7060
Lead	Acid Digestion	SW-846 : 3010	Graphite AA	SW-846 : 7420
Mercury	Acid Digestion	SW-846 : 7470	Cold Vapor AA	SW-846 : 7470
Selenium	Acid Digestion	SW-846 : 7740	Graphite AA	SW-846 : 7740
Additional Appendix IX Metals	Acid Digestion	SW-846 : 6010	ICPES	SW-846 : 6010
Cyanide	Distillation	SW-846 : 9010	Colorimetry	SW-846 : 9010
Polychlorinated Dioxins and Furans	Matrix-Specific Extraction	SW-846 : 8280	HRGC/LRMS	SW-846 : 8280
Fluoride	----------	EPA : 340.2	Potentiometric	EPA : 340.2
Organophosphorus Pesticides	Waste Dilution	SW-846 : 3580, 3620, or 3660	GC	SW-846 : 8140
Sulfides	Oxidization	SW-846 : 9030	Titration	SW-846 : 9030
Herbicides	Solvent Extraction	SW-846 : 8150	GC/ECD	SW-846 : 8150

TABLE 4-1. (Continued)

[a]Methods from SW-846 are used as modified for the U.S. EPA Contract Laboratory Program (CLP) scope of work effective in August 1985.

[b]Additional Appendix IX metals are: aluminum, antimony, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, osmium, potassium, silver, sodium, thallium, tin, vanadium, and zinc. (Source: Volume 51, Federal Register, No. 142, 24 July 1986.)

LEGEND:

SW-846	Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, July 1982, Second Edition.
GC/MS	Gas chromatography/mass spectrometry.
GC/ECD	Gas chromatography/electron capture detection.
AA	Atomic absorption spectrometry.
ICPES	Inductively coupled plasma (atomic) emission spectrometry.
HRGC/LRMS	High-resolution capillary column gas chromatography/low resolution mass spectrometry.
EPA	Methods for Analysis of Water and Wastes, March 1979, EPA Publication No. 600/4-79-020.

TABLE 4-2. DETECTION LIMITS FOR GROUND-WATER SAMPLES BASED ON METHODS IDENTIFIED IN TABLE 4-1

Parameter	Detection Limit (ug/L)
Volatile Organic Compounds	
Xylenes (total)	4.6
Chloromethane	5.0
Bromomethane	5.0
Vinyl Chloride	5.0
Chloroethane	5.0
Methylene Chloride	2.8
Acetone	7.5
Carbon Disulfide	1.7
Trichlorofluoromethane	5.0
1,1-Dichloroethene	4.7
1,1-Dichloroethane	2.8
trans-1,2-Dichloroethene	1.6
Chloroform	1.6
1,2-Dichloroethane	2.8
2-Butanone	25
1,1,1-Trichloroethane	3.8
Carbon tetrachloride	2.8
Vinyl acetate	6.9
Bromodichloromethane	2.2
1,2-Dichloropropane	6.0
trans-1,3-Dichloropropene	5.0
Trichloroethene	1.9
Benzene	4.4
Dibromochloromethane	3.1
1,1,2-Trichloroethane	5.0
cis-1,3-Dichloropropene	5.0
2-Chloroethyl vinyl ether	5.0
Bromoform	4.7
2-Hexanone	36
1,1,2,2-Tetrachloroethane	6.9
4-Methyl-2-pentanone	46
Tetrachloroethene	4.1
Toluene	6.0
Chlorobenzene	6.0
Ethyl benzene	7.2
Styrene	3.0
Formaldehyde	100
Acetonitrile	2.0
2-Chloro-1,3-butadiene	(ND)
trans-1,4-Dichloro-2-butene	4.0
1,4-Dioxane	10.0
Pentachloroethane	2.0
Dibromomomethane	2.0

(Continued)

TABLE 4-2. (Continued)

Parameter	Detection Limit (ug/L)
Dichlorodifluoromethane	2.0
Trichloromethanethiol	(ND)
Ethylene Oxide	(ND)
1,2-Dibromo-3-chloropropane	2.0
1,2,3-Trichloropropane	5.0
Ethyl Cyanide	(ND)
3-Chloropropionitrile	10 mg/L
Isobutyl Alcohol	10 mg/L
Acrolein	100
3-Chloropropene	(N)
Methacrylonitrile	10 mg/L
Acrylonitrile	10
Ethyl Methacrylate	2
Methyl Methacrylate	2
Allyl Alcohol	10 mg/L
2-propyn-1-01	10 mg/L
Extractable Organic Compounds	
2-Chlorophenol	4
2-Nitrophenol	4
Phenol	2
2,4-Dimethylphenol	3
2,4-Dichlorophenol	3
2,4,6-Trichlorophenol	3
4-Chloro-3-methylphenol	3
2,4-Dinitrophenol	42
2-Methyl-4,6-Dinitrophenol	24
Pentachlorophenol	4
4-Nitrophenol	3
Pronamide	10
5-Nitro-o-toluidine	(ND)
p-Chloroaniline	2
p-Nitroaniline	5
4,4-Methylenebis (2-chloroaniline)	(ND)
Benzyl Alcohol	(ND)
Benzenethiol	(ND)
Safrole	5
Benzoic Acid	(ND)
3,3-Dimethylbenzidine	(ND)
Dibenzo[a,h]pyrene	(ND)
N-Nitrosodiethylamine	(ND)
Iodomethane	2
N-Nitrosomorpholine	(ND)
1,4-Naphthoquinone	5
Dibenzo[a,e]pyrene	(ND)
2-sec-Butyl-4,6-dinitrophenol	(ND)

(Continued)

TABLE 4-2. (Continued)

Parameter	Detection Limit (ug/L)
Ortho-Cresol	3
Hexachlorophene	(ND)
2,3,4,6-Tetrachlorophenol	10
Pyridine	5
N-Nitrosopyrrolidine	5
Aramite	(ND)
1,2-Dichlorobenzene	2
1,3-Dichlorobenzene	2
1,4-Dichlorobenzene	5
Hexachloroethane	2
Bis (2-chloroethyl) ether	6
N-Nitroso-di-N-propylamine	12
Nitrobenzene	2
Hexachlorobutadiene	1
1,2,4-Trichlorobenzene	2
Isophorone	3
Naphthalene	2
Bix (2-chloroethoxy) methane	6
Hexachlorocyclopentadiene	6
2-Chloronaphthalene	2
Acenaphthylene	4
Acenaphthene	2
Dimethyl phthalate	2
2,6-Dinitrotoluene	2
Fluorene	2
4-Chlorophenyl phenyl ether	5
2,4-Dinitrotoluene	6
Diethyl phthalate	2
N-Nitrosodiphenylamine	2
Hexachlorobenzene	2
4-Bromophenyl phenyl ether	2
Bis (2-chloroisopropyl) ether	6
Fluoranthene	2
Phenanthrene	6
Phenacetine	(ND)
7,12-Dimethylbenz[a]anthracens	5
3-Methylcholanthrene	5
Aniline	4
2-Nitroaniline	(ND)
3-Nitroaniline	(ND)
Diphenylamine	(ND)
p-Dimethylaminoazobenzene	6
1,2,4,5-Tetrachlorobenzene	5
meta-Dinitrobenzene	10
Pentachlorobenzene	5

(Continued)

TABLE 4-2. (Continued)

Parameter	Detection Limit (ug/L)
Pentachloronitrobenzene	10
alpha,alpha-Dimethylphenethylamine	(ND)
Dibenzo[a,i]pyrene	(ND)
3,3'-Dimethoxybenzidine	(ND)
4-Aminobiphenyl	5
N-Nitrosodi-n-butylamine	5
Dibenzofuran,	3
Hexachlorodibenzofuran	
Pentachlorodibenzofuran	
Tetrachlorodibenzofuran	
N-Nitrosomethylethylanine	(ND)
Acetophenone	2
1,2-Diphenylhydrazine	2
Methyl methanesulfonate	5
1-Napthylamine	5
2-Naphthylamine	(ND)
2-Methylnapthalene	2
N-Nitrosopiperidine	5
2-Picoline	5
Anthracene	2
Dibutyl phthalate	3
Pyrene	2
Benzidine	40
Butyl benzyl phthalate	3
Bis (2-ethylhexyl) phthalate	3
Chrysene	3
Benzo (a) anthracene	8
3,3'-Dichlorobenzidine	17
Di-n-octyl phthalate	3
Benzo (b) fluoroanthene	5
Benzo (k) fluoranthene	3
Benzo (a) pyrene	3
Indeno (1,2,3-c,d) pyrene	4
Dibenzo (a,h) anthracene	3
Benzo (g,h,i) perylene	5
N-Nitrosodimethylamine	9
Pesticides	
Aldrin	0.01
Alpha-BHC	0.01
Beta-BHC	0.01
Gamma-BHC (Lindane)	0.01
Delta-BHC	0.01
Chlordane	0.04
4,4'-DDD	0.01
4,4'-DDE	0.01

(Continued)

TABLE 4-2. (Continued)

Parameter	Detection Limit (ug/L)
4,4'-DDT	0.02
Dieldrin	0.01
Endosulfan I	0.01
Endosulfan II	0.03
Endrin	0.01
Endrin Aldehyde	0.02
Heptachlor	0.01
Heptachlor Epoxide	0.01
Toxaphene	0.4
Methoxychlor	(ND)
Polychlorinated Biphenyls	
Arochlor 1016	0.1
Arochlor 1221	0.2
Arochlor 1232	0.2
Arochlor 1242	0.1
Arochlor 1248	0.1
Arochlor 1254	0.2
Arochlor 1620	0.2
Metals	
Arsenic	10
Lead	5
Mercury	0.2
Selenium	5
Aluminum	200
Antimony	60
Barium	200
Beryllium	5
Cadmium	5
Calcium	5,000
Chromium	10
Cobalt	50
Copper	25
Iron	100
Magnesium	5,000
Manganese	15
Nickel	40
Potassium	5,000
Silver	10
Sodium	5,000
Thallium	10
Tin	40
Vanadium	50
Zinc	20

(Continued)

TABLE 4-2. (Continued)

Parameter	Detection Limit (ug/L)
Cyanide	10
Sulfide	1 mg/L
Fluoride	0.1 mg/L
Herbicides	
2,4,5-T	0.15
Silvex	0.15
Dioxins, Furans	
2,3,7,8-Tetrachlorodibenzo-p-dioxin	10 mg/L
Hexachlorodibenzo-p-dioxins	
Pentachlorodibenzo-p-dioxins	
Tetrachlorodibenzo-p-dioxins	
Organophosphorus Pesticides	
Phosate	(ND)
Disulfoton	0.1
Famphur	(ND)
Parathion	0.3
0,0-Diethyl 0-2-pyrazinyl phosphorothioate	(ND)
Methyl parathion	0.3
Tetraethyldithiopyrophosphate	(ND)
Miscellaneous (No Methods Determined)	
Phenacetin	
Chlorobenzilate	
Resorcinol	
Isosafrole	
Isodrin	
Methapyrilene	
Ethylene Oxide	
Malononitrile	
Tris(2,3-dibromopropyl) phosphate	

The limits of detection shown in Table 4-2 were taken from the following sources:

- For volatile organic compounds, data published in Method 8240 and experience by Radian Analytical Services (RAS) with Method 8240.

- For extractable organic compounds, RAS experience with Method 8270.

- For pesticides and polychlorinated biphenyls, RAS experience with Method 8080.

- For Appendix IX metals, contract requirements of the EPA Contract Laboratory Program (CLP) effective August 1985.

- For sulfides, RAS experience with Method 9030.

- For cyanide, requirements of the CLP effective August 1985.

- For dioxins and furans, RAS experience with Method 8280.

- For fluoride, RAS experience with Method 340.2.

- For organophosphorus pesticides, RAS experience with Method 8140.

- For herbicides, RAS experience with Method 8150.

4.3 Description of Analytical Methods

The analytical methods identified in Section 4.1 are described in more detail in the following paragraphs. A complete description is given for

most of the methods by the references shown in Table 4-1; for the remaining methods, a complete description is provided in this section. The descriptions include procedures for instrument operation and interference identification.

4.3.1 Volatile Organic Compound Analysis Using Methods 8240 and 5030

Method 8240 is a gas chromatographic/mass spectrometric method for determining volatile organic compounds in a variety of sample matrices, including groundwater. Sample introduction is accomplished by the purge-and-trap technique described in Method 5030. Operating parameters and interferences are described in Methods 8240 and 5030.

4.3.2 Extractable Organic Compound Analysis Using Methods 8270 and 3530

Method 8270 is a capillary column gas chromatographic/mass spectrometric technique used for determining acidic, basic, and neutral organic compounds that are soluble in methylene chloride; methylene chloride extraction is the basis of Method 3530. Operating parameters and interferences are described in Methods 8270 and 3530.

4.3.3 Pesticide and Polychlorinated Biphenyl Analysis Using Methods 8080 and 3510 (or 3520)

Method 8080 is a gas chromatographic method using electron capture detection or halide-specific detection. This method is used to determine the concentration of certain organochlorine pesticides and polychlorinated biphenyls in a variety of matrices, including groundwater.

Prior to analysis, samples are extracted at a neutral pH using methylene chloride as a solvent. Groundwater samples can be extracted using either Method 3510 (separatory funnel) or Method 3520 (continuous liquid - liquid extractor). Operating parameters and interferences are described in Methods 8080, 3510, and 3520.

4.3.4 Arsenic, Lead, and Selenium Analysis Using Methods 7060, 7420, and 7740: Graphite Furnace Atomic Absorption

Furnace atomic absorption spectrophotometry is used for arsenic, lead, and selenium analysis, according to the procedures outlined in EPA Methods 7060, 7420, and 7740, respectively. Prior to analysis, acid digestion of the sample is required. Digestion methods are listed in Table 4-1.

Following acid digestion, an aliquot of sample is dried, charred, and atomized in a graphite furnace. Light from a metal-specific hollow cathode lamp is passed through the resulting vapor containing ground-state atoms. The decrease in the spectral intensity across the vapor is proportional to the concentration of the metal being determined. Operating parameters and interferences are described in Methods 7060, 7420, and 7740.

4.3.5 Mercury Analysis Using Method 7470: Cold Vapor Atomic Absorption

Following acid digestion as described in Method 7470, mercury is reduced to its elemental state with stannous sulfate. The mercuric vapor is then pumped through a closed system to a cell positioned in the light path of an atomic absorption spectrophotometer. The amount of light absorbed is proportional to the amount of mercury in the sample. Operating parameters and interferences are described in Method 7470.

4.3.6 Metal Analysis Using Method 6610: Inductively Coupled Plasma (Atomic) Emission Spectrometry

Prior to analysis, samples are subjected to the acid digestion procedures described in Method 6610. ICPES is used for Appendix IX metals other than arsenic, lead, mercury, and selenium. These metals are listed in Table 4-1.

The basis of chemical analysis by ICPES is the measurement of atomic emission by an optical spectroscopic technique. Samples are nebulized, and the aerosol that is produced is transported to the plasma torch where excitation occurs. Characteristic atomic-line emission spectra are produced by a radio frequency inductively coupled plasma. The resulting spectra are dispersed by a grating spectrometer, and the intensities of the line are multiplied by photomultiplier tubes. Inter-element correction is used for all analyses. Operating parameters and interferences are described in Method 6610.

4.3.7 Cyanide Analysis Using Method 9010

Method 9010 is used to determine the concentration of inorganic cyanide in groundwater and other sample types. Following distillation of the sample, cyanide is converted to a highly colored complex. The absorbance of the sample is compared to the absorbance of standard solutions to determine the cyanide concentrations of the sample.

Interferences, distillation, and the procedure for colorimetric determination are described in Method 9010. Automated apparatus will be used.

4.3.8 Polychlorinated dibenzo-p-dioxins and Polychlorinated debenzofurans Analysis Using Method 8280

Method 8280 uses a matrix-specific extraction, analyte-specific cleanup, and high-resolution capillary column gas chromatography/low resolution mass spectrometry technique. If interferents are encountered, the method provides selected cleanup procedures to aid the analyst in their elimination. The sensitivity of this method is dependent upon the level of interferents within a given matrix. Operating procedures and interferences are described in Method 8280.

4.3.9 Fluoride Analysis Using EPA Method 340.2

The concentration values of fluoride is determined poteniometrically using a fluoride electrode in conjunction with a standard single junction sleeve-type reference electrode and a pH meter having an expanded millivolt scale or a selective ion meter having a direct concentration scale for fluoride. The fluoride electrode consists of a lanthanum fluoride crystal across which a potential is developed by fluoride ions. This method can measure concentrations from 0.1 to 1000 mg/L. Operating procedures and interferences are described in EPA Method 340.2.

4.3.10 Organophosphorus Pesticides Analysis Using SW-846 Method 8140

Method 8140 provides gas chromatographic conditions for the detection of ppb levels of organophosphorus pesticides. Prior to analysis appropriate sample extraction techniques must be used. Both neat and diluted organic liquids may be analyzed by direct injection. A 2 to 5 microliter aliquot of the extract is injected into a gas chromatograph, and compounds in the GC effluent are detected with a flame photometric or thermionic detector. Operating procedures and interferences are described in Method 8140.

4.3.11 Sulfide Analysis Using SW-846 Method 9030

Method 9030 is used to measure the concentration of total and dissolved sulfides in water. The method does not measure acid-insoluble sulfides.

Excess iodine is added to a sample which has been treated with zinc acetate to produce zinc sulfide. The iodine oxidizes the sulfide to sulfur under acidic conditions. The excess iodine is back-titrated with sodium thiosulfate or phenylarsine oxide. Operating procedures and interferences are described in Method 9030.

4.3.12 Herbicide Analysis Using SW-846 Method 8150

Method 8150 provides extraction, esterification, and gas chromatographic conditions for the analysis of chlorinated acid herbicides. Spiked samples are used to verify the applicability of the chosen extraction technique to each new sample type. The esters are hydrolyzed with potassium hydroxide, and extraneous organic material is removed by a solvent wash. After acidification, the acids are extracted with solvent and converted to their methyl esters using diazomethane as the derivatizing agent. After excess reagent is removed, the esters are determined by gas chromatography employing an electron capture detector, microcoulometric detector, or electrolytic conductivity detector. The results are reported as the acid equivalents. The sensitivity of Method 8150 usually depends on the level of interferences rather than on instrumental limitations. Operating procedures and interferences are described in Method 8150.

4.4 Validation of Analytical Methods

Several procedures will be used to validate the analytical methods as they are applied to the groundwater matrix. The groundwater samples to be analyzed are expected to contain high concentrations of chloride; total filterable residue (total dissolved solids) is expected to be approximately 20,000 mg/L.

Validation procedures fall into two categories: 1) those designed to verify that the analytical system itself is performing as well as required; and 2) those designed to verify that the analytical methods are adequate for the groundwater matrix being analyzed.

System validation procedures will consist of the following:

- Analysis of method blanks;
- Calibration checks;

- Analysis of surrogate standards; and
- Analysis of standard reference materials.

The following procedures will be used to verify that the analytical methods used are adequate for the groundwater matrix being analyzed:

- Duplicate analysis of samples;

- Analysis of samples spiked with a known amount of analyte; and

- Analysis using the method of standard additions, if spiked groundwater samples show interferences caused by the matrix.

The validation procedures listed above will be performed at the frequencies specified in Section 5.0. Section 5.0 also contains more detailed descriptions of these validation procedures.

4.5 Laboratory Instrumentation, Reagents, and Standards

The instrumentation listed below will be used for the analytical methods as indicated; Table 4-1 lists these instruments by analytical method and year of manufacture.

- Volatile organic compound analysis using Method 8240: Finnegan model 4021 mass spectrometer with INCOS data system.

- Extractable organic compound analysis using Method 8270: Finnegan model 4021 mass spectrometer with INCOS data system and Finnegan model 3200 mass spectrometer with INCOS data system.

- Pesticides and polychlorinated biphenyls analysis using Method 8080, organophosphorus pesticides using Method 8140, and

herbicides using Method 8150: 1) Varian Vista 6000 gas chromatograph with dual electron capture detectors and Model 8000 auto samplers; and 2) Varian 3700 gas chromatograph with dual electron capture detectors and model 8000 autosamplers.

- Arsenic, lead, and selenium analysis using Methods 7060, 7420, and 7740: Perkin Elmer models 3030 and 3030 Zeeman atomic absorption spectrophotometers.

- Mercury analysis using Method 7470: Perkin Elmer Model 403 atomic absorption spectrophotometers.

- Metal analysis using Method 6610: ARL Model 34000B ICPES spectrometer, simultaneous detection, with a fixed array for 40 elements and a scanning monochromator.

- Cyanide analysis using Method 9010 (colorimetry): Technicon Autoanalyzer II.

- Dioxin and Furans analysis using Method 8280: HP 5985/87 GC/MS.

Laboratory reagents and standards are obtained from the following suppliers:

- For inorganic analysis, spectral grade and reagent grade standards and reagents are obtained from Spex, Fisher, and Ricca. Standard reference materials are obtained from the National Bureau of Standards and the EPA Environmental Monitoring and Support Laboratory.

- For organic analysis, spectral grade and reagent grade solvents and reagents are obtained from Aldridge, Sigma, and Burdick and

Jackson. Analytical standards are obtained from repositories maintained by EPA and by the National Toxicology Program administered by the National Institute of Environmental Health Sciences.

5.0 ANALYTICAL/STATISTICAL CONTROL PARAMETERS

The purpose of quality control procedures and documentation is to ensure that the analytical systems are operating within specified limits of accuracy and precision and that the conditions of control are properly documented. Results for quality control tests will also be used to estimate precision and bias associated with measurement data.

Specific measures taken to control analytical data quality include use of specific acceptance criteria for instrument calibration, QC check samples, duplicate analyses, blank samples and spiked samples. Acceptance criteria for each QC test, its required frequency, and corrective action are summarized in Table 5-1.

5.1 Data Quality Objectives

In formulating project-specific QA/QC strategies, Radian establishes specific objectives for measurement data quality for each measurement parameter. These objectives provide the framework for designing an effective QA/QC system which is responsive to the needs of the project.

Accuracy and precision objectives are presented in Table 5-2. These values are not intended to represent data validation criteria. Rather, these values represent estimates of the magnitude of uncertainty which might be associated with the measurement data due to measurement error.

Accuracy objectives reflect recovery of target analytes spiked into actual field samples, expressed as a percentage of the amount spiked. Preci-

TABLE 5-1. SUMMARY OF INTERNAL QUALITY CONTROL PROCEDURES

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Organochlorine Pesticides and PCBs	SW 8080	Multipoint calibration (minimum five points)	Initially, as required	RSD <20%	Repeat calibration
		Single point calibration	Daily prior to sample analyses	RPD <15%	Repeat 5-point calibration
		Surrogate standards	Every sample	±50%; lab must set own criteria (p±3s) after 30 samples	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike	5%	Refer to method	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike duplicate	5%	RPD <50%	Flag data
		Method blank	5%	None	Used to assess contamination
		QC check standard	Initially, and as required by method	Refer to method	1) Evaluate system 2) Repeat test for criteria that failed
Chlorinated Herbicides	SW 8150	Multipoint calibration, (minimum five points)	Initially, and as required by daily check	RSD <20% for RFs	Repeat calibration
		Single point calibration	Daily prior to sample analyses	RPD <15%	Repeat 5-point calibration
		Surrogate standards	Every sample	±30% error	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike	5%	Refer to method	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike duplicate	5%	RPD <50%	Flag data
		Method blank	5%	None	Used to assess contamination
		QC check standard	Initially, and as required by the method	Refer to method	1) Evaluate system 2) Repeat test for criteria that failed

(Continued)

TABLE 5-1. (Con l)

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Organophosphorus Pesticides	SW 8140	Multipoint calibration, 5 points	Initially, and as required by daily check	RPD <20%	Repeat calibration
		Single point calibration	Daily prior to sample analyses	RPD <15%	Repeat calibration
		Surrogate standards	Every sample	±30% error	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike	5%	Refer to method	1) Check calculations 2) Reanalyze extract 3) Reextract or flag data
		Matrix spike duplicate	5%	RPD <50%	Flag data
		Method blank	5%	None	Used to assess contamination
		QC check standard	Initially, and as required by method	Refer to method	1) Evaluate system 2) Repeat test for criteria that failed
Volatiles	SW 8240 (GC/MS)	Mass scale calibration using PFTBA	Daily prior to sample analyses	Refer to method	Repeat calibration
		Check of mass spectral ion intensities using BFB	Daily prior to sample analyses	Refer to method	Retune instrument Repeat BFB analysis
		System performance check compounds	Every 12 hours	RF ≥0.300 (0.250 for bromoform)	1) Evaluate system 2) Repeat calibration
		Calibration check compounds	Every 12 hours	% Difference <25%	1) Evaluate system 2) Repeat calibration
		Surrogate spikes	Every sample	Refer to method	1) Evaluate system 2) Recalculate data and/or reanalyze extract 3) Reextract and reanalyze sample or flag data
		Internal standard	Every sample	Refer to method	Flag data
		Method blank	Daily prior to sample analyses	None	1) Clean system 2) Repeat blank analysis
		Matrix spike	5%	Refer to method	1) Run check standard 2) Correct problem 3) Flag data
		Matrix spike duplicate	5%	RPD <50%	Flag data

(Continued)

TABLE 5-1. (Continued)

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Semivolatiles	8270 (GC/MS)	Mass scale calibration using PFTBA	Daily prior to sample analyses	Refer to method	Repeat calibration
		Check of mass spectral ion intensities using DFTPP	Daily prior to sample analyses	Refer to method	Retune instrument Repeat DFTPP analysis
		System performance check compounds	Every 12 hours	RF $\geq$0.050	1) Evaluate system 2) Repeat calibration
		Calibration check compounds	Every 12 hours	% Difference <30%	1) Evaluate system 2) Take corrective action 3) Repeat test 4) See lab manager
		Surrogate spikes	Every sample	Refer to method	1) Evaluate system 2) Recalculate data and/or reanalyze extract 3) Reextract and reanalyze sample or flag data
		Internal standards	Every sample	Refer to method	Flag data
		Extraction blank	5%	<5 X MDL	1) Run solvent blank 2) Evaluate system
		Matrix spike analysis	5%	Refer to method	1) Run check standard 2) Correct problem 3) Flag data
		Matrix spike duplicate samples	5%	RPD <50%	Evaluate system
Dioxins and Furans	SW 8280	Mass scale calibration using PFTBA	Daily prior to sample analyses	Refer to method	Repeat calibration
		Initial calibration Multipoint, 5 levels in triplicate	Yearly with fresh standards	Relative standard deviation (RSD) <30%	1) Repeat initial calibration 2) If still unacceptable, make necessary adjustment 3) Repeat initial calibration
		Single point check	Daily	Agreement within 30% of value predicted from multipoint calibration curve	1) Repeat single point check 2) If still unacceptable, perform new multi-point calibration

(Continued)

TABLE 5-1. (Continued)

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Dioxins and Furans (continued)		TCDD chromatography check	Daily	25% valley between 1,2,3,4-TCDD and 2,3,7,8-TCDD	Replace column
		PCDD/PCDF retention time window check	Daily unless retention times internal standards	Less than ±0.2 min. variation on internal standards	Rerun retention time standard, adjust SIM windows
		Sensitivity check	Daily	50:1 S/N from 200 ng/mL 2,3,7,8-TCDD standard	Evaluate instrument Take corrective action
		QC sample	Once every project	Refer to method	1) Repeat test 2) Repeat calibration 3) See lab manager
		Extraction blank	5%	None	Used to assess memory effects
		Duplicate analyses	5%	Refer to method	Obtain third value
		Surrogate spike recovery	Every sample	Refer to method	1) Evaluate system 2) Flag data
Metals - ICPES	6010	Mixed standard calibration	Daily	Measured value for high (standard within 10% of expected value)	Repeat calibration
		Calibration check	10%	Measured value within 10% of true value for element of interest	Repeat calibration
		Method blank	10%	≤5 x MDL	1) Repeat test, average results 2) Evaluate system 3) Recalibrate
		Matrix spike analysis	5%	±25% error	Flag data
		Matrix spike duplicate	5%	RPD <20%	Flag data
		ICP interference check	Run at beginning, middle, and end of daily run	80-120% of true value for EPA check sample elements	1) Repeat calibration 2) See lab manager
		ICP linear range check	Quarterly	Measured value within ±5% of expected value	Tests upper limit of ICP linear range
		LOD check	Quarterly	None	Used to verify current LOD

(Continued)

TABLE 5-1. (Continued)

Parameter	Analytical Method	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Metals - AAS					
As	7060	Multipoint calibration	Daily prior to analyses	r ≥0.995	Repeat calibration
Se	7740				
Hg	7470				
Pb	7420	Calibration cbeck	10%	±15% error	Recalibrate
		Method blank	10%	≤5 x MDL	Will be used to indicate analytical contaminants
		Matrix spike analysis	5%	±25% error	Flag data
		Matrix spike duplicete	5%	RPD <20%	Flag data
		LOD cbeck	Quarterly	None	Used to verify current LOD
Sulfide	9030	Standardization of Iodine	Daily	RPD for standard duplicates <5%	Repeat calibration
		Blank	One per batch	None	Used to assess memory effects
		Duplicate analysis	5%	RPD <15%	1) Obtain third value 2) Flag data
		Matrix spike	5%	±20% error	Flag data
Cyanide	9010	Calibration curve	Daily prior to sample analyses	r >0.995	Repeat calibration
		QC check standard	10%	±15% error	1) Reanalyze 2) Repeat calibration 3) See lab manager
		Reagent blank	1 per batch	recovery less than 0.02 μg/L	1) Clean instrument/equipment 2) Rerun test
		Matrix spike	10%	±25% error	Flag data
		Matrix spike duplicate	10%	RPD ≤20%	Obtain third value
Fluoride	340.2	Multipoint calibration	Daily prior to analyses	r ≥0.995	Repeat calibration
		QC Check Sample	10%	±10% error	Repeat calibration
		Blank	10%	None	Used to assess memory
		Duplicate analyses	10%	RPD <10%	1) Obtain third value 2) Flag data
		Matrix spike	10%	±10% error	Flag data

TABLE 5-2. ESTIMATED ACCURACY AND PRECISION OBJECTIVES

Parameter	Method	Accuracy[a]	Precision[b]
Trace Elements		90-100%	20%[c]
Volatile Organics	8240	Per CLP Method QC Acceptance Criteria	50%
Extractable Organics	8270	Per CLP Method QC Acceptance Criteria	50%
Pesticides/PCBs	8080	Per CLP Method QC Acceptance Criteria	50%
Cyanide	9010	85-115%	20%
Herbicides	8150	Per CLP Method QC Acceptance Criteria	50%
Dioxins, Furans	8280	Per CLP Method QC Acceptance Criteria	50%
Organophosphorus Pesticides	8140	See Method 8140 Table 1	50%
Fluoride	340.2	90-110%	10%
Sulfide	9030	90-110%	15%

sion objectives reflect differences between measurements of duplicate aliquots of field samples, expressed as a percentage of the mean measured value.

5.2 Internal Quality Control Checks

Specific QC procedures will be followed to ensure the production of valid data for this project. The QC checks and procedures described in this section represent an integral part of the overall sampling/analytical scheme. A discussion of sampling and analytical QC checks is discussed below.

5.2.1 Sampling Quality Control Checks

Internal sampling QC checks will include the collection of duplicate samples and field blanks. Duplicate samples and field blanks will each be collected at a minimum frequency of 10% of all field samples collected. The field blanks will be of two types: (1) a "trip blank," consisting of organic-free water for organic parameters and deionized water for inorganic parameters, and (2) a "rinsate blank," consisting of organic-free or deionized water which has been in intimate contact with the sampling equipment. Details of sampling QC procedures are discussed in the Sampling Plan.

5.2.2 Analytical Quality Control Procedures

Internal analytical QC checks will be performed according to the protocols and guidelines established for the EPA Contract Laboratory Program (CLP) for all parameters except propionic acid and formaldehyde. QC requirements will be followed as specified in the method descriptions for propionic acid and formaldehyde. The equipment, standards, procedures and calculations cited in the methods will be used. The proposed methods were described in Table 4-1.

5.2.2.1 Definitions of Quality Control Samples

The following quality control samples will be used to control and assess data quality:

1) System blank - deionized water analyzed after calibration to assess system calibration.

2) Reagent blank - an aliquot of reagent water taken through the digestion/extraction process as though it were an actual sample.

3) QC check sample - known concentration of reference materials spiked into an aliquot of deionized water. This is not taken through the digestion/extraction process. The purpose of a QC check sample analysis is to determine whether failure to meet QC acceptance criteria for matrix spike is due to matrix interference in the sample, or to an out-of-control condition associated with the analytical system.

4) Matrix spike - splits from field samples spiked with known concentrations of reference materials and taken through the entire digestion/extraction process. The matrix spike allows the laboratory to assess the efficiency of extraction, accuracy of the analysis, and possible matrix effects. For GC/MS analyses, surrogate spikes - easily identifiable compounds not present in the sample matrix - are added to every field sample.

5) Duplicate samples - samples split in the field and treated as two independent samples, although logged as splits of one sample.

6) Duplicate analyses - samples split in the lab and treated as two independent samples.

7) Dilution control sample - a control sample diluted in the same manner as required for actual field samples.

8) ICPES Interference check sample - an ICPES QC check sample which contains interferents and analyte concentrations at levels specified by EPA. Analyzed at the beginning and end of each sample analysis run, results are used to verify inter-element and background correction factors.

5.2.2.2 Preparation of Controls

Internal quality control samples used in the laboratory will be prepared and inserted into the analytical queue by the bench analyst. Control samples will be prepared as follows:

1) Calibration standards will be prepared fresh daily from stock solutions.

2) QC check samples will be prepared daily from EPA QC samples (not the same source as the calibration standards) or other stock solutions prepared independently of the calibration standards. QC check samples will not be taken through any sample preparation/digestion procedures.

3) Aliquots taken for duplicate analyses will be split from the original sample prior to any sample preparation/digestion.

4) Spiked samples will be split and spiked prior to any preparation/digestion procedures. The spike solution will be prepared from the calibration stock solution. The spike to sample volume ratio must be negligible (1:100 to 1:1000). The concentration of analyte added should approximate a sample concentration between 10 times the detection limit and the midpoint of the calibration range.

5) Reagent blanks will be taken through all sample preparation/digestion procedures.

6) System blanks (deionized H_2O) will not be taken through any sample preparation/digestion procedures.

5.3 Corrective Action Procedures

Each measurement system must initially satisfy specific criteria for calibration linearity, reference material recovery, and freedom from contamination. Thereafter, control samples are analyzed at a 10% frequency to monitor any changes in the quality of the data being produced. An out-of-control condition is defined as:

1) Detection of any compounds of interest in a reagent blank at >3 times the limit of detection.

2) Failure to meet the acceptance criteria for recovery of any compound of interest in a QC sample.

3) Exceeding the action limit for matrix spike recovery and subsequent failure to meet the acceptance criteria for a QC check sample for the same parameter(s) which failed the matrix spike test. Any parameter which fails the matrix spike test but not the QC check sample test will be flagged as suspect for the parameter due to matrix effect.

When an out-of-control situation is detected, efforts are undertaken to determine the cause. Corrective action for routine QC checks is outlined in Table 5-1. Procedures related to corrective action are described below.

5.3.1 Roles and Responsibilities

The laboratory organizational structure and responsibilities for responding to an out-of-control event are outlined as follows:

1) The bench analyst reports the situation to the laboratory supervisor and the quality assurance officer.

2) The supervisor and analyst determine and implement the appropriate corrective action.

3) If routine corrective actions rectify the situation, analytical work is resumed. The event is documented and the RAS QA officer is advised.

4) If the situation cannot be corrected immediately, the supervisor will notify the RAS QA officer who will in turn notify the project Quality Assurance Coordinator.

5.3.2 Corrective Actions

During the course of the Holloman AFB Groundwater Study, it will be the responsibility of the laboratory QA officers, Project Director, Task Leaders, and other project team members to see that all measurement procedures are followed as specified and that measurement data meet the prescribed acceptance criteria. In the event a problem arises, it is imperative that prompt action be taken to correct the problem(s). Laboratory supervisors will initiate corrective action in the event of QC results which exceed acceptability limits. Corrective action may also be initiated upon identification of some other problems or potential problem. Corrective action may also be initiated by the Laboratory QA Officer based upon QC data or other anomalies noted during data review.

5.3.3 Documenting Malfunctions

Any events which might compromise data quality will be documented using the malfunction report form illustrated in Figure 5-1. This report format also provides the mechanism for formal documentation of the corrective

MALFUNCTION REPORT

Malfunction Type _____
1 - QC Limits Exceeded
2 - Documentation
3 - Other (explain)

Urgency Level _____
1 - Requires immediate attention
2 - Should be addressed within 7 days
3 - Requires written explanation within 14 days

Laboratory: _____ Reported to: _____

Location: _____ Position: _____

Contract: _____

Date/Time of Malfunction: _____ Date Reported: _____

Malfunction Reported by: _____

Matrix: ☐ Solid ☐ Liquid Hydrocarbon ☐ Groundwater ☐ Air

Description of Problem: _____

Action: _____

Date/Time Resolved: _____ By Whom: _____

(Upon completion, send copies to distribution listed and return original to person who reported the malfunction.)

White - Original
Yellow - Laboratory Supervisor's Copy
Pink - Originator's Copy

Distribution: _____ _____ _____ _____ _____ _____

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Figure 5-1. Example of Malfunction/Correctible Action Report

action which is implemented to correct the out-of-control situation. In addition to the malfunction report, specific activities related to the malfunction incident may be recorded in analytical notebooks, on analytical bench sheets and data report forms, in instrument maintenance logbooks, etc., as applicable.

5.4 Extended Quality Assurance Samples

External QA samples will consist of field duplicates and field blanks collected in the same sample containers and handled in the same manner as field samples. The duplicate and blank samples will be collected at a frequency of 10% of all samples collected. Assuming 30 field samples will be collected for each parameter group, a minimum of three field duplicate and three field blanks will be collected for each parameter group. These external QA samples will be sent to:

U.S. Army Engineer Division, Missouri River
Attn: MRDED-L (Joe Solsky)
427 South 18th Street
Omaha, NE 68102

5.5 Schedule of Inspections and Performance Audits

A laboratory inspection under the auspices of the Missouri River Division, Corps of Engineers has been conducted 15-16 October 1986. The objectives of such an inspection were to evaluate laboratory operations for compliance with the "A-E Guidance for Developing A-E Quality Management Procedures for Site Investigative Activities."

A performance audit was also performed as part of this project. Radian also participates in a number of other performance evaluation programs. Among these are programs sponsored by EPA, U.S. Navy, the California Department of Health Services (DHS), and commercial clients. Further, the corporate Quality Assurance group and the Quality Assurance

Officer at each facility submit performance evaluation samples on a regular basis. The laboratories in Austin and Sacramento were, until recently, participants in the inorganic and organic phases, respectively, of the EPA-CLP. The performance of these laboratories was monitored by site audits and quarterly analysis of blind and/or double blind evaluation samples. Both laboratories continue to adhere to the CLP protocols for handling and analyzing samples. Radian participates in the EPA-EMSL Water Pollution Laboratory Performance Evaluation Studies, the EPA-OSW Interlaboratory Comparison Studies, and performance evaluation programs necessary to qualify for specific EPA contracts.

Radian welcomes site audits by all Federal and state regulatory agencies, governmental clients, and commercial clients. The facility in Sacramento is certified for the analysis of water and hazardous waste by the California DHS. The facility in Austin has applied for similar certification. In the absence of a formal state certification program, the Austin laboratory is audited by the Texas Water Commission (TWC) to document proper and continuing laboratory performance. The Austin laboratory has satisfied the requirements of TWC during all site audits.

6.0 CALIBRATION PROCEDURES AND FREQUENCY

Information presented in this section pertains to calibration of equipment and instrumentation which will be used for this project. Included is a description of the procedure or reference to an applicable standard operating procedure.

6.1 Organochlorine Pesticides and PCBs - Method 8080

All samples for organochlorine pesticides and PCBs will be analyzed by gas chromatography following SW 846, Method 8080, 3rd ed.

The external standard quantitation discussed in the method will be used to quantitate all pesticides/PCBs. The retention time window will be calculated for each pesticide/PCB after adjusting the GC operating conditions for the routine retention times of 4,4'-DDT. Any compounds tentatively identified in the primary analysis will be confirmed on a second GC column. The GC/ECD will be calibrated at a minimum of five concentrations. Concentration of the components in a standard will vary depending on the response of the compounds in the analytical system. Breakdown of 4,4'-DDT and endrin will also be monitored. Breakdown may not exceed 20 percent. A daily single-point calibration check must agree within ±15 percent or the instrument is recalibrated.

6.2 Chlorinated Herbicides - Method 8150

Method 8150 is a gas chromatographic (GC) method for determining certain chlorinated acid herbicides.

The external standard quantitation method will be used to quantitate all herbicides. The retention time window will be calculated for each herbicide after adjusting the GC operating conditions for the routine retention times of each parameter of interest. Any compounds tentatively identified in the primary analysis will be confirmed on a second GC column. The GC/ECD will be calibrated at a minimum of five concentrations. Concen tration of the components in a standard will vary depending on the response of the compounds in the analytical system. A daily single-point calibration check must agree within ±15 percent of the multipoint response or the instrument is recalibrated.

Organophosphorus Pesticides - Method 8140

Method 8140 is a gas chromatographic (GC) method used to determine the concentration of various organophosphorus pesticides.

The external standard quantitation method will be used to quantitate all pesticides. The retention time window will be calculated for each pesticide after adjusting the GC operating conditions for the routine retention times of each parameter of interest. Any compounds tentatively identified in the primary analysis will be confirmed on a second GC column. The GC/NPD will be calibrated at a minimum of five concentrations. Concentration of the components in a standard will vary depending on the response of the compounds in the analytical system. A daily single-point calibration check must agree within ±15 percent or the instrument is recalibrated.

6.4 Volatile Organics - Method 8240

Samples for volatile organics will be analyzed by scanning gas chromatography/mass spectrometry (GC/MS) following SW-846 Method 8240, 3rd ed. Analyses will be performed on a Finnigan MAT model 5100 or model 4510 GC/MS/DS system. Analyte identification and quantitation will be performed using response factors and retention times generated from a five point calibration curve, relative to the closest eluting of three internal standards. The three internal standards are:

- Bromochloromethane;
- 1,4-Difluorobenzene; and
- Chlorobenzene-d_5.

Tentatively identified compounds are identified only when a good match (Purity & Fit >.75) is obtained between the unknown spectra and the library spectra. The tentatively identified compound is then quantitated using a response factor of 1.0, with respect to the closest eluting internal standard.

The mass spectrometer will be tuned daily to give an acceptable spectrum for bromofluorobenzene (BFB). Relative ion abundance criteria for BFB are given in SW-846.

System performance will be verified initially and after every 12 hours to ensure a minimum average response factor of 0.3 (0.25 for bromoform) for the following system performance check compounds (SPCCs):

- Chloromethane;
- 1,1-Dichloroethane;
- Bromoform;
- 1,1,2,2-Tetrachloroethane; and
- Chlorobenzene.

A 5-point calibration, used for generating response factors, will be performed initially using 10, 20, 50, 100, and 200 ug/L standards. The relative standard deviation (RSD) must be less than 30 percent for the five response factors calculated for each of the following calibration check compounds (CCCs):

- 1,1-Dichloroethene;
- Chloroform;
- 1,2-Dichloropropane;
- Toluene;
- Ethylbenzene; and
- Vinyl chloride.

A continuing (every 12 hours) calibration check will be performed, following the system performance check, using the CCCs listed above. A single concentration of each CCC will be analyzed and a response factor calculated. The single-point RF for each CCC must be within 25 percent of the average five-point RF; otherwise, a new five-point calibration must be generated.

6.5 Semivolatile Organics - Method 8270

Semivolatile extracts will be analyzed by high resolution gas chromatography/mass spectrometry following SW-846 Method 8270, 3rd ed. All

samples will be prepared following extraction procedures outlined in SW-846. Analyses will be performed on a Hewlett-Packard 5985 GC/MS. Identification and quantitation will be performed using response factors and retention times generated from a five point calibration curve, relative to the closest eluting of six internal standards. The six internal standards are:

- Dichlorobenzene-d_4;
- Naphthalene-d_8;
- Acenaphthene-d_{10};
- Phenanthrene-d_{10};
- Chrysene-d_{12}; and
- Perylene-d_{12}.

Tentatively identified compounds are identified only when a good match (Purity & Fit >.75) is obtained between the unknown spectra and the library spectra. The tentatively identified compound is then quantitated using a response factor of 1.0, with respect to the closest eluting internal standard.

The mass spectrometer will be tuned daily to give an acceptable spectrum for DFTPP. DFTPP ion abundance criteria are given in SW-846.

System performance will be verified initially and after every 12 hours to ensure a minimum average response factor of 0.050 for the following system performance check compounds (SPCCs):

- N-nitroso-di-n-propylamine;
- Hexachlorocyclopentadiene;
- 2,4-Dichlorophenol; and
- 4-Nitrophenol.

A 5-point calibration, used for generating response factors, will be performed initially using 10, 20, 50, 100, and 200 ug/L standards. The

variability for specific ion response factors for Method 8270 calibration check compounds must be less than 30 percent RSD over the range calibrated. The CCCs are:

- Phenol;
- 1,4-Dichlorobenzene;
- 2-Nitrophenol;
- 2,4-Dichlorophenol;
- Hexachlorobutadiene;
- 4-Chloro-3-methylphenol;
- Acenaphthene;
- 2,4,6-Trichlorophenol;
- N-nitroso-di-n-phenylamine;
- Pentachlorophenol;
- Fluoranthene;
- Di-n-octylphthalate; and
- Benzo(a)pyrene.

A continuing (every 12 hours) calibration check will be performed, following the system performance check, using the CCCs listed above. A single concentration of each CCC will be analyzed and a response factor calculated. The single-point RF for each CCC must be within 30 percent of the average five-point RF; otherwise, a new five-point calibration must be generated.

6.6 Dioxins and Furans - Method 8280

Instrumentation Calibration and Tuning--

PCDDs/PCDFs will be analyzed according to the procedures outlined in Method 8280, SW-846, 3rd ed., with minor modifications. Mass calibration of the instrument will be performed daily with PFTBA and verified using DFTPP ion abundance criteria (as specified in SW-846 Method 8270) for mass 198 and greater. Adherence to Method 8280 criteria for isotopic ratio measurements for PCDDs and PCDFs will then be verified.

PCDD/PCDF Retention Time Group Determination--

Since selected-ion-monitoring mass spectrometry is used for PCDD/PCDF analysis, it is first necessary to determine the retention time windows for each isomer group. This is accomplished by injection of a PCDD/PCDF retention time standard which contains the first and last eluter from each isomer group. The isomer group retention time analysis is performed once at the beginning of each project and again if retention times shift more than ±0.2 minutes. Adequate sensitivity is also verified from the retention time standard which contains 2,3,7,8-TCDD at a concentration of 0.2 ug/mL.

Chromatography Performance Check--

A TCDD chromatographic test mixture is analyzed daily to verify that there is at least 25 percent valley resolution between 2,3,7,8-TCDD and 1,2,3,4-TCDD.

PCDD/PCDF Calibration--

Response factors for each PCDD/PCDF isomer class are determined from a five point calibration at 0.1, 0.2, 0.5, 1.0, and 2.5 ug/mL concentrations. This five-point calibration is performed in triplicate and the average response factors are calculated. The response factors determined for each isomer class must not have a percent RSD greater than 15 percent. Radian uses a calibration standard containing the following analytes:

- 2,3,7,8-TCDD;
- 1,2,3,7,8-PeCDF;
- 2,3,4,7,8-PeCDF;
- 1,2,3,8,9-PeCDF;
- 1,2,3,4,7,8-HxCDF;
- 1,2,3,4,8,9-HxCDF;
- 1,2,3,4,6,7,8-HpCDF;
- OCDF;
- 2,3,7,8-TCDF;
- 1,2,3,7,8-PeCDD;

- 1,2,3,4,7-PeCDD;
- 1,2,3,4,7,8-HxCDD;
- 1,2,3,4,6,7,8-HpCDD; and
- OCDD.

Where more than one isomer per isomer group is present, the average response factor is used.

For quantitation, the following mixture of internal standards is contained in the calibration standard solutions. This mixture is also added to each sample before extraction:

- $^{13}C_{12}$-2,3,7,8-TCDD;
- $^{13}C_{12}$-2,3,7,8-TCDF;
- $^{13}C_{12}$-1,2,3,7,8-PeCDD;
- $^{13}C_{12}$-1,2,3,7,8-PeCDF;
- $^{13}C_{12}$-1,2,3,6,7,8-HxCDD;
- $^{13}C_{12}$-1,2,3,4,7,8-HxCDF;
- $^{13}C_{12}$-1,2,3,4,6,7,8-HpCDD;
- $^{13}C_{12}$-1,2,3,4,6,7,8-HpCDF;
- $^{13}C_{12}$-OCDD; and
- $^{13}C_{12}$-OCDF.

Each isomer class is quantitated using a C-13 internal standard from that class.

Daily Response Factor Check--

The 1.0 ug/mL PCDD/PCDF standard is analyzed at the beginning of each working day to verify that the response factors obtained for that day agree to within $\pm$30 percent of those obtained from the initial five-point cali bration in triplicate. Also, isotope ratios for each PCDD/PCDF isomer class are verified to be within $\pm$15 percent of their theoretical values.

QC Check Sample--

An EPA or NBS check sample is analyzed after every five-point calibration to determine that the PCDD/PCDF standards and calibration curve used are acceptable.

6.7 Metals by ICPES - Method 6010

Method 6010 describes the simultaneous, or sequential, determination of elements using inductively coupled plasma atomic emission spectroscopy.

Detailed calibration procedures for ICPES systems are described in SW-846, 3rd ed. A response factor is calculated daily for each metal based on three exposures of a calibration standard and calibration blank. The RF is calculated and stored in the ICPES computer. Following calibration, a mid-level calibration check sample is analyzed; agreement between the measured value and the expected value must be within 5 percent for analyses to proceed. Calibration is verified by analyzing a QC check standard (prpared independently of calibration standards) every 10 samples; agreement within ± 10 percent of the expected value is required for all metals analyzed by ICPES.

6.8 Metals by AAS - Methods 7060, 7420, 7740, 7470

Method 7060, 7420, and 7740 are graphite furnace atomic absorption techniques for determination of arsenic, lead, and selenium, respectively.

Method 7470 is a cold-vapor atomic absorption procedure for determining the concentration of mercury in waste samples.

The calibration procedures for the graphite furnace and cold vapor AAS systems are described in the respective method in SW-846, 3rd ed. A multipoint calibration curve is generated daily for each element using a calibration blank and three upscale standards. The correlation coefficient for the linear regression equation must exceed 0.995 to be acceptable.

Calibration will be verified every 10 samples by analyzing a QC check sample and calibration blank. Agreement within ±15 percent of the expected value is required; otherwise, a new calibration curve must be generated.

6.9 Total and Amenable Cyanide - Method 9010

Method 9010 is used to determine the concentration of inorganic cyanide in an aqueous waste or leachate. The method detects inorganic cyanides that are present as either sample soluble salts or complex radicals. It is used to determine values for both total cyanide and cyanide amenable to chlorination.

A daily calibration curve is prepared using a blank and a minimum of three standards, with a correlation coefficient greater than 0.995. A high and a low standard should be distilled and compared with similar values on the curve to ensure that the distillation technique is reliable. The distilled standards should agree within ±10 percent of the undistilled standards.

6.10 Fluoride - Method 340.2

This method is applicable to the measurement of fluoride in drinking, surface and saline waters, domestic and industrial wastes. The fluoride is determined potentiometrically using a fluoride electrode in conjunction with a standard single junction sleeve-type reference electrode and a pH meter having an expanded millivolt scale or a selective ion meter having a direct concentration scale for fluoride.

A calibration curve will be generated using a matrix blank and five to nine standards ranging from zero to 2.0 mg/L fluoride. The correlation coefficient must exceed 0.995 for the calibration equation. A quality control check sample will be analyzed every 10 samples; recovery must be within ±10 percent of the expected value.

6.11 Sulfides - Method 9030

Method 9030 is used to measure the concentration of total and dissolved sulfides in drinking, surface, and saline waters. Excess iodine is added to a sample which has been treated with zinc acetate to produce zinc sulfide. The iodine oxidizes the sulfide to sulfur under acidic conditions. The excess iodine is back titrated with sodium thiosulfate or phenylarsine oxide.

The thiosulfate solution is standardized periodically against primary standard potassium dichromate. The iodine solution is standardized daily against the standardized thiosulfate solution.

7.0 PREVENTIVE MAINTENANCE

The preventive maintenance program used by Radian is designed to minimize the downtime of analytical equipment. Routine preventive maintenance is performed on all instruments at Radian. Maintenance is based on manufacturers' recommendations and performed on a regular schedule. Service agreements are in place for about half of the instruments to be used for the Holloman groundwater study. All aspects of routine and nonroutine instrument maintenance are recorded in logbooks; a logbook is dedicated to each instrument.

8.0 DATA ANALYSIS AND REPORTING

The data analysis required to calculate sample concentrations will proceed according to procedures outlined in the analytical methods identified in Table 4-1.

After final review of raw analytical data in the laboratory, the laboratory supervisor transfers the data to the Sample Control area of Radian Analytical Services (RAS); the raw data are filed for subsequent review by the

RAS Quality Assurance Officer. Raw data, along with all supporting documentation, are stored permanently in confidential files by RAS Sample Control.

After all analyses have been completed, a preliminary report is generated for review by the laboratory supervisors and the Quality Control Officer. Data integrity is ensured by this review, as the Quality Control Officer includes a review of the data for adherence to the quality control objectives of the project.

Identification of outliers is also a part of the data review. An outlier is an unusually large (or small) value in a set of observations. There are many possible reasons for outliers. Among them are:

1) A faulty instrument or component part;
2) Inaccurate reading of a record, dialing error, etc.;
3) Error in transcribing data; or
4) Calculation errors.

Sometimes analysts or operators can identify outliers by noting the above types of occurrences when they record observations. These faulty observations may then be removed from the dataset before it is summarized. If no such information exists, the Dixon Criteria are used to test suspected outliers at the 5 percent significance level.

The data management system used by RAS is the SAM (Sample and Analysis Management System for Laboratory Information). Radian uses SAM to log samples, track status, and report analytical data. All pertinent technical and administrative information are logged using SAM including field identifications, tests required, sampling dates, and due dates. The laboratory supervisors are notified of the presence of samples by way of work and data sheets, generated by SAM, which specify the tests to be performed in the respective laboratories. All samples are stored in secured areas and usually under refrigeration as specified by the EPA storage protocols. Access to the sam-

ples is limited to the analysts and supervisors and is documented by logbooks located at each storage area. Thus, chain of custody is maintained and documented using SAM and a paper trail. Transfer of samples from laboratories and Radian facilities is documented by completing a new chain of custody document, attaching a photocopy of the original document, and filing the original document.

APPENDIX J

A-E DAILY QUALITY CONTROL REPORTS
HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

RADIAN CORPORATION

Date: 7 Aug 87
Sheet No.: 5

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-3, drilling and sampling

Weather: sunny, hot

Work Performed: drilled at D-3, 53' to 60'. (Jacobs) Showed Paul Clement sites, staging and decontamination area.

Sampling Performed: Split spoon samples at 53-55' BLS and 58-60' BLS.

Problems and Corrective Actions: Had augers only for 60' deep borehole. Augers + drill stem ordered and arrived 7 Aug 87 - at night.

Quality Control Activities Initiated:

Signature: Wendy J. Reynolds

Figure 8-5. Example of A-E Daily Quality Control Report.

RADIAN
CORPORATION

Date: 8 Aug 87
Sheet No.: 6

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-3: Soil boring, sampling, well installation

Weather: Sunny, hot, temp - 98°F.

Work Performed: Drilled 10 feet (~60-70' BLS) at D-3, sampled, completed drilling at D-3 (TD=73' BLS), installed screen and casing, sand pack, and bentonite seal.

Sampling Performed: Split spoon soil samples at: 63-64' BLS, 68-70', and 73-75'.

Problems and Corrective Actions: None

Quality Control Activities Initiated: —

Signature: Wendy J. Reynolds

Figure 8-5. Example of A-E Daily Quality Control Report.

RADIAN
CORPORATION

Date: 9 Aug 87
Sheet No.: 1

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-3, well completion

Weather: Sunny, hot

Work Performed: grouted well D-3 from bentonite seal to surface, decontaminated augers and drill pipe, set up on site S-12.

Sampling Performed: none

Problems and Corrective Actions: none

Quality Control Activities Initiated: —

Signature: [signature]

Figure 8-5. Example of A-E Daily Quality Control Report.

RADIAN
CORPORATION

Date: 10 Aug 87
Sheet No.: 1 8

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: Drilling, well installation 5-12 and 5-1.

Weather: Cloudy, some rain

Work Performed: Drilled, Soil Sampling and well installation at wells 5-12 and 5-1. Set forms for pads at D-3, 5-12, and 5-1. Cleaned up site at D-3 and 5-12.

Sampling Performed: Split spoon samples at 5-12: 0-2', 3-5', 8-10', 10-12'. Samples at 5-1: 0-2, 3-5, 5-7, 8-10, 13-15', 15-17'.

Problems and Corrective Actions: None

Quality Control Activities Initiated:

Signature: [illegible]

Figure 8-5. Example of A-E Daily Quality Control Report.

RADIAN CORPORATION

Date: 11 Aug 87
Sheet No.: 9

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-3, S-12, S-3, S-1

Weather: partly cloudy, hot

Work Performed: cement pads, protective posts emplaced at D-3, S-12, and S-1. Water-levels, Temp, pH, and conductivity measured at D-3, S-12, and S-3.

Sampling Performed: None

Problems and Corrective Actions: None

Quality Control Activities Initiated: None

Signature: [signature]

Figure 8-5. Example of A-E Daily Quality Control Report.

RADIAN
CORPORATION

Date: 17 Aug 1987
Sheet No.: 10

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-2

Weather: Sunny, hot

Work Performed: Drilling and sampling of shallow Borehole #2. Installation of piezometer, & sand pack, and bentonite seal. Sampled to 24.75'. 20' of casing (10' screen - 7'-17') installed; sand pack to 4.7', bentonite pellets to 2.8' BGL.

Sampling Performed: Split spoon samples 0-2, 3-5, 5-7, 7-9, 9-11, 11-13, 15-16.25, 18-18.5, 23-24.75. Samples for soil testing at 9'-11', 23'-24.75'.

Problems and Corrective Actions: Broken hammer for split spoon sampling and new drill bit for auger too long. Took to welding shop and repaired them.

Quality Control Activities Initiated:

Signature: Gary D. Henderson

RADIAN CORPORATION

Date: 18 Aug 1987

Sheet No.: 11

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-5

Weather: Sunny, very hot in pm!!

Work Performed: Drill and sample to ~ 57' on deep hole #5.

Sampling Performed: Split spoon samples at 0-2, 3-5, 8-10, 13-15, 18-20, 23-25, 28-30, 33-34.5, 38-40, 43-45, 48-50, 53-55, 55-56.8

Problems and Corrective Actions: No problems.

Quality Control Activities Initiated:

Signature: Gary D. Hanson

RADIAN
CORPORATION

Date: 19 Aug 1987
Sheet No.: 12

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: O-5 (continued)

Weather: Cloudy overcast 'til 0830, sunny to ~ 1300 hrs, start to rain ~1500

Work Performed: Drill and sample 58 - 65'. Set casing, install sand pack and bentonite seal. Set pad, cover, posts at S-2. Took driller to Zone 2 cluster. Got flat tire - walked out.

Sampling Performed: Split spoon 58-60, 63-64.7

Problems and Corrective Actions: Sand slowly settling through muddy water in bore hole. Had to let it settle. Raining in pm ~ 1500 hrs w/ thunder slowed operations down some.

Quality Control Activities Initiated:

Signature: Gary D. Yardley

RADIAN
CORPORATION

Date: 20 Aug. 1987
Sheet No.: 13

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-15

Weather: Sunny and hot.

Work Performed: Decon rig and augers 0630-0930. Drill and sample S-15. Sampled to 15'. Set piezometer in S-15, install sand pack and bentonite pellets. Decon auger flights from D-5 drilling.

Sampling Performed: Split spoon samples 0-2, 3-5, 8-10, 10-12, 13-15. Samples for analytical testing 4'-5' and 10'-12'.

Problems and Corrective Actions: High pressure cleaner broke down during decon have to get parts in Alamogordo to finish decon prior to move to next location.

Quality Control Activities Initiated:

Signature: Gary D. Hudson

RADIAN
CORPORATION

Date: 21 Aug 1987
Sheet No.: 14

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-5 / S-4

Weather: Sunny, hot

Work Performed: Work on steam cleaner first thing in a.m 0630-0700 hrs. Grout D-5 / Drill and sample to 20' at S-4; set well casing (6'-11'), install sand pack and bentonite pellets; decon auger/pipe/spoons / Mobilize rig and equipment back to D-4 at well cluster SW of lagoons.

Sampling Performed: Split spoon samples 0-2, 3-5, 6-8, 8-10, 13-15, and 18-20. Samples at 8-10 (sand) and 18-20 (clay) retained for soil analyses.

Problems and Corrective Actions: Minor problem with steam cleaner this morning. Carburetor cleaner cleared up problem.

Quality Control Activities Initiated:

Signature: Gary D. Henderson

RADIAN CORPORATION

Date: 22 Aug 1987

Sheet No.: ~~14~~ 15

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-4

Weather: Sunny, warm til 1200 hrs. Cloudy to 1500, start raining.

Work Performed: Sampled to 55', drilled to 58' at D-4. Dug pads and guard post holes for D-5, S-15, and S-4.

Sampling Performed: Split spoon samples 0-2, 3-5, 8-10, 13-15, 18-20, 23-25, 28-30, 33-35, 38-40, 43-45, 48-50, 53-55. Analytical sample 43-45 and 56-58 from auger flight.

Problems and Corrective Actions: Started raining ~1500 hrs, stopped well installation. Break for a while.

Quality Control Activities Initiated:

Signature: Gary D. Vaden

RADIAN CORPORATION

Date: 23 Aug 1987

Sheet No.: 16/6

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-4 / D-5, S-15, S-4

Weather: Raining 0630 - 0730; Partly Cloudy, Warm

Work Performed: Set piezometer at D-4. Had to drill out 3' of sloughing material. Installed sand pack and bentonite seal. Install pad, posts, and protective covers at D-5, S-15, S-4. Decon rig, augers, pipes, and equipment.

Sampling Performed: None

Problems and Corrective Actions: Raining from 0630 - 0730. Had to wait until 0800 to get to D-4 site to install casing.

Quality Control Activities Initiated:

Signature: Gary D. Henderson

RADIAN CORPORATION

Date: 24 August 1987

Sheet No.: 17

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.:

Weather: RAINING!!

Work Performed: None. Too much rain, can not get to drill site.

Sampling Performed:

Problems and Corrective Actions:

Quality Control Activities Initiated:

Signature: Gary D. Henderson

RADIAN CORPORATION

Date: 31 Aug. 1987
Sheet No.: 18

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-4

Weather: Sunny, hot

Work Performed: quested D-4 to surface, put pads and posts around D-4, S-B, + a pad on D-5. Took synoptic water-level measurements at all wells, tried using tri-lox pump for development of D-3.

Sampling Performed: none

Problems and Corrective Actions: Tri-lox pump did not work well for developing D-3 - too much silt + sand clogging it up. Will try using compressed air for developing. ~~Rented an air compressor~~

Quality Control Activities Initiated: none

Signature: Wendy J. Rozanski

RADIAN CORPORATION

Date: 1 Sept 1987
Sheet No.: 19

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-13

Weather: Sunny, hot

Work Performed: drilled S-13 and collected soil samples, installed well. TD = 20'.

Sampling Performed: Split spoon samples at 0-2', 3-5', 8-10', 13-15', and 18-20'.

Problems and Corrective Actions: ~~none~~ Rented an air compressor for well development.

Quality Control Activities Initiated: none

Signature: Wendy J. Reynolds

RADIAN
CORPORATION

Date: 2 Sept 87
Sheet No.: 20

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-14

Weather: Sunny, warm

Work Performed: drilled and collected soil samples at S-14, TD = 35', installed well, began developing S-4, decon. of drilling equipment

Sampling Performed: split spoon samples at S-14 at 8-10', 13-15, 18-20, 23-25', 28-30', and 33-35'

Problems and Corrective Actions: none

Quality Control Activities Initiated: none

Signature: Wendy J. Rzewuski

RADIAN
CORPORATION

Date: 3 Sept 87
Sheet No.: 21

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-14, D-3, S-12, D-4

Weather: Sunny, hot

Work Performed: grouted S-14 to surface, developed well D-3, S-12, and D-4

Sampling Performed: none

Problems and Corrective Actions: none

Quality Control Activities Initiated: none

Signature: Wendy J. Rozalski

RADIAN CORPORATION

Date: 4 Sept 87

Sheet No.: 22

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-14, S-4

Weather: rainy, warm

Work Performed: grouted pad + protective post at S-14, developed S-4, out of field until clearances from BLM are obtained

Sampling Performed: none

Problems and Corrective Actions: none

Quality Control Activities Initiated: none

Signature: Wendy J. Rzyczky

RADIAN
CORPORATION

Date: 18 SEPTEMBER 1987
Sheet No.: 1/1 - 23

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-1 (DEEP WELL)

Weather: cloudy AND RAINY

Work Performed: DRilled deep well D-1 to A depth of 28.0 feet below ground level. LOCATED previously staked locations S8, D2 & S10. D6 could not be located.

Sampling Performed: Lithologic SAMPLES WERE SAVED IN baggies for depths of 0-2', 3-5', 8-10', 13-15', 18-20' & 23-25' Below ground level At D-1 SITE. ONE SAMPLE D-1 (28-30) WAS SAVED IN A plastic CONTAINER FOR sedimentary ANALYSES ASTM D 421, 422, 4318 2216.

Problems and Corrective Actions:

The hammer ON THE MOBIL DRill B-50 WAS SEVERED. The hammer WAS REPAIRED by spot WELDING it together.

Quality Control Activities Initiated: N/A

Signature: Heidi Tomich

RADIAN
CORPORATION

Date: 19 SEPTEMBER 1987
Sheet No.: 1-24

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-1

Weather: cool and SUNNY

Work Performed: complete DRILLING OF D-1 to a total depth of 73 feet below ground level. D-1 is left with auger flight and cap in it. LOCATED D-6 and re-staked it.

Sampling Performed: Sampled 33-35', 38-40', 43-45', 48-50', 53-55', 58-60', 63-65', 68-70' AND 73-75' below ground level at D-1. All samples were obtained with a split spoon sampler.

Problems and Corrective Actions:

Hydraulics on MOBIL RIG B-50 ARE DAMAGED. The hydraulics were spot WELDED TO Rig.

Quality Control Activities Initiated: N/A

Signature: Heidi Tomich

RADIAN
CORPORATION

Date: 20 SEPTEMBER
Sheet No.: 1-25

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-1, S-11, S-5

Weather: warm and sunny

Work Performed: complete D-1 piezometer except for grouting above plug. Drill shallow well S-11 to a depth (total) of 17.0' below ground level. Complete well S-11 except for grouting to surface. Drill S-5 to a total depth of 15.0' below ground level.

Sampling Performed: obtained lithologic samples with split spoon at S-11 at depths of 0-2', 3-5', 8-10', 13-15', 15-17' and 17-19' below ground level. obtained lithologic samples with split spoon sampler from 0-2', 3-5', 8-10', 13-15' and 15-17' below ground level.

Problems and Corrective Actions: NONE

Quality Control Activities Initiated: Between D-1 and drilling of S-11 and S-5 the sampling and drilling equipment were steamcleaned.

Signature: Heidi Tomich

RADIAN
CORPORATION

Date: 21 SEPTEMBER 1987
Sheet No.: 1 (26)

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-5, D-1, S-6, S-11

Weather: SUNNY & WARM

Work Performed: complete piezometer well S-5 except for grouting from plug to surface, grout deep piezometer well D-1 to surface, decontaminate the rig, drilling and sampling equipment, grout S-11 to surface, set up on S-6 for drilling 23 september 1987.

Sampling Performed: NONE.

Problems and Corrective Actions:

DRILLERS ARE almost completely out of 10-20 silica sand — they will go 22 SEPTEMBER 1987 to Albuquerque, NM to retrieve remaining stock of sand.

The ~~JEEP~~ cherokee which I used for transportation broke down (wouldn't start because of ignition problems) so I obtained another car

Quality Control Activities Initiated: N/A

Signature: Linda Tomb

RADIAN
CORPORATION

Date: 22 September 1987
Sheet No.: 27

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: ALL SITES ON BLM LAND

Weather: Cool and sunny

Work Performed: undertook a water level survey of both completed and non-completed piezometer wells, located rest of drill site

Sampling Performed: N/A

Problems and Corrective Actions: Had problems trying to lead rental agency to the jeep which broke down (the ignition was damaged). Finally met with them at the Holiday Inn and showed them personally where the jeep was located.

Quality Control Activities Initiated: Decontaminated the E-LINE with Alconox and distilled water between measurements.

Signature: Hunter Tonely

RADIAN
CORPORATION

Date: 23 September 198
Sheet No.: 1 (28)

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-6, D-1

Weather: warm and sunny

Work Performed: Drill S-6 and sample with the split spoon, complete D-1 piezometer well installation.

Sampling Performed: S-6 sampled every five feet for lithologic purposes. 2 samples were saved for laboratory analysis.

Problems and Corrective Actions: N/A

Quality Control Activities Initiated: N/A

Signature: Heidi Tomich

RADIAN
CORPORATION

Date: 24 September 1987
Sheet No.: 1/29

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-8, S-5, S-6

Weather: warm and sunny

Work Performed: Decontaminated rig and sampling equipment. Drilled S-8 and set well except for grouting to surface. Complete S-5 guardposts & set up pad. Complete S-6 except for grouting to the surface.

Sampling Performed: took lithologic samples every five feet at S-8. took two lithologic samples for analysis purposes.

Problems and Corrective Actions: N/A

Quality Control Activities Initiated: covered non-completed piezometer S-6 with protective casing since it is located near the gravel road by L. Holloman.

Signature: Heidi Torick

RADIAN CORPORATION

Date: 25 SEPTEMBER 1987

Sheet No.: 30

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-5

Weather: RAINING (MODERATE TO HEAVY)

Work Performed: INSTALLED PAD AND GUARDPOSTS ON S-5, WE PLANNED ON DEVELOPING D-1, S-11, AND S-14 but could NOT BECAUSE OF WEATHER CONDITIONS.

Sampling Performed: N/A

Problems and Corrective Actions: LIGHTNING PRESENT, ROADS ARE EXTREMELY slick, RAIN is fairly heavy. We SHUT DOWN AT 9:00 AM in the field.

Quality Control Activities Initiated: N/A

Signature: Heidi Tomich

Date: 30 September 198

Sheet No.: 31

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-2

Weather: Sunny, warm

Work Performed: Drill and sample boring D-2. Drilled to 77', sampled with split spoon to 69'. Collected samples at 52'-54' and 67'-69' for analysis. Pulled auger flights

Sampling Performed: Sampled with split spoon at 0'-2', 2'-4', 7'-9', 12'-14', 17'-19', 22'-24', 27-28.5', 32'-34', 37'-39', 42'-44', 52'-54', 57'-59', 62'-64', 67'-69'. Kept samples 52'-54' and 67'-69' for lab analysis.

Problems and Corrective Actions: None

Quality Control Activities Initiated:

Signature: Gary D. Henderson

CORPORATION

Date: 1 Oct. 1987

Sheet No.: 32

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-2

Weather: Sunny, warm

Work Performed: Had to clean borehole to 65'. Installed casing, sand pack, and bentonite pellet seal. Went back to decon augers and steam cleaner quit. Replaced solenoid but still wouldn't work. Had to take to repair shop.

Sampling Performed: None

Problems and Corrective Actions: Steam cleaner down. Won't start. Replaced solenoid but starter is probably bad. Took to repair shop in Alamogordo. Will be down for awhile.

Quality Control Activities Initiated: None.

Signature: Gary D. Harlem

Date: 2 Oct. 1987

Sheet No.: 33

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-2 and S-10

Weather: Sunny and warm.

Work Performed: Grouted D-2 piezometer. Drilled and sampled to 34' at S-10. Installed casing, sand pack, and bentonite seal at S-10.

Sampling Performed: Split spoon sampled at 0-2, 7-9, 12-14, 17-19, 22-24, 27-29, and 32-34 at S-10. Saved ~~S-10~~ 12-14 and 27-29 for laboratory analysis.

Problems and Corrective Actions: None

Quality Control Activities Initiated: Decon rig, augers, and sampling equipment.

Signature: Gary D. Henderson

RADIAN CORPORATION

Date: 3 Oct 1987

Sheet No.: 34

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-7 and S-16

Weather: Sunny and warm.

Work Performed: Drilled and sampled to 22' on S-7. Installed piezometer in S-7, installed sand pack and bentonite. Drilled and sampled to 34' at S-16. Installed casing, sand pack, and bentonite seal in S-16.

Sampling Performed: Split spoon samples at 0-2, 7-9, 12-14, 17-19, 22-24, 27-29, 32-34 at S-16; saved 7-9 and 32-34 for analysis. Split spoon samples 0-2, 7-9, 12-14, 17-19, 20-22 at S-7; saved 17-19 for analysis.

Problems and Corrective Actions: None.

Quality Control Activities Initiated: Decon rig and augers, split spoons.

Signature: Gary D. Vaughan

Date: 4 Oct. 1987

Sheet No.: 35

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-7, S-10, S-16, D-2

Weather: Sunny and warm.

Work Performed: Grout wells S-7, S-10, S-16; finish grouting D-2. Set pads, protective casing, and guard posts at S-7, S-10, S-16, and D-2.

Sampling Performed: None

Problems and Corrective Actions: None

Quality Control Activities Initiated:

Signature: Gary D. Henderson

RADIAN
CORPORATION

Date: 5 Oct 1987

Sheet No.: 36

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-6

Weather: Sunny and Warm

Work Performed: Drill and sample at D-6. Sampled to 68.3', Auger to 67'.

Sampling Performed: Split spoon samples at 0-2, 7-9, 12-12.8, 15-17, 17-19, 22-24, 24-26, 27-29, 32-34, 37-39, 42-44, 47-49, 52-54, 57-59, 62-64, 67-68.3; kept 24-26, 32-34, and 67-68.3 for lab analysis.

Problems and Corrective Actions:

None

Quality Control Activities Initiated: Rig and auger decon

Signature: Gary D. Vendeler

RADIAN CORPORATION

Date: 6 Oct. 1987

Sheet No.: 37

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: D-6

Weather: Sunny and warm

Work Performed: Install casing and screen, sand pack, bentonite pellets, and grout in D-6.

Sampling Performed: None

Problems and Corrective Actions: Difficulty in getting key to locked gate off Highway 70/82 so we could have easier access to Test Boring and S-9. Finally got key at 1730 hrs.

Quality Control Activities Initiated: Decon augers, sampling equipment and tools.

Signature: Gary D. Henderson

RADIAN CORPORATION

Date: 7 Oct 1987

Sheet No.: 38

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-9 and B-1

Weather: Sunny and Warm

Work Performed: Drilled and sampled S-9 to 26'. Installed casing and screen, sand pack, bentonite pellets, and grout, set pads and posts, protective cover. Drilled and sampled B-1. Grout backfilled test boring. 30' TD.

Sampling Performed: Split spoon samples 0-2, 7-9, 12-14, 17-19, 22-24, and 24-26 at S-9; 24-26 and 12-14 for lab analysis. Split spoon samples 0-1.5, 7-7.7, 12-12.5, 17-17.3, 22-22.3, 27-27.3; none saved for analysis.

Problems and Corrective Actions: None

Quality Control Activities Initiated: Rig decon, auger decon.

Signature: Gary D. Harlan

RADIAN
CORPORATION

Date: 10/14/87
Sheet No.: 39

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: Pumpwell installation - P-2

Weather: Partly cloudy, warm, thunderstorm in P.M.

Work Performed: drilled 0 to 47 ft at P-2.

Sampling Performed: Split spoon samples at 37-39', 39-41, 42-44, and 47-49.

Problems and Corrective Actions: Shut down at 1615 because of lightning nearby.

Quality Control Activities Initiated: none

Signature: Wendy J. Rozenberg

RADIAN CORPORATION

Date: 10/15/87
Sheet No.: 40

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: P-2

Weather: Sunny, cool to warm

Work Performed: drilled from 47 ft to 52 ft at P-2, met surveyor - showed him all well locations.

Sampling Performed: split spoon sample at 52-54.

Problems and Corrective Actions: Tried to install well at P-2. Heaving sand prevented casing to reach 52 ft. Pulled out casing, redrilled hole, then rig broke down (broken clutch plate). Drillers worked rest of day fixing rig.

Quality Control Activities Initiated: none

Signature: Wendy J. Rzyacky

RADIAN
CORPORATION

Date: 10/16/87
Sheet No.: 41

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: P-2 drilling + well construction

Weather: Sunny/partly cloudy, warm

Work Performed: drilled 52 - 62 ft. at P-2. installed well at P-2, decontamination of augers.

Sampling Performed: Split spoon sample from 52 to 54 ft.

Problems and Corrective Actions: none

Quality Control Activities Initiated: none

Signature: Wendy J. Rozanski

RADIAN CORPORATION

Date: 10/17/87

Sheet No.: 42

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: P-1 pump well installation.

Weather: Some clouds, mostly clear and sunny, not much breeze

Work Performed: Drilled 0'-71' at P-1, put in a bentonite cap.

Sampling Performed: Split Spoon samples at 57'-59'
62'-64'
67'-69'

Problems and Corrective Actions: none

Quality Control Activities Initiated: none

Signature: [signature]

RADIAN CORPORATION

Date: 10/18/87
Sheet No.: 43

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: ALL WELLS + P1

Weather: Sunny and Warm, not much breeze

Work Performed: Took water level measurements for all wells except P1 + P2; P-2 grouted up in afternoon

Sampling Performed: none

Problems and Corrective Actions: M.P.'s stopped R. Petrossian; asked to leave base because of no I.D.; did so.

Quality Control Activities Initiated: none

Signature: [illegible]

RADIAN
CORPORATION

Date: 10/19/87
Sheet No.: 44

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: P-1; S-1, S-2, S-15, D-5

Weather: Very Clear, Very Sunny, No Breeze.

Work Performed: Finished grouting up the hole at P-1 and setting the casing; developed S-1, S-2, S-15, and D-5.

Sampling Performed: None

Problems and Corrective Actions: None

Quality Control Activities Initiated: None

Signature: [illegible]

RADIAN CORPORATION

Date: OCT 20 1987

Sheet No.: 45

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-13, S-14, S-5, S-11, S-10, D-1, S-6

Weather: Clear and Cold.

Work Performed: Developed the wells S-13, S-14, S-5, S-11, S-10, D-1, S-6 ; showed the Surveyors (after meeting them at the front gate) some of the wells.

Sampling Performed: None

Problems and Corrective Actions: The electric compressor wasn't working so Bob took it back into the rental place and found out we just couldn't use an extension cord on it.

Quality Control Activities Initiated: None

Signature: [signature]

RADIAN
CORPORATION

Date: OCT 21 1987
Sheet No.: 46

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: S-8, S-7, S-10, S-16, D-6, S-3, S-9, Huertz Spring.

Weather: Clear, Cool, and Sunny.

Work Performed: Developed S-8, S-7, S-10, S-16, D-6, S-3, and S-9. Took pH and conductivity readings, and temperatures. Looked for any surface expressions of groundwater other than Huertz Spring.

Sampling Performed: None

Problems and Corrective Actions: None

Quality Control Activities Initiated: None

Signature: [illegible]

RADIAN
CORPORATION

Date: OCT 22, 1987
Sheet No.: 47

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: P-1, P-2, D-4, S-13, S-14

Weather: Damp, Cloudy, Sun is coming out.

Work Performed: Developed P-1, P-2. Tested the pump at P-1 while monitoring water levels at the adjacent 3 wells D-4, S-13, and S-14.

Sampling Performed: None

Problems and Corrective Actions: None

Quality Control Activities Initiated: None

Signature: [illegible]

RADIAN
CORPORATION

Date: 2 Nov 1987
Sheet No.: 48

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: Pump test - P-1

Weather: Sunny to partly cloudy. cool to warm

Work Performed: Set up equipment for pump test at P-1. Tested different flow rates for pump. Measured static water levels at observation wells.

Sampling Performed: None

Problems and Corrective Actions: None

Quality Control Activities Initiated: None

Signature: Wendy J Rezacky

RADIAN
CORPORATION

Date: 3 Nov 87
Sheet No.: 49

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: Pump test - P-1

Weather: Sunny to partly cloudy. Cool to warm

Work Performed: Tried to run pump test at P-1. Pump quit after 5 hrs. Ran slug/recovery test on S-2.

Sampling Performed: none

Problems and Corrective Actions: After pump shut down (pumping at ~.6 gpm), decided to use a higher flow rate. Checked drawdowns at observation wells at different flow rates. Decided to run pump at 2 gpm for repeat of pump test tomorrow.

Quality Control Activities Initiated: Ran 2 slug/recovery tests at S-2 - one for QC.

Signature: Wendy J. Ryzenko

RADIAN
CORPORATION

Date: 4 Nov 87
Sheet No.: 50

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: Pump test - P-1

Weather: Sunny, Warm

Work Performed: Ran pump test at P-1. Repeated slug test at S-2 using a slug of formation water, set up equipment for pump test at P-2.

Sampling Performed: None

Problems and Corrective Actions: Problems with pump overheating and stopping 3 times (for about 3 min. ea. time) during end of pump test at P-1. Drawdown data for that period will not be used.

Quality Control Activities Initiated: None.

Signature: Wendy J. Rozycki

RADIAN
CORPORATION

Date: 5 Nov 87
Sheet No.: 51

A-E DAILY QUALITY CONTROL REPORT FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

Task/Site No.: Pump test – P-2.

Weather: Cool, rainy

Work Performed: Ran pump test at P-2 and slug test at S-4.

Sampling Performed: None

Problems and Corrective Actions: None

Quality Control Activities Initiated: Checked transducer water levels at observation wells with E-line.

Signature: Wendy J. Rozycki

APPENDIX K

EPA COMPLIANCE AGREEMENT WITH CONDITIONS AND SCHEDULES FOR HYDROGEOLOGIC INVESTIGATION AND DETECTION MONITORING HOLLOMAN AFB, NEW MEXICO

FILE 12-2-5 C.E

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION VI
DALLAS, TEXAS

IN THE MATTER OF:	)	
	)	
HOLLOMAN AIR FORCE BASE	)	DOCKET NUMBER
HOLLOMAN AFB, NEW MEXICO	)	RCRA VI-502-H and VI-661-H
	)	
EPA I. D. No. NM6572124422	)	FEDERAL FACILITIES
	)	COMPLIANCE AGREEMENT
	)	

PRELIMINARY STATEMENT

Complainant, the Director of the Hazardous Waste Management Division (formerly the Air and Waste Management Division), EPA, Region VI, on behalf of the Administrator of the United States Environmental Protection Agency (EPA), filed two (2) Notices of Noncompliance, Compliance Schedules and Notices of Necessity for Conference (Notices) against Holloman Air Force Base, Department of the Air Force (Holloman or Respondent), in which Complainant alleged violations of the Resource Conservation and Recovery Act of 1976 (RCRA or The Act) (as amended), 42 U.S.C. §§6921 - 6991 and the New Mexico Hazardous Waste Act, N.M. Stat. Ann. §§74-4-1 thru 74-4-12 (1978). Those Notices, filed August 23, 1985 and February 4, 1987, and docketed as RCRA VI-502-H and RCRA VI-661-H, respectively, are appended to and made part of this Agreement (Appendix A). Complainant, as duly authorized delegatee of the Administrator of the EPA, the New Mexico Environmental Improvement Division (NMEID) and Respondent, as duly authorized delegatee of the United States Department of the Air Force, hereby consent to entry of

this Agreement, without trial or hearing, in resolution of all the issues raised by the aforementioned Notices. All provisions, conditions and terms of the corrective measures to be taken, the schedule for achieving compliance and the requirements for reporting progress are integrated in this Agreement and its attachments, and documented herein. Any parol agreements not incorporated herein are null and void.

NOW THEREFORE, it is ORDERED, ADJUDGED and AGREED as follows:

I. ENFORCEABILITY

For purposes of this Agreement and all consequent proceedings, Holloman admits the jurisdictional allegations of the Notices. Holloman neither admits nor denies specific factual allegations contained in those Notices.

Holloman recognizes its obligations to comply with RCRA as set forth in Section 6001 of RCRA.

The provisions of this Agreement, including those related to statutory requirements, regulations, permits, colsure plans, or corrective action, including recordkeeping, reporting and schedules of compliance, shall be enforceable under citizen suits by the State and its agencies. Holloman agrees that the State and its agencies are a "person" within the meaning of Section 7002(a) of RCRA.

In the event of any action filed under Section 7002(a) of RCRA alleging any violation of any such requirement of this Agreement, it shall be presumed that the provisions of this Agreement, including those provisions which address recordkeeping, reporting, and schedules of compliance, are related to statutory requirements, regulations, permits, closure plans, or corrective action, and are thus enforceable under Section 7002(a) of RCRA.

II. COMPUTATION OF TIME

Unless otherwise specified in this document, all time periods delineated are to be computed from the date this Agreement is signed by Complainant. All time periods are to be calculated as calendar days, not working days, unless otherwise specified.

III. BINDING EFFECT

This Agreement shall apply to and be binding upon the Complainant, the Respondent, the United States Environmental Protection Agency, the State of New Mexico, the United States Department of the Air Force and all officers, directors, agents, trustees, servants, employees, successors or assigns of the named parties as well as upon all persons, firms and other legally cognizable entities in active concert or participation with the named parties.

IV. OBJECTIVES

All plans, studies, construction, maintenance and monitoring programs and other obligations created directly or indirectly by this Agreement shall be implemented in a manner calculated to bring the Respondent into compliance with Subtitle C of the Resource Conservation and Recovery Act as well as provisions of other applicable Federal and State permits, laws and regulations.

V. DEFINITIONS

As used in this Agreement:

"Act" means the Resource Conservation and Recovery Act of 1976 as it existed, in amended form, on January 1, 1988.

"Binding" means to be legally enforceable upon. Those entities bound by this Agreement are constrained and compelled to act in accord with the terms herein contained.

"Reviewers" means the following persons or their designees:

1) For Complainant: Section Chief, ALONM Section, RCRA Enforcement Branch, and Counsel.
2) For NMEID: Program Manager, Hazardous Waste Section, Groundwater and Hazardous Waste Bureau, and Counsel.
3) For Respondent: Commander, 833 Combat Support Group, Holloman Air Force Base, New Mexico, and Counsel.

"Submit" means to mail, certified, return-receipt requested, the specified number of copies of the applicable documentation to the following individuals or their successors in interest:

Mr. Courtland Fesmire, Environmental Engineer
U. S. Environmental Protection Agency, Region VI, 6H-CS
First Interstate Bank Tower
1445 Ross Avenue
Dallas, Texas 75202-2733
[Two (2) copies]

Mr. Mark Peycke, Assistant Regional Counsel
U. S. Environmental Protection Agency, Region VI, 6C-H
First Interstate Bank Tower
1445 Ross Avenue
Dallas, Texas 75202-2733
[One (1) copy]

Mr. Boyd Hamilton, Program Manager
Hazardous Waste Bureau
Environmental Improvement Division
New Mexico Health and Environment Department
P. O. Box 968
Sante Fe, New Mexico 87504
[One (1) copy]

VI. CORRECTIVE MEASURES

A. Identification of Alleged Violations

RCRA Notice VI-502-H alleges twelve (12) separate and distinct violations of the Act, which may be summarized as follows:

1. Failing to submit proper notification of hazardous waste activity,
2. Operating surface impoundments without a permit,
3. Failing to submit a complete Federal Part A Permit Application,
4. Maintaining an inadequate inspection log,

5. Providing inadequate personnel training,

6. Maintaining leaking containers of hazardous wastes,

7. Maintaining open containers in which hazardous wastes were stored,

8. Improperly handling containers of hazardous wastes,

9. Failing to install a groundwater monitoring system,

10. Failing to submit for approval an adequate closure plan for hazardous waste surface impoundments,

11. Failing to draft and implement an adequate Waste Analysis Plan, and

12. Providing inadequate security in hazardous waste disposal and treatment areas.

The full text of these allegations and the specific regulatory requirements violated are set out in the appended, incorporated Notice numbered RCRA VI-502-H.

RCRA Notice VI-661-H alleges that Respondent's facility lost interim status authorization to operate its surface impoundments on November 8, 1985, and realleges Respondent's failure to submit an adequate closure plan for hazardous waste surface impoundments. The full text of these allegations is set out in the appended, incorporated Notice numbered RCRA VI-661-H.

B. Resolution of Alleged Violations Numbered 1, 2, 3, 4, 5, 6, 7, 8, 11 and 12.

Without waiving their right to proceed against future violations of any nature, Complainant and the Director of the NMEID hereby acknowledge that Holloman has addressed and resolved those past violations cited in the Notice VI-502-H as:

1. Failing to submit proper notification of hazardous waste activity,

2. Operating surface impoundments without a permit,

3. Failing to submit a complete Federal Part A Permit Application,

4. Maintaining an inadequate inspection log,

5. Providing inadequate personnel training,

6. Maintaining leaking containers of hazardous wastes,

7. Maintaining open containers in which hazardous wastes were stored,

8. Improperly handling containers of hazardous wastes,

11. Failing to draft and implement an adequate Waste Analysis Plan, and

12. Providing inadequate security in hazardous waste disposal and treatment areas.

The Respondent agrees to continue implementation of those corrective measures heretofore commenced in rectification of those violations reiterated in this paragraph. Upon signing of this Compliance Agreement and Final Order by all signatories, violations 1 - 8, 11 and 12 shall be deemed settled, satisfied and closed.

C. Resolution of Alleged Violation Number 9 and of Notice VI-661-H.

In resolution of alleged violation number nine (9) of Notice VI-502-H -- failing to install a ground water monitoring system -- and also in resolution of that portion of Notice VI-661-H not pertaining to closure plans, Respondent agrees to comply with 40 CFR Part 265, Subpart F, by either installing and operating a ground water monitoring system at its hazardous waste surface impoundments or by obtaining a waiver under 40 CFR §265.90(c). If a system is installed it will comply with the regulatory requirements of Title 40, Part 265, Subpart F of the Code of Federal Regulations and will be designed, constructed and operated pursuant to the following conditions and schedule:

1. Respondent shall continue implementation of the Hydrogeologic Investigation Plan (HIP) prepared for Respondent by Radian Corporation, dated April 1987, and approved by EPA July 13, 1987.

2. Within sixty (60) days of signing this agreement, Respondent shall submit the findings and a proposal to install a ground

water monitoring system. Said proposal shall contain an implementation schedule and, if installation of a ground water monitoring system is proposed, the proposed system shall conform with the Technical Enforcement Guidance Document and the proposal shall include a Groundwater Sampling and Analysis Plan. Reviewers shall approve or shall provide their comments on the report and demands for modification, if any, to Respondent within thirty (30) days of receipt of the findings of the Hydrogeologic Investigation and Proposed Groundwater Monitoring Plan. Should further investigation be proposed by Respondent or demanded by Reviewer, Respondent shall submit a modified proposal, including an implementation schedule, for conducting the secondary investigation within sixty (60) days of submitting the original findings or receipt of the demands. Reviewers shall review said proposal, modify it as necessary to ensure that the investigation will provide information requisite to effective application of Subpart F, Part 265, Title 40 of the Code of Federal Regulations and approve same, as modified.

3. Within thirty (30) days of approval of the secondary investigation, if any is required, Respondent shall commence same and shall proceed in accord with the design and schedules it contains.

4. Within sixty (60) days of completion of the secondary investigation, if any, Respondent shall submit the findings and a proposal to install a ground water monitoring system.

5. Reviewers and Respondent ~~shall~~ review the proposed ground water monitoring system in light of the findings of the HIP and any secondary investigations. They shall, via negotiations, derive and approve a ground water monitoring system plan. If no approvable plan is consensually derived, an approved ground water monitoring system plan will be achieved via Dispute Resolution procedures.

6. Within thirty (30) days of approval of a proposed ground water monitoring system, Respondent shall commence installation of same. Installation shall proceed in accord with approved schedules.

7. Within thirty (30) days of completion of installation Respondent shall submit a ground water monitoring installation report prepared and certified by a Registered Professional Engineer. Said report must contain, at a minimum, comparisons of as-built details with proposed construction details and boring logs demonstrating that the system was constructed as designed.

8. The ground water monitoring installation report shall be reveiwed by Reviewers who shall determine whether the system constructed conforms to the approved design. If the constructed system differs from the approved design the Reviewers may

demand modification of the system as constructed. Reviewers will provide their comments on the report and demands for modification, if any, to Respondent within forty-five (45) days of receipt of the ground water monitoring installation report. Within forty-five (45) days of receipt of the demands, if any, Respondent shall modify the system as demanded.

9. Notwithstanding pending modifications that the Reviewers require, if any, Respondent shall commence ground water sampling in conformance with the Ground Water Sampling and Analysis Plan developed and approved pursuant to Condition 2. Said sampling shall be repeated monthly over five (5) consecutive months, the first four (4) samplings to be used in establishing initial background concentrations of parameters specified in 40 CFR §265.92(b)(1986) and the fifth sampling as detection monitoring. Thereafter detection monitoring shall proceed at the frequencies prescribed in 40 CFR §265.92(d)(1986).

10. Within fifteen (15) days of receipt of laboratory analyses for each of the four sampling replicates, Respondents shall submit a copy of said results.

11. Subsequent to the second sampling replicate but prior to submittal of the analysis of the fifth sampling replicate, Respondent shall submit to Complainant and NMEID a Ground Water Assessment Monitoring Outline that complies with 40 CFR §265.93.

12. Within thirty (30) days ~~of~~ receipt of analysis of the fifth sampling replicate, Respondent shall submit a report summarizing the ground water monitoring results theretofore acquired. Said report shall statistically interpret the data in accordance with the techniques approved in the Ground Water Sampling and Analysis Plan.

13. The report submitted pursuant to Condition Twelve (12) shall be reviewed by Respondent and Reviewers and from that review a determination of the facility's impact on the uppermost aquifer shall be derived.

    If the impact warrants institution of Assessment Monitoring, Respondent shall, within fifteen (15) days, submit a Ground Water Quality Assessment Plan drafted in accord with the dictates of 40 CFR §265.93(d)(3)(1986) and the Assessment Monitoring Outline prepared pursuant to Condition Eleven (11).

    If the Reviewers agree that the findings then known do not warrant institution of Assessment Monitoring at that time, Respondent shall continue ground water monitoring in accord with its Sampling and Analysis Plan and 40 CFR §265.92 (1986).

14. When a final determination of the facility's impact on the uppermost aquifer is achieved, and after a ground water mon-

itoring assessment plan has been approved and implemented, if warranted, alleged violation number nine (9) of Notice VI-502-H and that portion of Notice VI-661-H not pertaining to closure plans shall be deemed settled, satisfied and closed. Complainant shall then notify Respondent that it has fulfilled its obligations in resolution of those allegations.

D. Resolution of Alleged Violation Number 10 and of Notice VI-661-H.

1. Within thirty (30) days Respondent shall submit a closure plan, based upon information then available, that accords Title 40, Part 265, Subparts G and K, Code of Federal Regulations (1986) closure plan requirements for hazardous waste surface impoundments.

2. The closure plan will be reviewed by NMEID in accordance with 40 CFR 265.112 and New Mexico Hazardous Waste Management Regulations Section Part 6. During this review period NMEID and Respondent may discuss the closure plan. After its review, NMEID shall submit the closure plan with its comments to Complainant. Complainant shall then process the closure plan to the approvable stage.

3. Upon notice to Respondent, by Complainant,that the closure plan is approvable, further resolution of alleged violation number ten (10) and that portion of Notice VI-661-H pertaining to closure plans shall be subject to the provisions of part VI. E. of this Agreement.

4. Upon approval of the closure plan by Complainant, Respondent shall close in accord with the plan and all applicable federal and state regulations, but if Respondent contests the terms of the approved closure plan, Complainant and Respondent shall resolve that contest via the dispute resolution provisions contained in paragraph XI of the Agreement.

5. Once the closure plan has been approved and finalized by Complainant, NMEID shall have the option of either monitoring the implementation of the closure plan itself, or referring implementation of the closure plan to Complainant. Implementation of the closure plan shall be according to applicable state and federal regulations. Any disputes regarding implementation of the closure plan shall be resolved between Complainant and Respondent, in accordance with the Dispute Resolution provision contained herein.

6. Respondent shall certify completion of closure to either Complainant or NMEID (whichever agency is monitoring implementation of the closure plan). Once closure certification has been formally accepted by either Complainant or NMEID, Complainant, shall notify Respondent within forty-five (45) days that it has fulfilled its obligations in resolution of alleged violation number ten (10) of Notice VI-502-H and of those portions of Notice VI-661-H pertaining to closure plans and that those charges are deemed settled, satisfied and closed.

E. Covenant to Delay Compliance With Corrective Measure VI. D. Pending EPA Headquarter's Final Decision on Respondent's Petition to Delist Its Hazardous Wastes.

Acknowledgments and Caveats

1. Complainant and NMEID acknowledge that Respondent has filed with the Headquarters of the United States Environmental Protection Agency (HQ), preliminary data and a proposal for delisting the hazardous waste received by, or generated in, the Respondent's hazardous waste surface impoundments. That proposal did not contain all the information requisite to a delisting petition and was merely a step toward development of such a petition.

2. This covenant to delay is conditioned upon Respondent's good faith development and pursuit of a delisting petition.

   For purposes of this covenant, "good faith" is defined as compliance with final, agreed courses of action developed pursuant to paragraph VI. E. 5. of this Covenant.

   Should Complainant come to believe that Respondent has deviated from good faith compliance with any final agreed course of action to be taken pursuant to this Covenant, Complainant shall notify Respondent of the basis for its belief. Thereafter Respondent shall, within thirty (30) days, respond to Complainant's concerns. If, after consideration of Respondent's response, Complainant continues to believe that Respondent has deviated from good faith, Complainant shall proceed with approval of Respondent's closure plan in accord with then applicable regulations, and further resolution of alleged violation number ten (10) and that portion of Notice VI-661-H pertaining to closure plans shall thereafter proceed in accord with Conditions VI. D. 4, 5 and 6 of this Agreement.

3. If Respondent withdraws its proposal or its petition from consideration, Respondent shall immediately notify Complainant of this decision. Complainant shall then proceed with approval of Respondent's closure plan in accord with then applicable regulations and further resolution of alleged violation number ten (10) and that portion of Notice VI-661-H pertaining to closure plans shall thereafter proceed in accordance with Conditions VI. D. 4, 5 and 6 of this Agreement.

4. In a meeting at HQ, held February 6, 1987 and attended by representatives of Complainant, Respondent and HQ, Respondent was informed by HQ that additional information would have to be submitted before the proposal for delisting would be considered a petition. HQ informed Respondent that formal written comments on the proposal and calls for revision of the proposal would be formulated and forwarded by HQ to Respondent.

Actions

5. Within fifteen (15) days of receipt of comments, Respondent shall request a meeting with HQ to resolve issues raised by the comments. Said meeting will take place within fifteen (15) days of the request unless HQ dictates otherwise. At the meeting, all parties shall attempt to set a schedule of what must be done and when it will be done. If no agreed schedules are developed at the meeting, they will be developed via Dispute Resolution procedures. When an agreed schedule is developed it shall be documented by a party designated to do.

6. Immediately upon development of the final, agreed course of action, Respondent shall commence the approved activities.

7. If, subsequent to completion of the final, agreed course of action, HQ again finds that the petition is not complete HQ shall provide Respondent with additional comments that explicitly delinate the deficiencies in Respondents petition and the parties shall repeat step five (5). The process shall be repeated until Respondent withdraws its petition from consideration or until the petition is judged complete by HQ.

8. If Respondent's petition is granted by HQ, Complainant shall notify Respondent that it has fulfilled it obligations in resolution of alleged violation number ten (10) and that portion of Notice VI-661-H pertaining to closure plans.

   If Respondent's petition is denied by HQ, the Complainant shall proceed with approval of Respondent's closure plan and further actions in resolution of alleged violation number ten (10) and that portion of Notice VI-661-H pertaining to closure plans shall thereafter proceed in accordance with Conditions VI. D. 4, 5 and 6 of this Agreement.

VII. PROHIBITION

Respondent is proscribed from adding or discharging hazardous wastes to its surface impoundments unless in accordance with a RCRA permit.

VIII. FUNDING

Respondent shall request, through the Department of the Air Force and the Department of Defense, all funds and/or authorizations necessary to meet the conditions of this Agreement. With regard to funding, the timetables, schedules and courses of action reached in implementation of this Agreement are fixed and definite except to the extent that the Congress of the United States may fail to approve authorizations and/or appropriations requests

necessary to execute them. [Although failure to obtain approval of adequate authorization and/or appropriations from Congress may alter the established timetable and schedules in accordance with paragraph IX, Force Majeure, it does not release Holloman from its obligations of compliance with the Resource Conservation and Recovery Act, as amended, 42 U.S.C. 6901 et seq. If sufficient funds are not appropriated by the Congress as requested and existing funds are not available to achieve compliance with the schedules provided in this agreement, and the Respondent reports the lack of funds in accordance with Section X, Reporting Requirements and Extensions, then pursuant to Section X, the compliance schedule shall be revised as necessary.]

IX. FORCE MAJEURE

A Force Majeure shall mean any event arising from causes beyond the control of Holloman AFB which causes a delay in or prevents the performance of any obligation under this Agreement. ~~Force~~ Majeure includes but is not limited to, acts of God; fire; war; insurrection; civil disturbance; explosion; adverse weather conditions that could not be reasonably anticipated; unusual delays in transportation, beyond the control of Holloman AFB; restraint by court order or order of public authority; inability to obtain, at reasonable cost and after exercise of reasonable diligence, any necessary authorizations, approvals, permits, or licenses due to action or inaction of any governmental agency or authority other than the Air Force; delays caused by compliance with applicable statutes or regulations governing contracting, procurement or acquisition procedures, despite the exercise of reasonable diligence; and failure to obtain approval of adequate authorizations and/or appropriations from Congress, if Holloman shall have made timely request for such funds as part of the budgetary process as set forth in Part VIII (Funding) of this

Agreement. A Force Majeure shall also include any strike or other labor dispute, whether or not within the control of the Parties affected hereby, Force Majeure shall not include increased costs of activities covered by this Agreement, whether or not anticipated at the time such activities were initiated.

X. REPORTING AND EXTENSIONS

Commencing at the end of the first full quarter after Complainant signs this Agreement, Respondent shall submit a quarterly progress report by the fifth (5th) working day of each fourth month. Progress reports shall summarize the efforts undertaken pursuant to this Agreement during the previous quarter.

In addition to regularly scheduled progress reports, Respondent shall immediately submit notification to the Complainant and the NMEID whenever any delay is anticipated in meeting any scheduled compliance date (e.g., an event of Force Majeure). The notification shall describe in detail the anticipated length of delay, the precise cause or causes of the delay, when and how Respondent became aware of the causes of the delay, the measures taken and to be taken to prevent or minimize the delay (or similar, future delays) and the alternative timetable by which the measures shall be implemented. Within five (5) days of receiving such notification, Complainant shall make a determination whether the compliance schedule shall be revised. If Respondent disagrees with the Complainant's determination, Dispute Resolution procedures described herein shall control. If Complainant does not respond within fourteen (14) days to Respondent's notification, Respondent's alternative timetables shall be deemed approved.

XI. EMPOWERMENT TO AMEND

In the event that there is an amendment of the RCRA, or the NMHWA, or the regulations promulgated under those statutes, or in the event that any portion of Respondent's system of surface impoundments is declared Waters of the United States, or in the event that amendments to this Agreement are dictated by dispute resolvers pursuant to section XI of this Agreement, the effected provisions of this Agreement will be renegotiated as necessary. Disagreements in renegotiation shall be resolved pursuant to the Dispute Resolution provision of this Agreement. During the pendency of any request for renegotiation, this Compliance Agreement, to the extent it is not specifically abrogated by Complainant, shall remain in effect.

XII. DISPUTE RESOLUTION

Except as specifically set forth elsewhere in this Agreement, if a dispute arises under this Agreement, the procedures of this Part shall apply. In addition, during the pendency of any dispute, Holloman agrees that it shall continue to implement those portions of this Agreement which are not in dispute and which U. S. EPA and New Mexico determine can be reasonably implemented pending final resolution of the issue(s) in dispute. If U.S. EPA and New Mexico determine that all or part of those portions of work which are affected by the dispute should stop during the pendendy of the dispute, Holloman shall discontinue implementing those portions of the work.

All Parties to this Agreement shall make reasonable efforts to informally resolve disputes at the Project Manager or immediate supervisor level. If resolution cannot be achieved informally, the procedures of this Part shall be implemented to resolve a dispute.

A. Within thirty (30) days of the date of any action by U.S. EPA or New Mexico which leads to or generates a dispute, Holloman shall submit to

the Dispute Resolution Committee (DRC) a Written Statement of Dispute setting forth the nature of the dispute, Holloman's position with respect to the dispute and the information that Holloman is relying upon to support its position. If Holloman does not provide such written statement to the DRC with this thirty (30) day period, Holloman shall be deemed to have agreed with the action taken by U.S. EPA or New Mexico which led to or generated the dispute.

B. Where U.S. EPA or New Mexico issues a written Notice of Position, any other Party which disagrees with the Written Notice of Position may submit to the DRC a written statement of dispute setting forth the nature of the dispute, its position with respect to the dispute and the information it is relying upon to support its position. If no other Party provides such a written statement of dispute to the DRC within thirty (30) days of receipt of the Written Notice of Position, the Parties shall be deemed to have agreed with the Written Notice of Position.

C. Prior to any Party's issuance of a written statement of dispute, the disputing Party shall engage the other Party in informal dispute resolution among the Project Managers and/or their immediate supervisors. During this informal dispute resolution period the Parties shall meet as many times as are necessary to discuss and attempt resolution of the dispute.

D. The DRC will serve as a forum for resolution of disputes for which agreement has not been reached through informal dispute resolution. The parties shall each designate one individual and an alternate to serve on the DRC. The individuals designated to serve on the DRC shall be employed at the policy level (SES or equivalent) or be delegated to authority to participate on the DRC for the purposes of dispute resolution under this Agreement. The U.S. EPA representative on the DRC is the Hazardous Waste Management Division

Director of U.S. EPA Region VI. New Mexico's designated member is the Chief, Hazardous Waste Bureau, NMEID. Holloman's designated member is the Director, Engineering and Environmental Planning, Headquarters Tactical Air Command. Notice of any delegation of authority from a Party's designated representative on the DRC shall be immediately provided to all other Parties.

E. Following elevation of a dispute to the DRC, the DRC shall have twenty-one (21) days to unanimously resolve the dispute and issue a written decision. If the DRC is unable to unanimously resolve the dispute within this twenty-one (21) day period, the written statement of dispute shall be forwarded to the Senior Executive Committee (SEC) for resolution within seven (7) days after the close of the twenty-one (21) day resolution period.

F. The SEC will serve as the forum for resolution of disputes for which agreement has not been reached by the DRC. The U.S. EPA representative on the SEC is the Regional Administrator of U.S. EPA's Region VI. New Mexico's designated member is the Director, Envir~~onm~~ental Improvement Division. The Air Force's designated member is the Deputy Assistant Secretary of the Air Force for Environment, Safety, and Occupational Health. The SEC members shall, as appropriate, confer, meet and exert their best efforts to resolve the dispute and issue a written decision. If unanimous resolution of the dispute is not reached within twenty-one (21) days, U.S. EPA's Regional Administrator's issue a written position on the dispute. The Air Force may, within fourteen (14) days of the Regional Administrator's issuance of U.S. EPA's position, issue a written notice elevating the dispute to the Administrator of U.S. EPA for resolution in accordance with all applicable laws, directives and procedures. In the event that the Air Force elects not to elevate the dispute to the Administrator within the designated fourteen (14) day escalation period, the Air Force shall be deemed to have agreed with

the Regional Administrator's written position with respect to the dispute.

G. Upon escalation of a dispute to the Administrator of U.S. EPA pursuant to Subpart F, the Administrator will review and resolve the dispute within twenty-one (21) days. Upon request, and prior to resolving the dispute, the U.S. EPA Administrator shall meet and confer with both the NMEID Director and the Air Force's Secretariat Representative to discuss the issue(s) under dispute. Upon resolution, the Administrator shall provide NMEID and the Air Force with a written final decision setting forth resolution of the dispute. The duties of the Administrator set forth in this Part shall not be delegated.

H. The pendency of any dispute under this Part shall not affect the Air Force's responsibility for timely performance of the work required by this Agreement, except that the time period for completion of work affected by such a dispute shall be extended for a period of time usually not to exceed the actual time taken to resolve any good faith dispute in accordance with the dispute procedures specified herein. All elements of the work required by this Agreement which are not affected by the dispute shall continue and be completed in accordance with the applicable schedule.

I. When dispute resolution is in progress, work affected by the dispute will immediately be discontinued if the Hazardous Waste Division Director for U.S. EPA's Region VI requests, in writing, that work related to the dispute be stopped because, in U.S. EPA's opinion, such work is inadequate or defective, and such inadequacy or defect is likely to yield an adverse effect on human health or the environment, or is likely to have a substantial adverse effect on the implementation process. To the extent possible, U.S. EPA shall consult with the Air Force and NMEID prior to initiating a work stoppage request. After stoppage of work, if the Air Force believes that the work stoppage is inappropriate or may have potential significant adverse impacts, the Air Force

may meet with the Division Director and NMEID to discuss the work stoppage. Following this meeting, and further consideration of the issues, the Division Director will issue, in writing, a final decision with respect to the work stoppage. The final written decision of the Division Director may immediately be subjected to formal dispute resolution or such dispute may be brought directly to either the DRC or the SEC, at the discretion of the Air Force.

J. Within twenty-one (21) days of resolution of a dispute pursuant to the procedures specified in this Part, the Air Force shall incorporate the resolution and final determination into the appropriate plan, schedule or procedures and proceed to implement this Agreement according to the amended plan, schedule or procedures.

K. Resolution of a dispute pursuant to this Part of the Agreement constitutes a final resolution of any dispute arising under this Agreement. All applicable laws, directives, and procedures apply to resolution of disputes under this Part. All Parties shall abide by all terms and conditions of any final resolution of dispute obtained pursuant to this Part of this Agreement.

This Agreement shall become effective immediately.

Robert E. Layton Jr.

Robert E. Layton Jr., P.E.
Regional Administrator
U.S. Environmental Protection Agency
Region VI

Dated this 20th day of December 1988, at Dallas Texas.

AGREED:

Dated: 20 Dec 1988

By:
Commander
833rd Combat Support Group
Respondent

Dated: 12/20/88

Allyn M. Davis, Director
Hazardous Waste Management Division
U.S. Environmental Protection Agency
Region VI
Complainant

Dated: 12/13/88

Richard Mitzelfelt, Director
New Mexico Environmental
Improvement Division

APPENDIX L

SCOPE OF SERVICES CONTRACT
FOR HYDROGEOLOGIC INVESTIGATION
HOLLOMAN AFB, NEW MEXICO

SCOPE OF SERVICES
FOR
CONTRACT NO. DACA45-86-D-0052
HOLLOMAN AFB, NEW MEXICO
SUPPLEMENT TO APPENDIX "A"
14 AUGUST 1986
Revised 4 September 1986

1. PROJECT DESCRIPTION. The Architect-Engineer (A-E) shall conduct all necessary travel and professional analysis and perform all work required to establish a groundwater monitoring program in the vicinity of the Sewage Lagoons and Lake Holloman at Holloman Air Force Base, New Mexico. In general the A-E will be required to:

a. Prepare and submit a detailed descriptive groundwater monitoring plan. This groundwater monitoring plan shall be consistant with the latest EPA RCRA guidance and ultimately approved by EPA, Region VI. Official submission of the groundwater monitoring plan will be made by the U.S. Air Force. The A-E will be required to attend one official meeting with EPA, Region VI to assist the U.S. Air Force in explaining the intent of the groundwater monitoring plan.

b. Once the groundwater monitoring plan has been accepted by the U.S. Air Force the A-E shall implement the plan. That being installed up to twenty-two monitoring wells to obtain water samples of the groundwater upgradient and downgradient of the exist~~ing~~ sewage lagoons. Eleven (11) of the wells will be 100 feet deep and eleven (11) of the wells will be 150 feet deep. Specific details regarding the monitoring well installation are included in Paragraph 2.a. of this Scope of Services.

c. After the monitoring well installation has been completed, one complete round of water samples shall be obtained and analyzed. The analytical parameters are identified in Paragraph 2.b. of this Scope of Services.

d. At the completion of all field investigations and analytical work a final report shall be prepared and issued to the Contracting Officer. As a minimum, this final report shall contain the original approved groundwater monitoring plan, the surveyed monitoring wells showing a plan view, logs and construction diagrams of each well installed, a complete description of the analytical results with the analytical data and a descriptive analysis indicating the results of the field work with recommendations to the Air Force regarding future management of the site.

2. SCOPE OF SERVICES. The project will be performed in accordance with the information outlined in this Appendix "A" as well as ER1110-1-263 (in conjunction with "A-E Quality Management Procedures for Site Investigative Activities"). The following data gathering activities shall be included in this task order.

a. DRILLING.

(1) The A-E shall install up to twenty-two monitoring wells in the vicinity of the Holloman AFB Sewage Lagoons. A total of 2,750 lineal

feet of drilling shall be included in this task order. All monitoring wells shall meet all RCRA requirements for monitoring a hazardous waste surface impoundment. The wells shall be installed in clusters of two wells per cluster. One well in each cluster shall be approximately 150 feet in depth, the other well in each cluster shall be approximately 100 feet deep. Two clusters shall be installed upgradient of the sewage lagoons and the remaining clusters shall be installed downgradient. Any deviation from this approach shall be approved by the Contracting Officer.

(2) Monitoring Well Location: Prior to initiation of site activities, the contractor shall submit to the Contracting Officer a Monitoring Well Installation Plan. This plan shall include the proposed locations of the wells and reasons for these locations with a description of the equipment and procedures that will be used to install monitoring wells and to obtain the specific soil samples. At a minimum, the plan shall describe the drilling equipment and methods, well development procedure, in situ permeability test method, reasons for the well locations and procedure for decontaminating equipment between borings.

(3) Monitoring Well Installation: The monitoring wells shall be installed in accordance with all state and local certification requirements. The A-E shall be responsible for obtaining the well drilling permits and for complying with the state or local regulations concerning submission of well logs and samples.

(4) General Drilling Requirements:

(a) The A-E shall provide ~~a~~ qualified geologist who shall be on-site for all drilling, installation, development and testing operations.

(b) Protection of Water Yielding Zones. The use of contaminating additives (bentonite, gels, barite, etc.) in drilling fluids is not permitted. Grease or oil on drill rod joints is not permitted. Dispersing agents (such as phosphates) or acids shall not be used in well installation or development. There shall be no attempt made to chemically disinfect the well. The drill rig or rigs, drill tools, and associated equipment shall be cleaned with live steam prior to commencement of drilling at each well location. It is expressly understood that toxic and/or contaminating substances shall not be used during any part of the drilling, well installation or well development process. All drilling activities and methods shall be sufficient to prohibit the introduction of contaminants from one water bearing stratum to another via the well bore.

(c) Well Design. (See Figure 1). Boring Diameter. The boring shall be of sufficient diameter to permit at least two inches of annular space between the boring wall and all sides of the centered riser and screen.

(d) Well Riser, Screen and Tailpipe:

(1) Riser: Well riser shall consist of new threaded, flush joint steel line pipe with a minimum four inches inside diameter. All well risers shall, as a minimum, have a 1/4" wall thickness.

(2) Screen: The well screen shall be 20 feet in length and shall be constructed of 304 stainless steel with the same diameter as the well riser. The screen shall be a "continuous wrap" design. The slot size shall be determined by the A-E and designed to be compatible with aquifer and gravel pack material.

(3) Screen Location: The A-E shall have the responsibility of selecting the screened area of the borehole so that the completed monitoring well functions satisfactorily.

(4) Tailpipe: A five foot long tailpipe shall be attached below the screen. The tailpipe shall be of the same diameter and material as the riser pipe and shall be connected to the screen in the same fashion as the riser pipe.

(5) Joining Riser: Riser sections shall be joined by threaded flush joint couplings, to form watertight unions. No lead shot or lead wool is to be employed in producing seals at any point in the well.

(6) Well Plumbness and Alignment. All risers shall be sent round, plumb, and true to line. Centralizers shall be used to assure plumbness and alignment of the wells. A ten foot long section of pipe, 1/2 inch less in diameter than the inner diameter of the well riser pipe shall be run through the entire length of the well to check the alignment.

(7) Bentonite Seal and Grout. A minimum two (2) foot seal, consisting of tamped bentonite pellets shall be placed into the annular space between the riser and boring wall approximately 2 feet above the screened portion of the hole. Cement grout shall then be placed from the top of the bentonite seal to the ground surface. The cement grout shall consist of a mixture of portland cement (ASTM C 150) and water in the proportion of not more than seven (7) gallons of clean water per bag of cement (one cubic foot or 94 pounds). Additionally, 3% by weight of bentonite powder shall be added if permitted by state regulations.

(8) Soil Sampling for Geotechnical Analysis. During drilling the geologist and crew shall collect soil samples for geotechnical analysis as outlined below.

(a) Standard Penetration Tests (according to ASTM D 1586) shall be taken every 10 feet or change in material from the ground surface to the bottom of the hole in each 150 foot deep boring. Tests shall be taken in the 100 foot deep borings at 85 and 95 feet only. Soil samples shall be retained from each standard penetration test.

(b) Samples shall be stored in plastic or glass jars by the contractor until such time as they are needed for testing or the contract is complete.

(c) All soil samples shall be visually classified using the Unified Soil Classification System. The A-E shall verify the classification by laboratory analyses consisting of the following, if they are applicable:

Test	Tests/Boring
Grain-size distribution (ASTM D 421 & 422)	2
Atterbury limits (ASTM D 4318)	2
Moisture content (ASTM D 2216)	2

Specific soil samples to be tested, along with type of test, will be determined by the Contractor after reviewing the boring logs. Laboratory analyses shall use equipment and methods described in EM-1110-2-1906 (Reference 1.), or ASTM manuals (referenced above).

(9) Centralizers. Centralizers shall be placed at approximate 20 foot intervals, except that no centralizers shall be placed on the well screen itself. Centralizers shall be commercially fabricated or the A-E's design if approved by the Contracting Officer.

(10) Temporary Casing: If necessary, a temporary well casing of either iron or steel, new or used, may be used to support the sides of the entire hole during drilling and placement of screen, casing, and gravel filter pack material. If used casing is utilized it must be clean and free from contaminants to prevent introduction of foreign material into the well. Any temporary casing shall have an inside diameter large enough to provide a 2 1/2-inch minimum filter thickness entirely around the screen and shall have sufficient thickness to retain its shape and maintain a true section throughout its depth. The temporary casing shall be such as to permit its removal without damaging or interfering with the filter or permanent casing.

(11) Only clean, nonchlorinated water or formation water from the well being drilled may be used as drilling fluid. The water source shall be included in the Monitoring Well Installation Plan.

(12) Protection of Well. At all times during the progress of the work, precautions shall be used to prevent tampering with the well or the entrance of foreign material into it. Upon completion of the well, a suitable vented cap shall be installed to prevent material from entering the well. The well riser shall be surrounded by a larger diameter steel casing and rising 24"to 36" above ground level set into a concrete pad. The steel casing shall be provided with lock and cap. All locks shall be keyed alike. All keys shall be turned over to the Holloman Base Environmental Coordinator upon completion of all field work. A minimum three (3) foot square, four (4) inch thick concrete pad, sloped away from the well, shall be constructed around the well casing at the final ground level elevation. Three (3), two (2) inch diameter or larger steel posts shall be installed in the concrete pad around the wall. There shall be no openings in the protective casing wall below its top.

(13) Temporary Capping. Any well that is to be temporarily removed from service or left incomplete due to delay in construction shall be capped with a watertight cap and equipped with a "vandal proof" cover satisfying applicable state or local regulations or recommendations.

(14) Well Construction Logs. Suitable logs detailing construction practices shall be maintained for inclusion in the Final Report. The logs shall be prepared by a qualified geologist present during all drilling operations. The original and one (1) legible copy of each field well construction log shall be submitted to the CO not later than ten (10) calendar days after the well is completed. The well will not be accepted by the CO until the logs are received and approved. Information provided in the logs shall include but not limited to the following:

(a) Reference elevation for all depth measurements.

(b) Depth of each change of stratum.

(c) Thickness of each stratum.

(d) Identification of the material of which each stratum is composed according to the Unified Soil Classification System, or standard rock nomenclature, as necessary.

(e) Depth interval from which each formation sample was taken.

(f) Depth at which hole diameter (bit sizes) changes.

(g) Depth at which groundwater is first encountered.

(h) Depth to the static water level and changes in static water level with well depth.

(i) Total depth of completed well.

(j) Depth or location of any loss of drill water circulation, loss of tools or equipment.

(k) Location of any fractures, joints, faults, cavities or weathered zones.

(l) Depth of any grouting or sealing.

(m) Nominal hole diameters.

(n) Amount of cement used for grouting or sealing.

(o) Depth and type of well casing.

(p) Description (to include length, location, diameter, slot sizes, material, and manufacturer) of well screen(s).

(q) Any sealing-off of water-bearing strata.

(r) Static water level upon completion of the well and after development.

(s) Drilling date or dates.

(t) Construction details of monitoring well, including source and description of gravel pack material.

(15) Well Locations. Coordinates and elevations shall be established for each monitoring well. The coordinates shall be to the closest 1.0 foot and referenced to the State Plane Coordinate System. If the State Plane Coordinate System is not readily available, an existing local grid system shall be used. A ground elevation for the top of the casing to the closest 0.01 foot and an elevation for the top of the casing to the closest 0.01 foot shall be obtained at each well. These elevations shall be referenced to the National Geodetic Vertical Datum of 1929. If the 1929 Datum is not readily available, the existing local vertical Datum shall be used. The location, identification, coordinates and elevations of the wells and monuments shall be plotted on maps with a scale large enough to show their location with reference to other structures at the individual sites. A tabulated list of the monitoring wells, copies of all field books, and all computation sheets shall be prepared and submitted to the Omaha District, ATTN: MROED-EB. The tabulation shall consist of the designated number of the well, the X and Y coordinates, and all the required elevations. These items shall become a part of the final report.

(16) Identification of Wells. the Contractor shall affix a permanent marking or tag to the outer steel protective casing of each well which clearly identifies the well number, the U.S. Army Corps of Engineers, Omaha district, and the adjusted top of casing elevation.

(17) Responsibility for Monitoring Wells. It is the responsibility of the Contractor to properly plan, design, install, develop, and test monitoring wells so that they are suitable to produce representative groundwater samples in sufficient quantity and quality for geochemical and environmental contamination testing, and which meet all RCRA requirements. The A-E shall ensure that the intentions of this Scope of Services and good construction practices are carried out.

(a) If the A-E, due to his inadequate design or construction, installs monitoring wells that are not functional or not in accordance with specifications, the CO will disapprove the well and direct the A-E to repair or replace it at the CO's direction. This work shall be done at no additional cost to the Government.

(b) If a monitoring well is disapproved by the CO or is abandoned by the A-E for any reason, the hole shall be backfilled with neat cement grout from top to bottom by the A-E at no additional cost to the Government.

(18) Well Development. After each well has been constructed, but no sooner than 48 hours after grouting is completed, the Contractor shall direct a program for the development of the well by pumping and/or surging, without the use of acids, dispersing agents or

explosives. Development shall continue for a period of four (4) hours (minimum) and until groundwater removed from the well is clear and free of sand. At least as much water as was introduced during drilling shall be removed from the well. No water or other liquid may be introduced into the well other than formation water from the well. After final development of the well, the A-E shall collect approximately one (1) liter of water from the well in a clear glass jar, label and photograph it with a 35 mm color slide, and submit the slide as part of the well log. The photograph shall be a suitably back-lit close up which shows the clarity of the water.

(19) In Situ Permeability Determination. After development of monitoring wells, the A-E shall determine for each the in situ permeability of the uppermost water bearing statum in accordance with "Methods of Determining Permeability, Transmissibility and Drawdown," (Reference 2.). However, no water or other liquid may be introduced into the well other than formation water from that well.

(20) References:

(a) Laboratory soil testing, U.S. Army Engineering Manual No. EM-1110-2-1906, November 1970.

(b) Methods of Determining Permeability, Transmissibility and Drawdown, U.S. Geological Survey Water Supply Paper No. 1536-1, 1963.

b. SAMPLING AND ANALYTICAL REQUIREMENTS. At the completion of the monitoring well installation under the terms of this contract the A-E shall obtain one round of water samples from each well. Decontamination of all sampling equipment will be achieved using an industrial detergent wash, water rinse, methanol rinse and double deionized water rinse.

(1) All water samples obtained from the monitoring wells shall be analyzed for chemical constituents listed in Appendix IX of amended RCRA section 264.99 (Federal Register 51, 142 July 24, 1986) RCRA analysis shall proceed by the following methodologies: (Refer to Table II)

Chemical Compounds	SW-846 Method
Volatile Organics (including xylene, methanol and formaldehyde)	8240 - CLP
Extractable A/B/N Organics	8270 - CLP
Pesticides, PCB's	8080 - CLP
Metals (including Al, Sb, Ba, Be, Cd, Ca, Cr, Co, W, Fe, Sn, Mg, Mn, Na, Ni, K, Ag, Tl, V, 2n)	6010 w/digestion
Cyanide	9010
Selenium	7740

Arsenic	7060
Lead	7420
Mercury	7470
Propionic Acid	Std. Meth. 504A
Formaldehyde	GC/FID

(2) Sample containers, preservation requirements, holding times, sample custody and sample packaging procedures shall be according to the Corps of Engineers Sample Handling Protocol dated March 1986 and Table I attached to this Scope of Services.

(3) Quality control samples for contract lab analysis shall consist of duplicates and field blanks taken in the same sample containers and handled in the same manner as the field samples. The number of duplicates shall be one for each ten samples. At least one field blank shall be taken for each ten field samples. Field blanks for water samples may be sampler rinsates or distilled water trip blanks treated with the same preservatives as required for field samples. One sampler rinsate and one trip blank will be taken as groundwater field blanks for this project. These quality control samples will be analyzed for all parameters specified above.

(4) Quality Assurance Samples shall consist of duplicates and field blanks taken in the same sample containers and handled in the same manner as the field samples. Guidance for QA samples is derived from the COE Sample Handling Protocol dated March 1986. Sample number and type, chain-of-custody procedures and packaging guidelines shall be followed explicitly. The samples shall be sent to:

U.S. Army Engineer Division, Missouri River
ATTN: MRDED-L (Joe Solsky)
427 S. 18th Street
Omaha, NE 68102

(5) Matrix Spike analysis shall be run for 1 in 20 water analyses for Quality Control purposes. Methods specifying greater rates of spike analysis shall be followed explicity.

(6) Total number of samples collected shall be in accordance with Table 2.

3. Presentations. The A-E shall assist the U.S. Air Force in presenting the documents generated by this work order to the appropriate environmental agencies at meetings established by the Holloman, AFB Environmental Coordinator.

4. Special Considerations. All materials gathered and developed in the performance of this work listed in this contract shall be the property of the Corps of Engineers/U.S. Air Force and shall not be used, distributed,

or published by the Contractor without specific permission from the Corps of Engineers/U.S. Air Force.

5. Project Management.

a. Project Engineer. The Contractor shall assign a member or employee who will be known as the Project Engineer or Project Manager. This individual will oversee the correlation of the entire project, administer all instructions from this office, and answer or obtain answers to all questions from this office during and after the work.

b. Coordination. During the prosecution of the work under the contract, the Contractor shall keep in close liaison with the Corps of Engineers Project Manager (COE PM), who will coordinate the work with the Base Environmental Coordinator. All requests made by the Air Force shall be referred to the COE Project Manager.

6. General.

a. Travel. The Contractor will perform the following travel as part of the contract requirement, and the cost thereof shall be included with the contract cost. Responsible representatives of the Contractor's firm from the appropriate disciplines shall attend conferences and/or make the following listed trips:

(1) Attend one groundwater monitoring plan presentation at U.S. EPA office, Region VI located in Dallas, Texas.

(2) All travel required to obtain field data necessary to complete this work order.

b. Data Provided for Information.

(1) Installation Restoration Program Management Guidance dated July, 1985.

(2) ER-1110-1-263, Engineering and Design, Chemical Quality Management—Toxic and Hazardous Waste.

(3) Installation Restoration Program Records Search, dated August 1983. Installation Restoration Program Phase II, Confirmation/Quantification Stage I - dated March 1985.

(4) ER-385-1-92, Safety and Occupational Health Document Requirements for Hazardous Waste Site Remedial Actions.

(5) Safety and Health Requirements Manual EM 385-1-1, April, 1981, revised October, 1984.

(6) Sample of Health and Safety Plan.

(7) A-E Instruction Manual, June, 1983.

(8) User's Guide to the Contract Laboratory Program, EPA, October, 1984.

(9) A-E Guidance for Developing A-E Quality Management Procedures for Site Investigative Activities.

(10) Accident Prevention-FAR Clause 236-13: (one sheet).

(11) Evaluation of USGS Groundwater Data for Sewage Lagoons at Holloman AFB, New Mexico dated April 1986. Prepared by Wilson and Company.

(12) U.S. EPA, Region VI letter of August 23, 1985, Notice of Noncompliance, Compliance Schedule and Notice of Necessity for Conference.

(13) Copy of Federal Register Vol 51 No. 142 dated Thursday, July 24, 1986. Hazardous Waste Management System; Groundwater Monitoring, Proposed Rule.

c. Review of Progress and Technical Adequacy.

(1) At appropriate times, representatives of the Contracting Officer may review the progress and technical adequacy of the work. Such review will not relieve the Contractor from performing all contract requirements, except as may be waived by written instruction.

(2) The Contractor, under this contract, will interpose no objection nor restriction to the Contracting Officer's designation of a Contractor for the purpose of reviewing the adequacy and corrections of the work performed under this contract.

(3) The Contractor shall submit progress reports to the COE with each request for payment. The progress reports shall indicate work performed, costs, and problems incurred during the payment period.

d. Conference Notes and Confirmation Notices.

(1) Conference Notes. The Contractor will be responsible for taking notes and preparing the reports of all conferences. Conference notes will be prepared in typed form and the original furnished this office (within five (5) days after date of conference) for concurrence and distribution to all attendees. This report shall include the following items as a minimum:

(a) The date and place the conference was held with a list of attendees. The roster of attendees shall include name, organization, and telephone number.

(b) Written comments presented by attendees shall be attached to each report with the conference action noted. Conference action shall be "A" for an Approved comment, "D" for a Disapproved comment, "W" for a comment that has been Withdrawn, and "E" for a comment that has an Exception noted.

(c) Comments made during the conference, decisions affecting criteria changes, must be recorded in the basic conference

notes. Any augmentation of written comments should be documented by the conference notes.

(2) Confirmation Notices. The Contractor will be required to provide a record of all discussions, verbal directions, telephone conversations, etc., participated in by the Contractor and/or his representatives on matters relative to this contract and the work, irrespective of whom the other participants may have been. These records, entitled "Confirmation Notices," will be numbered sequentially and shall fully identify participating personnel, subject discussed, and any conclusions reached. The Contractor shall forward to the Contracting Officer or his representative as soon as possible (not more than five (5) work days), a reproducible copy of said confirmation notices. Distribution of said confirmation notices will be made by the Government.

e. Expert Testimony. All technical consultants required for this investigation will be provided by the Contractor and will be qualified to provide expert witness testimony, if required. In the event of litigation, the contract will be modified to compensate the Contractor for the additional services required.

7. Submittals. In general, the A-E is responsible for reproduction and distribution of all documents. Documents shall be mailed to all reviewers via a carrier service that will provide overnight service, such as express mail, unless otherwise noted. The following names and addresses will be submitted the number of copies indicated:

Item: Groundwater Monitoring Plan reference paragraph 1.a. this Scope of Services, and final report reference paragraph 1.d. of this Scope of Services.

Name and Address	No. of Copies
HQ Tactical Air Command ATTN: DEEV (Burnet) Langley AFB, VA 23665-5001	6 copies
HQ 833 CSG/DEEV ATTN: Mr. Bob Andreoli Holloman AFB, NM 88330-5000	6 copies
U.S. Army Engineer District, Omaha ATTN: MROED-EB (Dappen) 215 N. 17th Street Omaha, NE 68102-4910	3 copies

(1) Partial Submittals. Partial submittals will not be accepted unless prior approval is given.

(2) Cover Letters. A cover letter should accompany each document and indicate the project, project phase, the date comments are due, to whom comments are to be submitted, the date and location of the review conference, etc., as appropriate. (Note that, depending on the recipient, not all letters will contain the same information.) The

contents of the cover letters should be coordinated with the COE Project Manager prior to the submittal date.

(3) Reproducibles. One reproducible, unbound copy of each submittal shall be provided to the COE. While all submittals should be error-free, an extra effort shall be made to provide an error-free Final Report.

a. The Contractor designated laboratory(ies) will require validation by MRDED-L. This validation will consist of submitting an "off-the-shelf" Quality Management document to the COE PM as soon after the site meeting as possible. The validation may also require a lab visit by MRDED-L staff and analysis of performance evaluation samples for project-specific parameters. The samples will consist of one (1) analytical test for each parameter and will be supplied by the COE. The Contractor may only charge for the analytical cost of the successful run of the performance evaluation samples.

b. Specific Submittal Requirements. All necessary actions to support this work request shall include a detailed discussion of the technical approach and schedules. These plans are "working documents" and shall be structured to absorb changes during the course of the project. These documents shall be submitted in loose-leaf binders and revisions distributed in the form of new and/or replacement pages. All plans must be approved prior to commencement of that work effort. The Contractor shall submit to the Contracting Officer three (3) copies each of a Sampling Plan (SP), an A-E Quality Control Plan (A-EQCP), a Safety, Health and Emergency Response Plan (A-E SHERP), and an A-E Lab Quality Management Plan (A-ELQMP) as outlined below.

(1) Sampling Plan (SP). A Sampling Plan to address all field activities shall be prepared in order to obtain additional site data. The Sampling Plan will contain a statement of sampling objectives; specification of equipment, analyses of interest, sample types, and sample locations and frequency; and schedule. Use of field screening techniques to screen out samples that do not require off-site laboratory analysis should be considered.

(2) A-E Quality Control Plan (A-EQCP). An effective working plan for chemical data quality control developed by the design A-E. An A-EQCP will include the information outlined in the A-E Guidance for Developing A-E Quality Management Procedures for Site Investigative Activities.

(3) Safety, Health and Emergency Response Plan (A-E SHERP).

(a) Investigative activities pose unique construction safety and chemical exposure hazards which require specialized expertise to effectively eliminate. Accordingly, the Contractor shall be required to develop a project-specific A-E Safety, Health and Emergency Response Plan (A-E SHERP) which shall address accident prevention, personal protection, and emergency response procedures. The A-E SHERP shall establish in detail the protocols necessary for protecting workers from any hazards associated with drilling/sampling equipment and procedures and from hazards attendant to potential exposures from chemicals suspected to

be on-site. The A-E SHERP shall be submitted to the Contracting Officer for approval prior to the commencement of any on-site activities. The Contractor shall refer to the following requirements in formulating the A-E SHERP, applying those standards which provide the greatest degree of protection.

(1) Federal Acquisition Regulation Clause 52.236-13, Accident Prevention, referencing:

(a) COE Safety and Health Requirements Manual, EM-385-1-1.

(b) U.S. Department of Labor OSHA Standards for Construction Industry, 29 CFR Part 1926.

(2) EPA Standard Operating Safety Guides, November, 1984.

(3) Applicable sections of Recommended Practice for Handling Underground Leakage of Flammable and Combustible Liquids, NFPA 329-1983.

(b) The Contractor shall address the following topics in detail in the A-E SHERP submitted to the Contracting Officer.

(1) Staff organization, qualifications and responsibilities: Chain-of-command including the individuals responsible for the development, implementation, oversight and enforcement of the site specific safety and health requirements delineated in the A-E SHERP for all phases of the work. Professional Industrial Hygiene support to be provided by the Contractor for the project shall be delineated. The names, qualifications and work experience of all safety and health personnel to be used by the Contractor throughout the performance of this contract shall be submitted for approval with the A-E SHERP.

(2) Accident prevention: An accident prevention plan and description of work phase safety plans shall be presented as discussed in Para. 01.A.03, 01.A.04, 01.A.05 and 01.A.06 and Appendix Y of COE EM385-1-1. Each phase safety plan shall include a description of the work activity, and positive precautionary measures to be taken to safeguard against, and to reduce or eliminate each particular hazard.

(3) Site description, site access controls and work zones, as referenced in EPA Standard Operating Safety Guides, November, 1984, where applicable.

(4) Personnel protective equipment: Protective clothing, head and foot protection, eye/face protection, respirator requirements for each work phase and work zone.

(5) Personnel and equipment decontamination procedures and facilities where applicable.

(6) Health and safety work precautions: Buddy system, controlled access, eating and drinking precautions, smoking and ignition sources, and explosive atmospheres.

(7) Medical surveillance: Pre- and post-physical examinations, lost work day injuries.

(8) Training and education of workers: Initial training prior to commencement of work to be conducted in basic construction safety emphasizing site specific hazards; acute and chronic effects of chemicals expected on site; personal protective equipment requirements including proper use, limitations and fitting; and emergency/fire response procedures. Follow-up training is to be performed prior to each change in phases of work where applicable.

(9) Personnel and environmental monitoring: Explosive atmospheres; personnel exposures to toxic air contaminants, specifying appropriate action levels for donning personal protective equipment and emergency response.

(10) Emergency response equipment and procedures: Fire/explosion provisions; emergency spill control; first aid provisions and emergency equipment; communications and notification protocols; site evacuation procedures and contingency plans. Phone numbers.

(11) Logs, reports, and recordkeeping: Safety inspection reports; medical certifications; training logs; monitoring results.

(c) The Contractor shall review the project information provided for the development of the A-E SHERP. If the information made available is insufficient to allow the Contractor to develop the A-E SHERP, a description of all additional information required shall be prepared and submitted to the Contracting Officer.

(d) The following are examples of available guidance which can be used (lastest editions shall be used).

(1) ER-385-1-92, Safety and Occupational Health Document Requirements for Hazardous Waste Site Remedial Actions, July 16, 1984.

(2) TLV's, Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment with Intended Changes Adopted by ACGIH (American Conference of Governmental Industrial Hygienists).

(3) ANSI Z88.2 - 1980, American National Standard Practices for Respiratory Protection.

(4) Air Sampling Instructions for Evaluation of Atmospheric Contaminants, 6th Edition, 1983, American Conference of Governmental Industrial Hygienists.

(5) Fundamentals of Industrial Hygiene, 2nd Edition, 1979, National Safety Council.

(4) A-E Lab Quality Management Plan (AE-LQMP). An extremely important aspect of this project is the management of the chemical data. A quality management plan must be established assuring that the Contractor collects, analyzes, and documents chemical data that are scientifically and legally defensible. The QM Plan prepared shall be in accordance with provisions covered in ER-1110-1-263 and applicable EPA and DOT regulations. As a part of this plan, the Contractor shall furnish, to the CO, at a minimum, the following:

(a) The quality control organization (including chain-of command) to be followed by the Contractor.

(b) Qualifications of personnel to be used for this purpose.

(c) Authority and responsibilities of all quality control personnel.

(d) Schedule of inspections.

(e) Proposed analytical methods (exact references and descriptions), names and qualifications (education, training and experience) of technicians and specific analysts performing each method, specific instrumentation (including manufacturer, model types, accessories, calibrations, year of purchase) and equipment to be used, and Contractor's laboratory facilities.

(f) Methods of performing, documenting and enforcing quality control operations of the prime contractor and subcontractors including inspection and testing. Lists of percentages and types of internal quality control checks, external quality assurance samples and performance audits are required.

(g) Types and contents of required quality control reports.

(h) As an example, a copy of a letter of direction to the Contractor's representative responsible for quality control, outlining his duties and responsibilities to be signed by a responsible senior officer of the firm.

(5) A-E Quality Control Summary Report (A-E QCSR). A report submitted to the CO by the A-E at the conclusion of the project (1) outlining QC practices employed by the A-E including any problems and acceptable corrective actions taken, and (2) containing a consolidation and summary of the A-E daily Quality Control Reports, as prescribed in the contract.

(6) A-E Daily Quality Control Reports (A-E DQCR). During the field investigative activities the contractor will provide Daily Quality Control Report (DQCR) to the Contracting Officer and the Holloman AFB Environmental Coordinator which will include the information found in A-E

Guidance for Developing A-E Quality Management Procedures for Site Investigative Activities. These reports shall be sent to the individuals indicated on a daily basis.

(7) Schedules. The Contractor shall include with his proposal a tentative schedule for the completion of all work as outlined in these schedules of services.

MONITORING WELL DESIGN

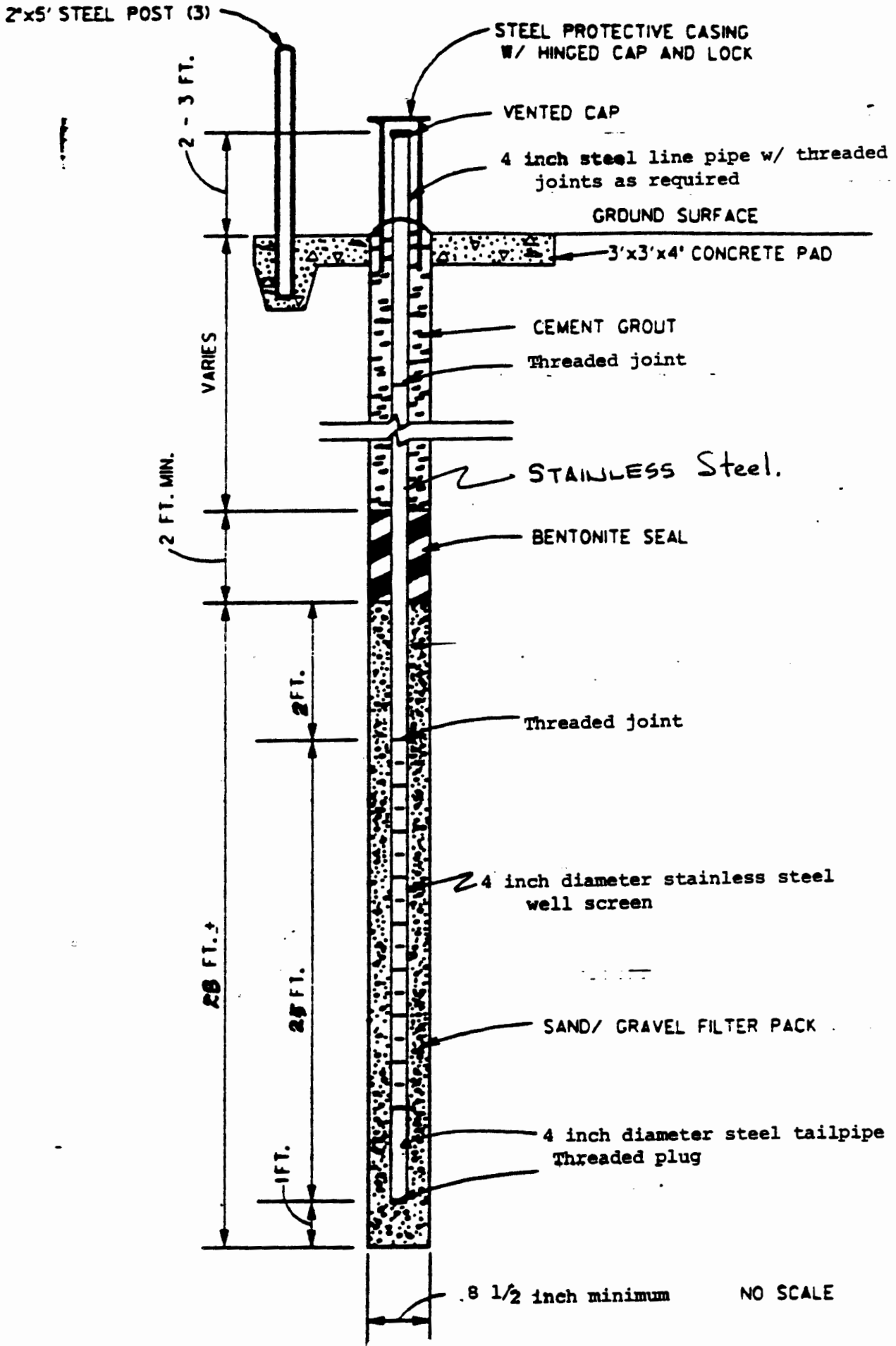

FIGURE 1

TABLE I
SAMPLE CONTAINERS, PRESERVATIVES, HOLDING TIMES
HOLLOMAN AFB, NEW MEXICO

PARAMETER	CONTAINER	PRESERVATIVE	HOLDING TIME
Volatile Organics (8240 - CLP)	3 ~~2~~-40 ml glass vials w/Teflon lined lids. No headspace.	Iced to 4°C Adjust Ph 2w/HCL	14 days
Formaldehyde (GCFID - Radian)	2-40 ml glass vials w/Teflon lined lids. No headspace.	Iced to 4°C	7 days
Extractable Organics (8270- CLP)	3-1 L amber glass bottles w/ Teflon lined caps, leave headspace.	Iced to 4°C	Extract within 5 days. Analyze within ~~40~~ 30 days from extraction.
Pesticides, PCB's (8080 - CLP)	3-1 L amber glass bottles w/Teflon lined caps), leave headspace.	Iced to 4°C	Extract within 5 days. Analyze within ~~40~~ 30 days from extraction.
Total Metals (6010 w/digestion) (*To include Al, Sb, Ba, Be, Cd Ca, Cr, Co, Cu, Fe, Mg, Mn, Ni, K, Ag, Tl, V, 2n, Na, Sn)	1-L high density polyethylene bottle (Teflon lined caps).	Adjust pH>12 w/HNO_3	Six months.
Total Mercury (7470)	Sample aliquot to be drawn from metals container.		Total 13 days.
Arsenic (7060)	Sample aliquot to be drawn from metals containder		
Total Organic Acids (Propionic acid) (504A)	500 ml glass bottle	None given	None given
Cyanide (9010)	500 ml high density polyethlene bottle (Teflon-lined cap)	pH>12 w/ NaOH Cool to 4°C	7 or 14[a] days

PARAMETER	CONTAINER	PRESERVATIVE	HOLDING TIME
Selenium (EPA 7740)	Sample aliquot to be drawn from metals container		
Lead (EPA 7420)	Sample aliquot to be drawn from metals container		

(a) Cyanide holding time (in presence of sulfide) is 7 days, but can be extended to 14 days if sample is treated in field with cadmium nitrate.

TABLE 2
ANALYTICAL SAMPLE BREAKDOWN
HOLLOMAN AFB, NEW MEXICO

ANALYTICAL PARAMETER	FIELD SAMPLES	DUPLICATE SAMPLES	FIELD BLANKS	TOTAL NUMBER
Volatile Organics	22	2	2*	26
Extractable Organics	22	2	2	26
Total Organic Acids	22	2	2	26
Pesticides, PCB's	22	2	2	26
Total Metals (including lead, selenium, arsenic)	22	2	2	26
Total Mercury	22	2	2	26
Cyanide	22	2	2	26
Formaldehyde	22	2	2	26

*Rinsate and Trip Blank.

DEPARTMENT OF THE ARMY
OMAHA DISTRICT, CORPS OF ENGINEERS
1612 U.S. POST OFFICE AND COURTHOUSE
OMAHA, NEBRASKA 68102-4978

REPLY TO
ATTENTION OF

June 17, 1987

Environmental Branch

Mr. Nelson Lund
Radian Corporation
8501 Mo-Pac Boulevard
Austin, Texas 78758

Dear Mr. Lund:

I am writing to inform you that this request for proposal on the enclosed Scope of Services at Holloman AFB, New Mexico is a modification to Delivery Order Number 2 under Contract Number DACA45-86-D-0052.

Please provide the original and one copy of your proposal by July 2, 1987. You are not to proceed with this work until your proposal has been accepted and you are authorized to proceed.

If you have any questions, please contact Mr. Brian D. Stewart of my staff, Telephone: (402) 221-4827.

Sincerely,

S. L. Carlock

S. L. Carlock, P.E.
Chief, Environmental Branch
Engineering Division

Enclosures

SCOPE OF SERVICES
FOR
CONTRACT NO. DACA45-86-D-0052
HOLLOMAN AFB, NEW MEXICO
8 JUNE 1987
MODIFICATION TO DELIVERY ORDER NO. 2

1. Project Description. The Architect-Engineer (A-E) shall conduct all necessary travel and professional analysis and perform all work required to establish a Hydrogeologic Investigation Plan (HIP) in the vicinity of the Sewage Lagoons, and Lakes Holloman and Stinky at Holloman Air Force Base, New Mexico. In general, the A-E will be required to:

a. Develop a Hydrogeologic Investigation Plan that shall outline field investigations required to obtain site specific hydrogeological data necessary to support a Groundwater Monitoring Plan for the Sewage Lagoons at Holloman AFB.

b. Once the HIP has been developed and revised, the HIP will be submitted to the U.S. Environmental Protection Agency (EPA), Region VI for their approval prior to field activities beginning. This will include a site visit at Holloman AFB with representatives of EPA, U.S. Army Corps of Engineers (USACE), Headquarters - Tactical Air Command (HQ TAC), the Base Environmental Coordinator, and A-E representatives.

c. At the completion of all field investigations and analyses, a final report shall be prepared and presented to the Project Manager.

2. Scope of Work. The project will be performed in accordance with the information outlined in this scope request as well as ER 1110-1-263 (in conjunction with "A-E Quality Management Procedures for Site Investigative Activities"). The following activities shall be included in this task order.

a. The A-E will be required to meet with EPA, HQ TAC, and USACE representatives to discuss the outline of the HIP, and the overall parameters of analysis to validate the future well locations for groundwater monitoring. The meeting locations will be announced by HQ TAC and EPA and the A-E will be notified by the USACE project manager as to their dates and locations.

b. The HIP will be labeled "proposed" or "draft" Hydrogeological Investigation Plan until the final on-site review is performed at Holloman AFB. The "proposed" HIP will be altered, modified or changed in accordance with HQ TAC requirements and requests, as well as by the USACE reviewing process. The "final proposed" HIP shall be submitted to the USACE project manager for final review and shipment to the Base Environmental Coordinator and HQ TAC representative. The details, methods, procedures, and equipment to be used for the field investigations shall be described in the Hydrogeologic Investigation Plan. Upon approval this plan shall be used for conducting the field investigations.

c. At the completion of field activities a final report shall be submitted. At a minimum, this report shall contain:

(1) Drill logs and construction diagrams for all wells, piezometers, and boreholes.

(2) Surveyed locations of all wells, piezometers and boreholes.

(3) Top of the well elevation and ground elevations for all instruments.

(4) Description of pump test, including any deviations from planned activities and problems encountered.

(5) Pump test data, including field notes and analyses.

(6) Laboratory soils analyses.

(7) Field measurements, including water levels, pH, temperatures and specific conductance.

(8) Descriptive discussion of all activities and an interpretation of the data obtained from the field investigations. The characteristics of the uppermost water-bearing units shall be described including but not limited to: its possible interconnections with lower units, hydraulic conductivity and transmissivity, groundwater flow direction, and velocity. Geologic cross-sections and maps shall be used as required to illustrate and support the geologic interpretations made. This information will be used to design a groundwater monitoring plan which meets RCRA requirements.

d. Field Activities. The A-E shall install up to 16 shallow piezometers, 6 deep piezometers, and 2 aquifer test wells. One soil boring shall be drilled just west of an alleged fault zone located west of Lake Holloman and Lake Stinky. The piezometers shall be installed in the vicinity of the sewage lagoons, the drainage ditch, and Lakes Holloman and Stinky. Approximate depths of piezometers shall be 25 feet for shallow and 60 feet for deep piezometers.

Two aquifer tests shall be performed. One in the upper water-bearing unit and one below the first confining unit. The A-E shall propose in the HIP his methods and procedures for performing these tests. The objective of these tests is to obtain hydraulic conductivities and transmissivity for each unit and to investigate the possible interconnections of the two zones.

The use of contaminating additives (bentonite, gels, barite, etc.) in drilling fluids is not permitted. Grease or oil on drill rod joints is not permitted. Dispersing agents (such as phosphates) or acids shall not be used in well installation or development. There shall be no attempt made to chemically disinfect the well. The A-E drill rig or rigs, drill tools, and associated equipment shall be cleaned with steam prior to commencement of drilling at each well location. It is expressly understood that toxic and/or contaminating substances shall not be used during any part of the drilling, well installation or well development process. All drilling activities and methods shall be sufficient to positively prohibit the

introduction of contaminants from one water bearing stratum to another via the well bore.

The A-E shall provide a qualified geologist or geotechnical engineer who shall be on-site for all drilling, installation, development and testing operations. The A-E shall use dry, hollow-stem auger in overburden and no water may be used in the soil drilling process.

e. Well Design.

(1) Boring Diameter. The boring shall be of sufficient diameter to permit at least two (2) inches of annular space between the boring wall and all sides of the riser and screen.

(2) Well Riser and Screen.

(a) Riser. Well riser shall consist of new threaded, flush joint, PVC (polyvinyl chloride) pipe with a minimum two (2) inches inside diameter. All well risers shall, as a minimum, conform to the requirements of ASTM D 1785 Schedule 40 pipe and shall bear markings that will identify the material as that which is specified.

(b) Screen. The well screen shall be ten (10) feet in length and shall be constructed of the same size and strength PVC material as the well riser and shall be compatible with the monitored groundwater. The screen shall be noncontaminating, factory-constructed slotted or "continuous wrap" design. Field slotted screen is not permitted. The slot size shall be determined by the A-E and designed to be compatible with aquifer and gravel pack material.

(c) Screen Location. The A-E shall have the responsibility of selecting the screened area of the borehole so that the completed piezometer functions satisfactorily.

(d) Joining Riser. Riser sections shall be joined by threaded, flush-joint couplings to form watertight unions. Solvent PVC glue shall not be used at any time in construction of the wells. No lead shot or lead wool is to be employed in producing seals at any point in the well.

(3) Bentonite Seal and Grout. A minimum two (2) foot seal, consisting of tamped bentonite pellets shall be placed into the annular space between the riser and boring wall immediately above the screened portion of the hole. The bentonite pellets shall be allowed to hydrate for a minimum of 8 hours. Cement grout shall then be placed from the top of the bentonite seal to the ground surface. The cement grout shall consist of a mixture of Portland Cement (ASTM C 150) and water in the proportion of not more than seven (7) gallons of clean water per bag of cement (one cubic foot or 94 pounds). Additionally, three (3) percent by weight of bentonite powder shall be added if permitted by state regulations.

(4) Soil Sampling for Geotechnical Analysis. During drilling, the geologist or geotechnical engineer and crew shall collect soil samples for geotechnical analysis as outlined below.

(a) Soil samples shall be taken at five (5) foot intervals.

(b) Sampling shall be done with a split-spoon sampler (ASTM D 1586-67) or thin wall sampler (ASTM D 1587-74) using standard sampling techniques.

(c) Samples shall be stored in plastic or glass jars by the A-E until such time as they are needed for testing or the contract is complete.

(d) All soil samples shall be visually classified by the Unified Soil Classification System. The A-E shall verify the classification by laboratory analyses consisting of the following, if they are applicable:

Test	Tests/Boring
Grain-Size Distritution (ASTM D 421 & 422)	2
Atterburg Limits (ASTM D 4318)	2
Moisture Content (ASTM D 2216)	2

Specific soil samples to be tested, along with type of test, shall be determined by the A-E after reviewing the boring logs. Laboratory analyses shall use equipment and methods described in EM 1110-2-1906 or ASTM manuals.

(5) Protection of Well. At all times during the progress of the work, precautions shall be used to prevent tampering with the well or the entrance of foreign material into it. Upon completion of the well, a suitable vented cap shall be installed to prevent material from entering the well. The PVC well riser shall be surrounded by a six (6) inch diameter steel casing and rising 24 inches to 36 inches above ground level set into a concrete pad. The steel casing shall be provided with lock and cap. All locks shall be keyed alike. A minimum three (3) foot square, four (4) inch thick concrete pad, sloped away from the well, shall be constructed around the well casing at the final ground level elevation. Three (3), two (2) inch diameter or larger steel posts shall be equally spaced around the well and embedded in the concrete pad. The ground immediately surrounding the top of the well shall be sloped away from the well.

(6) Temporary Capping. Any well that is to be temporarily removed from service or left incompleted due to delay in construction shall be capped with a watertight cap and equipped with a "vandal proof" cover satisfying applicable state or local regulations or recommendations.

(7) Well Construction Logs. Suitable logs detailing construction practices shall be maintained for inclusion in the Engineering Report. Copies of the field logs shall be included in the Draft Engineering Report and final drafted boring logs shall be submitted in the Final Engineering Report. The logs shall be prepared by a qualified geologist or geotechnical engineer present during all drilling operations. The original and one (1) copy of each field well construction log shall be submitted to the

Project Manager not later than ten (10) calendar days after the well is completed. The well will not be accepted by the USACE until the logs are received and approved. Information provided in the logs shall include but not be limited to the following:

(a) Reference elevation for all depth measurements.

(b) Depth of each change of stratum.

(c) Thickness of each stratum.

(d) Identification of the material of which each stratum is composed according to the Unified Soil Classification System, or standard rock nomenclature, as necessary.

(e) Depth interval from which each formation sample was taken.

(f) Depth at which hole diameter (bit sizes) changes.

(g) Depth at which groundwater is first encountered.

(h) Depth to the static water level and changes in static water level with well depth.

(i) Total depth of completed well.

(j) Depth or location of any loss of drill water circulation, loss of tools or equipment.

(k) Location of any fractures, joints, faults, cavities or weathered zones.

(l) Depth of any grouting or sealing.

(m) Nominal hole diameters.

(n) Amount of cement used for grouting or sealing.

(o) Depth and type of well casing.

(p) Description (to include length, location, diameter, slot sizes, material, and manufacturer) of well screen(s).

(q) Any sealing-off of water-bearing strata.

(r) Static water level upon completion of the well and after development.

(s) Drilling date or dates.

(t) Construction details of the wells, including source and description of gravel pack material.

f. Well Locations. Coordinates and elevations shall be established for each monitoring well. The coordinates shall be to the closest 1.0 foot and referenced to the State Plane Coordinate System. If the State Plane Coordinate System is not readily available, an existing local grid system shall be used. A ground elevation for the top of the casing to the closest 0.01 foot and an elevation for the top of the casing to the closest 0.01 foot shall be obtained at each well. These elevations shall be referenced to the National Geodetic Vertical Datum of 1929. If the 1929 Datum is not readily available, the existing local vertical Datum shall be used. The location, identification, coordinates and elevations of the wells and monuments shall be plotted on maps with a scale large enough to show their location with reference to other structures at the individual sites. A tabulated list of the monitoring wells, copies of all field books, and all computation sheets shall be prepared and submitted to the Omaha District, ATTN: CEMRO-ED-EB. The tabulation shall consist of the designated number of the well, the X and Y coordinates, and all the required elevations. These items shall become a part of the final report.

g. Identification of Wells. The Contractor shall affix a permanent marking or tag to the outer steel protective casing of each well which clearly identifies the well number, the U.S. Army Corps of Engineers, Omaha District, and the adjusted top of casing elevation.

h. Responsibility for These Investigation Wells. It is the responsibility of the Contractor to properly plan, design, install, develop, and test these wells so that they are suitable to produce representative groundwater analysis in sufficient quantity and quality for geochemical and environmental contamination testing, and which met all RCRA requirements. The A-E shall ensure that the intentions of this Scope of Services and good construction practices are carried out.

(1) If the A-E, due to his inadequate design or construction, installs monitoring wells that are not functional or not in accordance with specifications, the Project Manager will disapprove the well and direct the A-E to repair or replace it at the Project Manager's direction. This work shall be done at no additional cost to the Government.

(2) If a monitoring well is disapproved by the Project Manager or is abandoned by the A-E for any reason, the hole shall be backfilled with neat cement grout from top to bottom by the A-E at no additional cost to the Government.

i. Well Development. Within two (2) weeks after each piezometer has been constructed, but no sooner than 48 hours after grouting is completed, the A-E shall direct a program for the development of the well by pumping and/or surging, without the use of acids, dispersing agents or explosives. Development shall continue until near sand-free conditions are obtained or measurements of pH, temperature, and conductivity have stabilized. At least as much water as was introduced during drilling shall be removed from the well. No water or other liquid may be introduced into the well other than formation water from that well.

j. In-Situ Permeability Determination. After development of monitoring wells, the A-E shall determine for ten of the piezometers the permeability of the stratum. However, no water or other liquid may be

introduced into the well other than formation water from that well.

k. Groundwater Measurements. Water level measurements shall be made in each piezometer after it has been developed and has stabilized. Measurements shall be made in all wells within 24 hours of one another. Measurements shall be taken at two different times separated by at least 2 weeks. Measurements of pH, temperature, and conductivity shall be taken from each piezometer after they have been properly purged. Before a sample is collected from a well, the water level shall be measured and recorded, then the well shall be pumped or bailed with clean equipment to remove a quantity of water equal to at least five times the submerged volume of the casing. If the well does not recharge fast enough to permit removing five (5) casing volumes, the well shall be pumped or bailed dry and sampled as soon as sufficient recharge has occurred. Methods and equipment to be used shall be included in the Hydrogeologic Investigation Plan.

3. Safety, Health and Emergency Response Plan A-E SHERP. The A-E SHERP submitted for the original Scope of Services dated 14 August 1986 and revised 4 September 1986, has been reviewed and approved by the USACE to be satisfactory to use for the HIP field activities which is the same site location at Holloman AFB. The title for this SHERP shall include reference to the HIP.

4. Presentations. The A-E shall assist the U.S. Air Force in presenting the documents generated by this work order to the appropriate environmental agencies at meetings established by the Base Environmental Coordinator.

5. Special Considerations. All materials gathered and developed in the performance of this work listed in this contract shall be the property of the Corps of Engineers/U.S. Air Force and shall not be used, distributed, or published by the A-E without specific permission from the Corps of Engineers/U.S. Air Force.

6. Project Management.

a. Project Engineer. The A-E shall assign a member or employee who will be known as the Project Engineer or Project Manager. This individual will oversee the correlation of the entire project, administer all instructions from this office, and answer or obtain answers to all questions from this office during and after the work.

b. Coordination. During the prosecution of the work under the contract, the A-E shall keep in close liaison with the Corps of Engineers Project Manager (USACE PM), who will coordinate the work with the Base Environmental Coordinator. All requests made by the Air Force shall be referred to the COE Project Manager.

7. General.

a. Travel. The A-E will perform the following travel as part of the contract requirement, and the cost thereof shall be included with the contract cost. Responsible representatives of the A-E's firm from the appropriate disciplines shall attend conferences and/or make the following listed trips:

(1) Information Meeting.

(a) Purpose. The purpose of this additional informal meeting will be to discuss the status of the Groundwater Monitoring Plan Scope of Service to ensure a complete understanding in relation to the conditions of the Sewage Lagoons.

(b) Location. The meeting will be held at Air Force Regional Civil engineers office in Dallas, Texas.

(c) Attendees. Expected attendees are HQ TAC-PM, Base Environmental Representative, A-E Project Manager, A-E Project Engineer, and COE-PM and COE Technical Staff.

(2) Groundwater Monitoring Plan Review and Hydrogeologic Investigation Request Meeting.

(a) Purpose. This informal meeting will be to discuss the A-E's GMP and the initiated request by EPA to submit a Hydrogeologic Investigation Plan (HIP).

(b) Location. the meeting will be held at EPA Headquarters, Washington DC.

(c) Attendees. Expected attendees are HQ TAC-PM, Base Environmental Representative, A-E Project Manager, COE-PM.

(3) Site Visit and HIP Clarification Meeting.

(a) Purpose. The purpose for this site visit and meeting is to allow the A-E, EPA consultant (Jacob's Engineering), EPA lawyer, and COE geologist to visit the site and to discuss comments presented by EPA's consultant on the HIP.

(b) Location. The meeting will be at Holloman AFB in a building to be designated by the Base.

(c) Attendees. Expected attendees are HQTAC-PM, Base Commander, Base JAG Representative, Base Environmental Coordinator, A-E, COE-PM and Technical Staff.

(4) Pre-Mobilization Coordination Meeting.

(a) Purpose. The purpose of this informal meeting will be to discuss base support required to perform the field activities. This meeting shall be held at least 3 weeks prior to field mobilization efforts. The A-E will come prepared to discuss the assistance he deems necessary to successfully mobilize the field team. The A-E will provide names, Social Security numbers, driver's license numbers, and vehicle numbers for all persons and equipment to be used during field activities. The A-E shall be responsible for coordinating the time of this meeting with appropriate Base personnel and the COE-PM.

(b) Location. This meeting will be held at Holloman AFB in a building to be designated by the Base.

(1) Information Meeting.

(a) Purpose. The purpose of this additional informal meeting will be to discuss the status of the Groundwater Monitoring Plan Scope of Service to ensure a complete understanding in relation to the conditions of the Sewage Lagoons.

(b) Location. The meeting will be held at Air Force Regional Civil engineers office in Dallas, Texas.

(c) Attendees. Expected attendees are HQ TAC-PM, Base Environmental Representative, A-E Project Manager, A-E Project Engineer, and COE-PM and COE Technical Staff.

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(a) Purpose. This informal meeting will be to discuss the A-E's GMP and the initiated request by EPA to submit a Hydrogeologic Investigation Plan (HIP).

(b) Location. the meeting will be held at EPA Headquarters, Washington DC.

(c) Attendees. Expected attendees are HQ TAC-PM, Base Environmental Representative, A-E Project Manager, COE-PM.

(3) Site Visit and HIP Clarification Meeting.

(a) Purpose. The purpose for this site visit and meeting is to allow the A-E, EPA consultant (Jacob's Engineering), EPA lawyer, and COE geologist to visit the site and to discuss comments presented by EPA's consultant on the HIP.

(b) Location. The meeting will be at Holloman AFB in a building to be designated by the Base.

(c) Attendees. Expected attendees are HQTAC-PM, Base Commander, Base JAG Representative, Base Environmental Coordinator, A-E, COE-PM and Technical Staff.

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(b) Location. This meeting will be held at Holloman AFB in a building to be designated by the Base.

(c) Attendees. Expected attendees are the A-E Project Engineer, A-E Field Team Leader, Base Environmental Coordinator, and COE-PM.

(5) Field Work Progress Meeting.

(a) Purpose. The purpose of this informal meeting will be to allow both the Base and the A-E to air any concerns, conflicts or problems regarding the field work which is on-going. This meeting shall be held within one (1) week of the start of field investigations. The A-E shall be responsible for coordinating the time of this meeting with appropriate Base personnel and the COE-PM.

(b) Location. This meeting will be held at Holloman AFB in a building to be designated by the Base.

(c) Attendees. Expected attendees are the A-E Field Team Leader, Base Environmental Coordinator and the COE-PM.

(6) Demobilization Meeting.

(a) Purpose. The purpose of this informal meeting will be to ensure that the A-E and his site investigation forces leave the Base in an orderly state. This meeting shall be held not later than one (1) week prior to the A-E's demobilization from the Base. The A-E shall be responsible for coordinating the time of this meeting with appropriate Base personnel and the COE-PM.

(b) Location. This meeting will be held at Holloman AFB in a building to be desingated by the Base.

(c) Attendees. Expected attendees are the A-E Project Engineer, A-E Project Field Team Leader, Base Environmental Coordinator and the COE-PM.

b. Review of Progress and Technical Adequacy.

(1) At appropriate times, representatives of the Contracting Officer may review the progress and technical adequacy of the work. Such review will not relieve the Contractor from performing all contract requirements, except as may be waived by written instruction.

(2) The Contractor, under this contract, will interpose no objection nor restriction to the Contracting Officer's designation of a Contractor for the purpose of reviewing the adequacy and corrections of the work performed under this contract.

(3) The Contractor shall submit progress reports to the COE with each request for payment. The progress reports shall indicate work performed, costs, and problems incurred during the payment period.

c. Conference Notes and Confirmation Notices.

(1) Conference Notes. The Contractor will be responsible for

taking notes and preparing the reports of all conferences. Conference notes will be prepared in typed form and the original furnished this office (within five (5) days after date of conference) for concurrence and distribution to all attendees. This report shall include the following items as a minimum:

(a) The date and place the conference was held with a list of attendees. The roster of attendees shall include name, organization, and telephone number.

(b) Written comments presented by attendees shall be attached to each report with the conference action noted. Conference action shall be "A" for an Approved comment, "D" for a Disapproved comment, "W" for a comment that has been Withdrawn, and "E" for a comment that has an Exception noted.

(c) Comments made during the conference, decisions affecting criteria changes, must be recorded in the basic conference notes. Any augmentation of written comments should be documented by the conference notes.

(2) Confirmation Notices. The Contractor will be required to provide a record of all discussions, verbal directions, telephone conversations, etc., participated in by the Contractor and/or his representatives on matters relative to this contract and the work, irrespective of whom the other participants may have been. These records, entitled "Confirmation Notices," will be numbered sequentially and shall fully identify participating personnel, subject discussed, and any conclusions reached. The Contractor shall forward to the Contracting Officer or his representative as soon as possible (not more than five (5) work days), a reproducible copy of said confirmation notices. Distribution of said confirmation notices will be made by the Government.

d. Expert Testimony. All technical consultants required for this investigation will be provided by the Contractor and will be qualified to provide expert witness testimony, if required. In the event of litigation, the contract will be modified to compensate the Contractor for the additional services required.

8. Submittals. In general, the A-E is responsible for reproduction and distribution of all documents. Documents shall be mailed to the reviewers via a carrier service that will provide overnight service, unless otherwise noted. The following names and addresses for review of the "first draft" proposed HIP and the number of copies indicated:

Name and Address	No. of Copies
U.S. Army Engineering District, Omaha ATTN: CEMRO-ED-EB (Stewart) 215 North 17th Street Omaha, NE 68102-4978	4 copies - (3) bound (1) unbound reproducible copy

The following names and addresses for review of the revised HIP prior to submittal to EPA are as follows:

Name and Address	No. of Copies
HQ TAC/DEEV ATTN: CPT H. Briesmaster Building 681 Langley AFB, VA 23665-5001	4 copies
HQ 833/CSG DEEV ATTN; Mr. Terry Boone Building 55 Holloman AFB, NM 88330-5000	2 copies
U.S. Army Engineer District, Omaha ATTN: CEMRO-ED-EB (Stewart) 215 N. 17th Street Omaha, NE 68102-4978	3 copies

a. The Engineering Report based on the HIP analysis performed shall be submitted to the above addresses prior to submittal to EPA. HQTAC will submit the revised Engineering Report to EPA. EPA will have comments and requests that also may require a further revision of the HIP. These submittals will be handled in the same manner as the revised HIP using the addresses above.

b. Partial Submittals. Partial submittals will not be accepted unless prior approval is given.

c. Cover Letters. A cover letter should accompany each document and indicate the project, project phase, the date comments are due, to whom comments are to be submitted, the date and location of the review conference, etc., as appropriate. (Note that, depending on the recipient, not all letters will contain the same information.) The contents of the cover letters should be coordinated with the USACE Project Manager prior to the submittal date.

d. Reproducibles. One reproducible, unbound copy of each submittal shall be provided to the USACE PM. While all submittals should be error-free, an extra effort shall be made to provide an error-free Final Report.

9. Schedules. The Contractor shall include with his proposal a tentative schedule for the completion of all work as outlined in these schedules of services.

10. Groundwater Monitoring Plan Revisions. Upon completion of the Engineering Report for the HIP and its approval by USACE, HQ TAC, EPA and the BEC, the Groundwater Monitoring Plan (GMP) will be revised in accordance to the findings in the HIP report. This is an additional revision on the GMP necessary to produce a qualified and documented GMP for the Sewage Lagoons. This additional revision and change according to the HIP analyses will be handled at a later date as a modification to the Groundwater Monitoring Plan.