GW - 28

REPORTS

YEAR(S):

1986

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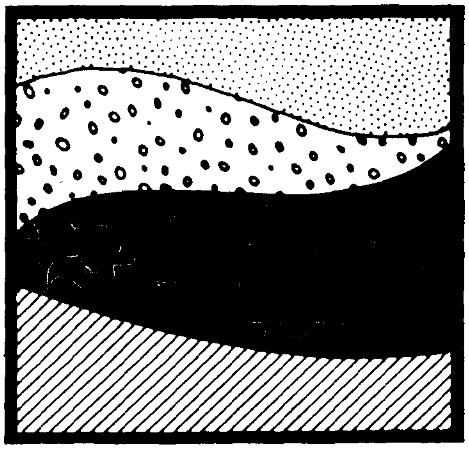

Geoscience Consultants, Ltd. GCL

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December 24, 1986

Mr. Dave Boyer
New Mexico Oil Conservation Division
PO Box 2088
Land Office Building
Santa Fe, NM 87501

RE: Requested Additional Data for Discharge Plan GW-28, Navajo Refining Company, Artesia Refinery

Dear Mr. Boyer:

This letter accompanies the additional geohydrologic data that you requested in Item #2 of your July 18, 1986 letter to Mr. David Griffin of Navajo Refining Company. The attached items include:

1) Two copies of the Proposed Investigations of the pond #1 and conveyance ditch areas, as submitted to NMEID

2) Water-table maps of the evaporation-pond area, including maps showing monthly changes

3) Hydrographs of the Pecos River, from the gauging station at the Highway bridge (approximately 1 mile south of the evaporation ponds).

The Proposed Investigations document includes considerable data on site geohydrology and ground water chemistry derived since the submission of the original Discharge Plan. Analyses of these data, including the relationship between shallow ground water and the Pecos River, is continuing. Also, we plan to install and sample additional ground water monitoring points in January, 1987. Reports of progress in these tasks will be submitted to NMOCD in a timely manner.

Please contact me if you have any questions regarding this submission or our future investigations.

Yours very truly,
GEOSCIENCE CONSULTANTS, LTD.

Trent H. Thomas, MS
Project Director

THT/pe/NAVAJO/BOYER001.LTR

cc: David Griffin, Navajo

Enclosures

PROPOSED SITE INVESTIGATIONS OF POND #1 AND CONVEYANCE DITCH TO DETERMINE POTENTIAL EFFECTS TO GROUND WATER QUALITY NAVAJO REFINERY, ARTESIA, NEW MEXICO

May 21, 1986
Revised October 29, 1986

Prepared for:

NAVAJO REFINING COMPANY
Dave Griffin
P.O. Drawer 159
Artesia, New Mexico 88210

Prepared by:

Geoscience Consultants, Ltd.
500 Copper Avenue, NW
Suite 325
Albuquerque, New Mexico 87102

RECEIVED
JAN 12 1987
OIL CONSERVATION DIVISION
SANTA FE

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SECTION 1.0

1.0 EXECUTIVE SUMMARY

The New Mexico Environmental Improvement Division (NMEID) has requested certain technical data regarding the waste conveyance ditch and Evaporation Pond #1 currently used by Navajo Refining Company and a planned field program to determine if the operation of these units has resulted in any impact to ground water. In developing its field proposal, NMEID requested that Navajo address 16 specific issues (Appendix A of this report) identified in the April 21, 1986 meeting between NMEID, Navajo Refining Company and Geoscience Consultants, Ltd., and to submit their proposed field investigation "as soon as practical". Navajo submitted its proposed site investigation addressing those specific issues to NMEID on May 21, 1986. Following a review of NMEID comments transmitted to Navajo on June 30, 1986. Navajo Refining Company has revised the site investigation plan to reflect those changes and additions requested by NMEID and the events that have occurred to date in the initial phase of the ground water quality assessment program.

Results of the first round of sampling in August, 1986 revealed the presence of organic species (toluene, ethylbenzene, 1,2-dimethylphenol) in wells MW-2, MW-4, MW-5, MW-6, MW-7, Navajo well #13 and a non-RCRA well point, #2. These analyses indicate the presence of potentially contaminated ground water in the area of the evaporation ponds.

Navajo proposed that an assessment program be instituted to characterize any apparent plume. This program will involve:

- A ground water sampling program to define the 2-dimensional extent of the plume
- Analysis of the results of the study to determine the initial locations and depths of additional monitor wells,
- Installation of additional monitor wells with depth-discrete completions to define the vertical extent of the plume
- Installation of additional detection wells outside the periphery of any plume to detect any further migration of hazardous constituents

This approach will provide a rapid and efficient means of defining and characterizing any ground water contamination plume. In submitting this report/proposal Navajo has addressed all 16 issues listed in Exhibit A of the Consent Agreement which became effective September 29, 1986. Subsequent monthly reports will provide more data regarding these issues.

SECTION 2.0

2.0 WASTE CONSTITUENT IDENTIFICATION

This section outlines the sampling program that Navajo Refining Company began on June 4, 1986 to characterize the waste constituents in Evaporation Pond #1. The purpose of these samples was to characterize the wastes in the pond in order to assist in the selection of appropriate parameters for future ground water monitoring programs (see Section 5.0).

2.1 EVAPORATION POND #1

2.1.1 Sampling Procedures

Three composite samples were collected from the sludge which has accumulated in Evaporation Pond #1. The Pond was sub-divided into three gridded areas of approximately equal size and a random-numbers table was used to select 4 individual sampling sites in each area. The three areas were sub-divided (Figure 2-1) into the following areas: the shallow, "delta" area located in the western third; the middle area of intermediate depth; and the deeper area located at the pond's eastern boundary.

Four core samples were collected in each of the middle eastern and "delta" areas using a steam-cleaned, hand-driven core tool. The cores were collected at depths of 8-12 inches in the sludge layer. Samples were collected in steam-cleaned, 2 foot sections of 2 inch I.D. stainless steel pipe. The pipe sections were hand-driven into the sludge layer. As each sample was collected, the ends were sealed with aluminum foil and placed in a cooler chest for compositing. Samples were composited at the 0-12 inch sludge level depending on the amount of sample retrieved. This procedure yielded 1 composite for each of the 3 areas. The water level in the western third of the pond proved too shallow to maneuver the boat, therefore, four samples were collected at the water line along the southern boundary.

Each composite sample was assigned a unique identification number (yymmddtttt), corresponding to the current year, month, day and military time. This number was then entered on a field log/sample analysis

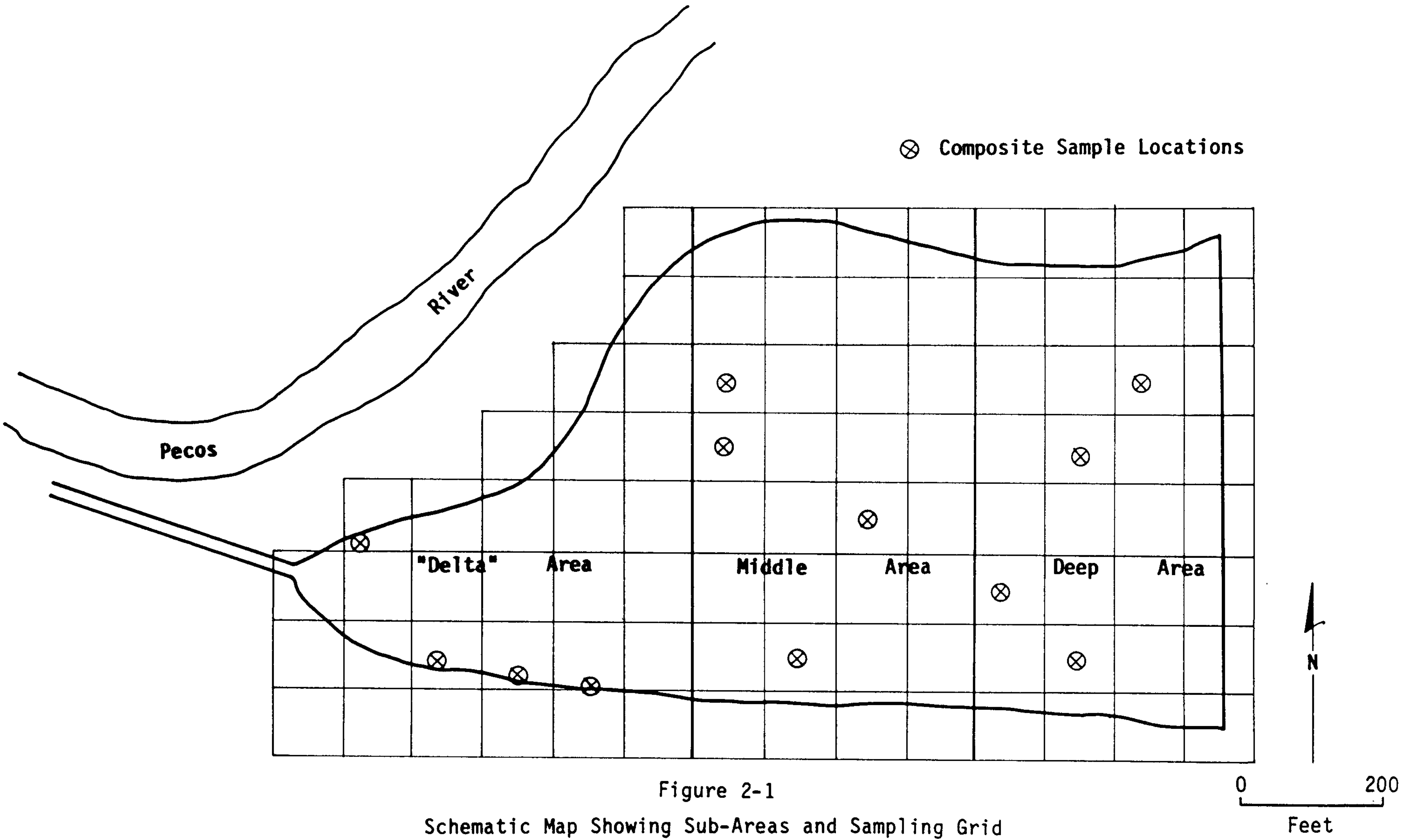


Figure 2-1

Schematic Map Showing Sub-Areas and Sampling Grid
In Area of Evaporation Pond #1

request form (Figure 2-2). As each sample was composited, it was properly containerized and preserved as required using the methods outlined in Table 2-1. Each sample container was then sealed with a chain-of-custody tape (Figure 2-3) and all identifying information was logged on a chain-of-custody form (Figure 2-4). The chain-of-custody form accompanied all samples to the analytical laboratory.

2.1.2 Analytical Protocols

All composited sludge samples collected from Pond #1 were shipped to Rocky Mountain Analytical Laboratories for analysis. Each sludge sample was accompanied by a field log/sample analysis request form (Figure 2-2) and was analyzed for those hazardous constituents listed in the "Modified Skinner List" (Table 2-2) as found in U.S. EPA publication Petitions to Delist Hazardous Waste--A Guidance Manual, EPA/530-SW-85-003, April 1985 plus additional compounds from the priority pollutants list. This list contains 12 metals and 43 organic constituents which are known or suspected to be found in petroleum refining waste. Listed metals were analyzed for total concentrations using EPA Method 200.7-ICP Emission Spectroscopy, Furnace Atomic Absorption Spectroscopy, or Cold Vapor Atomic Absorption Spectroscopy as indicated in Table 2-3.

Organic constituents included 15 volatile compounds, 31 base/neutral extractable organics and 7 acid-extractable organics. Volatile compounds were analyzed using EPA Method 8240, purge and trap GC/MS, as indicated in Table 2-4. Semi-volatile compounds (base/neutral and acid extractables) were analyzed using EPA Method 8270,capillary column GC/MS, as found in SW-846, Test Methods for Evaluating Solid Waste--Physical/Chemical Methods, June 1982.

2.2 WASTEWATER CONVEYANCE DITCH

Because all waste constituents in Pond #1 were transported to the pond via the conveyance ditch, the sludges in the ditch are very similar to those in the pond, therefore, ditch sludges were not sampled at this time.

GUIDELINES FOR SAMPLE BOTTLES AND PRESERVATIVES[a]

Bottle No.	Parameters	Container	Preservative	Notes
1	Cl^-, F^-, $SO_4^=$, Tot. Alk., $CO_3^=$ Alk., HCO_3^- Alk., OH^- Alk., pH, spec. cond., TDS, TSS, TS, TVS, o-PO_4 SiO_2, BOD, Br^-, res. Cl_2, Cr^{+6}, color, NO_2^-, $SO_3^=$, MBAS, Turbidity.	1 liter poly	4° C	Provide unfiltered sample for solids and turbidity.
2	Tot. P, COD, TOC, NH_3, TKN, TON, Phenolics $NO_3 + NO_2$.	500 ml poly	2 ml 50% H_2SO_4, 4°C	
3	O & G	1 liter glass	4 ml 50% H_2SO_4, 4°C	Do not filter, collec directly in bottle.
4	Na, K, Ca, Mg, Al, Sb, As, Ba, Be, B, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, Ag, Sr, Tl, Sn, Ti, V, Zn, ICP, Hardness.	500 ml poly	5 ml 50% HNO_3	Provide separate samples for total an dissolved sample (filter before adding to bottle.)
5	Alpha, Beta, Ra^{226}, Ra^{228}, U	1 liter poly (no Ra^{228}) ½ gallon poly (with Ra^{228})	10 ml 50% HNO_3 20 ml 50% HNO_3	
6	Free CN, Tot. CN	500 ml poly	2 ml 50% NaOH, 4°C	
7	Sulfide	250 ml poly	1 ml 1 N Zn acetate, 1 ml 50% NaOH, 4°C	
8	Fecal coli., total coli.	8 oz. sterile	4° C	Collect directly in sterile bottle
11	VOA, purgeable organics, THM	2 - 40 ml glass vial	4° C	Completely fill bottle, leave no air bubbles.
12	B/NA	1 liter glass	4° C	
13	Pest./PCB	1 liter glass	4° C	
14	Herbicides	1 liter glass	4° C	
15	TOX	1 liter glass	4° C	

[a] Federal Register, 40 CFR 136, December 3, 1979, as updated by EPA, EMSL-Cincinnati, September 22, 1981.

TABLE 2-1

Consultants, Ltd.

PO# ____________________
Sample ID# ____________________
Descriptor ____________________

Facility Name ____________________
Address ____________________
____
Contact ____________________

Sampling Firm ____________________
Address ____________________
____
Receiving Lab ____________________

Sample Location ____________________
Sample Description ____________________
Date __________ Time ______ Collected By ____________________

SAMPLING CONDITIONS

Samp. Type ______________
Color ______________
Temp ______________
Water Level ______________
Datum ______________

pH ______________
Cond ______________
Odor ______________
Flow Rate ______________
Elevation ______________

Remarks on sampling and preservation ____________________

PRESERVATION AND ANALYSIS

_____ 16 oz glass

APPENDIX VIII CONSTITUENTS
FOR PETROLEUM REFINERIES
☐ Total Metals
☐ Semi-Volatiles
☐ ______________

OTHER
☐
☐
☐
☐
☐

_____ 7 oz glass cool to 4°C

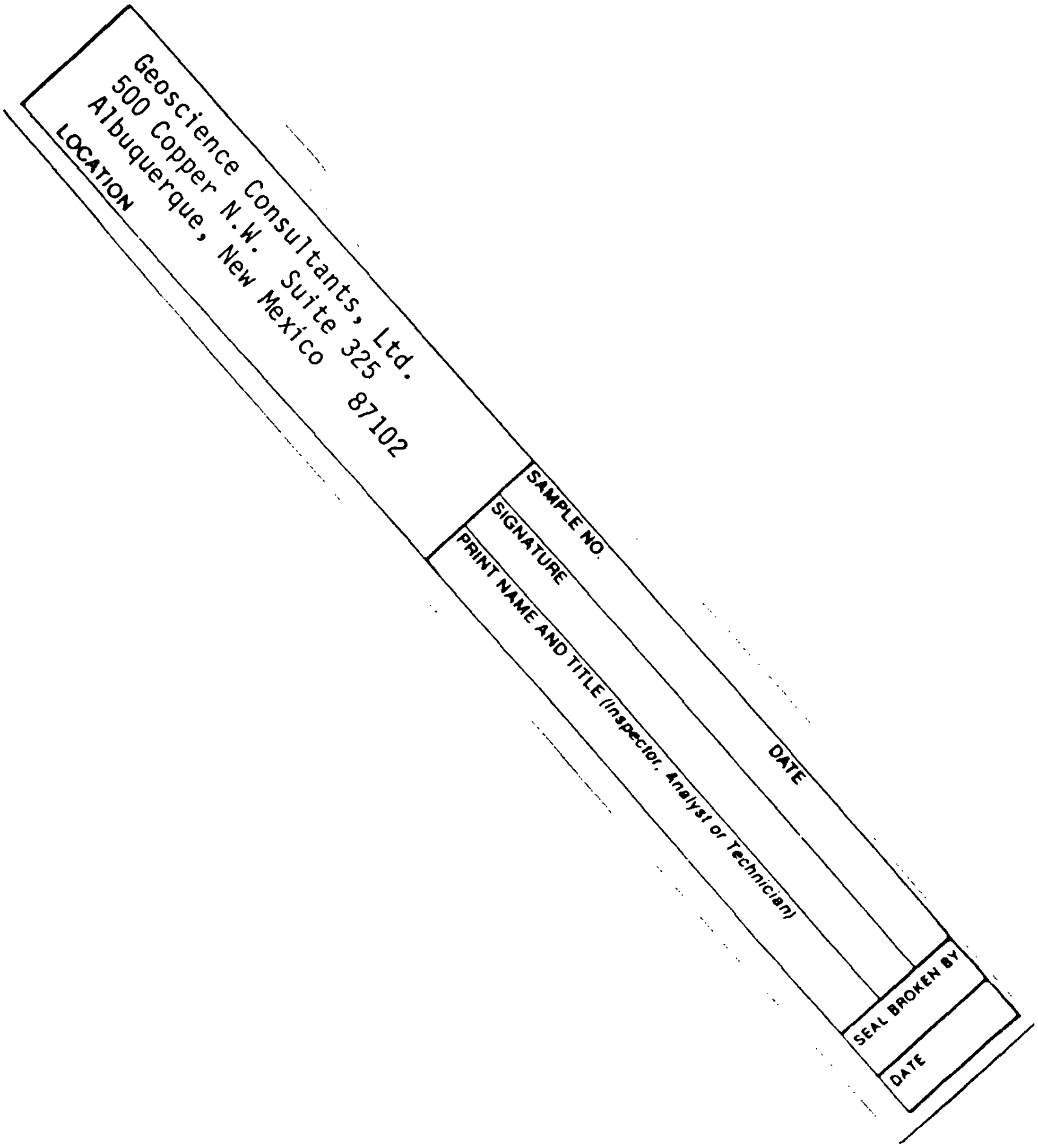
APPENDIX VIII CONSTITUENTS
FOR PETROLEUM REFINERIES
☐ Volatiles

_____ 40 mil septum vials cool to 4°C

APPENDIX VIII CONSTITUENTS
FOR PETROLEUM REFINERIES
☐Volatiles

Remarks on Analyses: ____________________

FIGURE 2-2
SAMPLE ANALYSIS FIELD FORM



Geoscience Consultants, Ltd.
500 Copper N.W. Suite 325
Albuquerque, New Mexico 87102
LOCATION

SAMPLE NO.
DATE
SIGNATURE
PRINT NAME AND TITLE *(Inspector, Analyst or Technician)*
SEAL BROKEN BY
DATE

FIGURE 2-3
CHAIN OF CUSTODY TAPE

Geoscience Consultants, Ltd.

Figure 2-4
CHAIN OF CUSTODY FORM

CHAIN OF CUSTODY

Shipped or delivered to lab by ______________________________

Date ______________ Time ____________

I hereby certify that to the best of my knowledge the samples listed below were obtained in accordance with the approved sampling and analysis plan and are safely containerized and labeled for delivery to the laboratory.

Signature ____

Relinquished by: __________________ Received by: ___________________

Date/Time: _____________________________

Relinquished by: __________________ Received by: __________________

Date/Time: _____________________________

Signature _______________________ RECEIVING LABORATORY ____________

Address ____________________________________

Attn: ____________________________________

			Number of Containers			
Sample ID Number	poly			septum	glass	sterile

_________________ Samples received intact.

TABLE 2-2

"MODIFIED" SKINNER LIST
CONSTITUENTS OF PETROLEUM REFINING WASTES

1. Metals

Antimony
Arsenic
Barium
Beryllium
Cadmium
Chromium
Cobalt
Lead
Mercury
Nickel
Selenium
Vanadium

2. Volatiles

Benzene
Carbon disulfide
Chlorobenzene
Chloroform
1,2-Dichloroethane
1,4-Dioxane
Ethyl benzene
Ethylene dibromide
Methyl ethyl ketone
Styrene
Toluene
Xylene

3. Semivolatile Base/Neutral Extractable Compounds

Anthracene
Benzo(a)anthracene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Bis(2-ethylhexyl) phthalate
Butylbenzyl phthalate
Chrysene
Dibenz(a,h)acridine
Dibenz(a,h)anthracene
Dichlorobenzenes
Diethyl phthalate
7,12-Dimethylbenz(a)anthracene
Dimethyl phthalate
Di(n)butyl phthalate
Di(n)octyl phthalate
Fluoranthene
Lindene
Methyl chrysene
1-Methylnaphthalene
Naphthalene
Phenanthrene
Pyrene
Pyridine
Quinoline

4. Semivolatile Acid-Extractable Compounds

Benzenethiol
Cresols
2,4-Dimethylphenol
2,4-Dinitrophenol
4-Nitrophenol
Phenol

TABLE 2-3
Inorganic Analytical Methodology

Parameter	Units	Nominal Detection Limit[a]	Methodology	Reference	Preservation Bottle No.	Maximu Holding T
TRACE METALS[c]						
Aluminum	mg/l	0.05	ICP Emission Spectroscopy	3	4	6 mont
Antimony	mg/l	0.002	Furnace Atomic Absorption	1-204.2	4	6 mont
Arsenic	mg/l	0.002	Furnace Atomic Absorption	1-206.2	4	6 mont
Barium	mg/l	0.005	ICP Emission Spectroscopy	3	4	6 mont
Beryllium	mg/l	0.001	ICP Emission Spectroscopy	3	4	6 mont
Boron	mg/l	0.004	ICP Emission Spectroscopy	3	4	6 mont
Cadmium	mg/l	0.002	ICP Emission Spectroscopy	3	4	6 mont
Chromium	mg/l	0.005	ICP Emission Spectroscopy	3	4	6 mont
Cobalt	mg/l	0.003	ICP Emission Spectroscopy	3	4	6 mont
Copper	mg/l	0.002	ICP Emission Spectroscopy	3	4	6 mont
Iron	mg/l	0.05	ICP Emission Spectroscopy	3	4	6 mont
Lead	mg/l	0.025	ICP Emission Spectroscopy	3	4	6 mont
		0.001	Furnace Atomic Absorption	1-239.2	4	6 mont
Manganese	mg/l	0.005	ICP Emission Spectroscopy	3	4	6 mont
Mercury	mg/l	0.0002	Cold Vapor Atomic Absorption	1-245.1	4	6 mont
Molybdenum	mg/l	0.005	ICP Emission Spectroscopy	3	4	6 month
Nickel	mg/l	0.01	ICP Emission Spectroscopy	3	4	6 month
Selenium	mg/l	0.002	Furnace Atomic Absorption	1-270.2	4	6 month
Silver	mg/l	0.003	ICP Emission Spectroscopy	3	4	6 month
Strontium	mg/l	0.005	ICP Emission Spectroscopy	3	4	6 month
Thallium	mg/l	0.002	Furnace Atomic Absorption	1-279.2	4	6 month
Tin	mg/l	0.03	ICP Emission Spectroscopy	3	4	6 month
Titanium	mg/l	0.002	ICP Emission Spectroscopy	3	4	6 month
Vanadium	mg/l	0.002	ICP Emission Spectroscopy	3	4	6 month
Zinc	mg/l	0.004	ICP Emission Spectroscopy	3	4	6 month

TABLE 2-4
Organic Analytical Methodology

Parameter	Units	Nominal Detection Limit[(a)]	Methodology	Reference(1)	Preservation Bottle No.	Maximum Holding Time
Purgeables	ug/l	1	Purge & Trap GC/MS	624	11	14 days
Base/Neutrals	ug/l	10	Extraction/GC/MS	625	12	7 days/40 da
Acids	ug/l	10	Extraction/GC/MS	625	12	7 days/40 da
Organochlorine Pesticides/PCB's	ug/l	0.01	Extraction/GC/ECD	608	13	7 days/40 da
		10	Extraction/GC/MS	625	12	7 days/40 da
Phenoxy Herbicides	ug/l	0.01	Extraction/GC/ECD	(2)	14	7 days/40 da
Total Organic Halogen (TOX)	ug/l	5	Adsorbtion/Coulometric	450.1(3)	15	-
Trihalomethanes (THM)	ug/l	1	Extraction/GC/ECD	(4)	11	14 days
		1	Purge & Trap GC/MS	(4)	11	14 days
Dioxin	ug/l	0.005	Extraction/GC/MS/ECD	613	16	7 days/40 da
Purgeable Halocarbons	ug/l	0.01	Purge & Trap/GC/Hall	601	11	14 days
Purgeable Aromatics	ug/l	1	Purge & Trap/GC/FID	602	17	14 days
Acrolein & Acrylonitrile	ug/l	100	Purge & Trap/GC/FID	603	18	14 days
Phenols by GC	ug/l	10	Extraction/GC/FID	604	16	7 days/40 da
Benzidines	ug/l	0.1	Extraction/HPLC	605	19	7 days/40 da
Phthalate Esters	ug/l	10	Extraction/GC/FID	606	12	7 days/40 da
Nitrosamines	ug/l	1	Extraction/GC/NPD	607	20	7 days/40 da
Nitroaromatics/isophorone	ug/l	1	Extraction/GC/FID & GC/ECD	609	12	7 days/40 da
Polynuclear Aromatics	ug/l	0.5	Extraction/HPLC	610	20	7 days/40 da
Haloethers	ug/l	1	Extraction/GC/Hall	611	17	7 days/40 da
Chlorinated Hydrocarbons	ug/l	0.02	Extraction/GC/ECD	612	12	7 days/40 da
Organophosphorus Pesticides	ug/l	0.1	Extraction/GC/NPD	622(5)	12	7 days/40 da
Triazine Pesticides	ug/l	0.1	Extraction/GC/NPD	(6)	12	7 days/40 da

References

(1) Federal Register, Vol. 44, No. 233, Monday, December 3, 1979.
(2) "Method for Chlorinated Phenoxy Acid Herbicides in Industrial Effluents," Federal Register, Vol. 38, No. 75, Part II.
(3) "Total Organic Halide," US EPA-EMSL, Cincinnati, November, 1980.
(4) Federal Register, Vol. 44, No. 231, Thursday, November 29, 1979, Appendix, Part I.
(5) "Method 622- Organophosphorus Pesticides," Proposed EPA Method, 304 (h) Committee.
(6) Federal Register, Vol. 38, No. 75, 1973.

Notes

[a] Nominal values are the best achievable with the listed analytical method for a typical component. Interferrences in specific samples may res in a higher detection limit.

[b] Applicable to NPDES Wastes as updated by Robert C. Booth, Director, EMSL-Cincinnati, September 22, 1981. Where two times are given, th first refers to the time to extraction, the second to the time of instrumental analysis.

TABLE 2-4 (continued)
Inorganic Analytical Methodology (Continued)

References

(1) "Methods for Chemical Analysis of Water and Wastes", EPA-600/4-79-020, EMSL, Cincinnati, 1979.

(2) "Standard Methods for the Examination of Water and Wastewater", 15th Edition, APHA, 1980.

(3) Federal Register, 40 CFR 136, December 3, 1979; USEPA EMSL-Cincinnati, OH 45268.

(4) "Annual Book of ASTM Standards", Part 31, Water, 1980.

Notes

[a] Nominal values are the best achievable with the listed analytical method. Interferences in specific samples may result in a higher detection limit.

[b] Applicable to NPDES wastes as updated by Robert C. Booth, Director, EMSL-Cincinnati, September 22, 1981.

[c] Digestion procedure 1-4.1.4 used for elements determined by ICP Emission Spectroscopy when determining total metals. Digestion procedures for graphite furnace elements included with reference listed.

Navajo has analyzed ground water samples from the ditch and pond area for all hazardous constituents identified in the recent pond analyses and previous ditch sludge analyses. The results of the ground water sampling are discussed in Sections 5.0 and 6.0.

2.3 ANALYTICAL RESULTS

The analytical results from the June 4, 1986 sludge sampling are included in Appendix B. As indicated by the results, a number of organic and inorganic constituents were detected in the sludges from Pond #1 (Table 2-5 and Table 2-6). These detected constituents have been considered in conjunction with the results from the first ground water sampling event (August, 1986) to formulate a parameter list for the subsequent ground water monitoring programs (Section 5.0).

2.4 QUALITY ASSURANCE/QUALITY CONTROL

Because the results of analyses were critical to future decisions and actions, it was necessary to assure that analytical results are precise and accurate. For this reason, a randomly-selected sample was taken and sent to a second laboratory for duplicate analysis. This sample was sent to Raba-Kistner Laboratories and analyzed for selected parameters from Table 2-2. The results of the QA/QC analyses are also included in Appendix B.

TABLE 2-5

POND #1 SLUDGE ORGANIC CONSTITUENTS

Parameter	Concentration*
Volatiles:	
Benzene	2.0
Ethyl benzene	4.5 - 8.7
Toluene	3.9 - 12.0
m-Xylene	5.1 - 10.0
o-,p-Xylenes	3.7 - 9.1
Base/Neutrals:	
Fluoranthene	7.8 - 24.0
Naphthalene	
Benzo(a)anthracene	4.6 - 13.0
Benzo(b)fluoranthene	9.2
Chrysene	8.5 - 30.0
Anthracene	5.3 - 8.5
Fluorene	17.0 - 27.0
Pyrene	14.0 - 35.0
1-Methylnaphthalene	34.0 - 59.0
Acid Extractable:	
2,4-Dimethyl phenol	4.1
phenol	4.4 - 12.0
o-Cresol	4.9 - 7.7
p-,m-Cresol	5.8 - 10.0

*Concentration in parts per million (ppm)

TABLE 2-6

POND #1 SLUDGE INORGANIC CONSTITUENTS

Parameter	Concentration*
Antimony	ND
Arsenic	11 - 15
Beryllium	0.4 - 0.6
Cadmium	ND
Chromium	250 - 820
Copper	89 - 360
Lead	31 - 61
Mercury	0.06 - 0.52
Nickel	7.5 - 11
Selenium	4
Silver	ND
Thallium	ND
Zinc	62 - 330
Barium	75 - 96
Cobalt	3.6 - 4.0
Vanadium	12 - 18

*Concentrations in parts per million (ppm)

SECTION 3.0

3.0 FACILITY DESCRIPTION

Evaporation Pond #1 and the wastewater conveyance ditch are the waste management facilities which have been identified for on-going investigations in this field study. The ditch (Plates 1 and 2) is approximately 15,000 feet in length, 3 to 4 feet wide, 1 to 2 feet deep and conveys wastewater by gravity flow from the refinery directly into Pond #1. Pond #1 (Plate 2) has an area of 16.1 acres and is 0.5 to 2.5 feet deep.

3.1 CONVEYANCE DITCH

Refinery wastewater flows to a series of 4 permanent evaporation ponds via a gravity-flow ditch. The ditch has a slope of approximately 0.003 and is built on soils of the Arno, Harkeley and Karro series. The ditch lies approximately parallel to the path of a natural drainage (Eagle Creek) for approximately 15,000 feet to the ponds. The ditch is <u>not</u> in Eagle Creek, but rather parallels the natural drainage (Plate 1). Soil characteristics are discussed in detail in Section 4-2. No plans or specifications were prepared when the ditch was built, and none are currently available.

The conveyance ditch begins at the discharge from the oil-water separator, and is typically 3-4 feet wide and 1 foot deep. The ditch is bermed along its course to prevent overflow or influx of surface water (stormwater and irrigation runoff). The ditch carries refinery wastewater with a typical total dissolved solids content of 2000-4000 mg/l. From site observations, it is clear that an oily sludge accumulates in the bottom of the conveyance ditch. This sludge may act as a "natural" liner and limit infiltration of organic and inorganic constituents by reducing the permeability of the ditch sides and bottom.

Navajo is presently in the process of designing a pipeline to replace the existing ditch.

3.2 EVAPORATION POND #1

Wastewater from the conveyance ditch flows directly into Pond #1. Pond #1 has a surface area of 16.1 acres, and is 0.5 to 2.5 feet deep. The pond is built on, and of, silts, sands and clays of the Pecos Valley alluvium (see Section 4.2--Soils). As shown in the cross-sections (Plate 3), all ponds are contained by earthen dikes 3 to 5 feet high and 12 to 13 feet wide at their base. The ponds are located on a terrace approximately 10 feet above the Pecos River's channel.

Water flows from Pond #1 to Ponds #2, #3 and, if required, to overflow Pond #4 by gravity flow. The original dike between Ponds 2 and 3 is breached, and these are effectively a single pond. The sludge which has accumulated in Pond #1 may act as a "natural" liner as previously discussed in Section 3.1. As such, the sludge reduces the permeability (and hence leaching) of wastewater through the bottom of the pond. Wastewater is evaporated in these ponds; there is no direct discharge to the Pecos River.

SECTION 4.0

4.0 GEOLOGY, SOILS AND HYDROGEOLOGY

4.1 GEOLOGY

The town of Artesia and Navajo Refinery are underlain by thin (20 feet or less) layers of soils, alluvium and weathered bedrock which generally conceal subcrops of the Artesia Group (Permian). As seen in the explanation of Plate 4, the Artesia Group consists of carbonates, evaporites, and shales deposited in a backreef environment. The Artesia area is located on the northwestern shelf of the Permian Basin where bedrock strikes 20 to 60 degrees northwest and basinward (southeasterly) and dips of 1 to 3 degrees are typical. Surficial deposits are shown in Plate 5.

Structure in the Artesia area is expressed as gentle (1-3 degree) southeasterly dips, with few other features. One fault inferred from subsurface data is mapped in the area. This fault trends about N. 40 E. through Sections 11, 12 and 14 (Plate 6), and is apparently a normal fault with the northwest block downthrown. This structure parallels the other major structural elements of this area, such as the Y-O and K-M "buckles" or fault zones (Kelley, 1971).

In Section 12, the fault appears to pass beneath the Navajo Refining Company's evaporation ponds near the Pecos River. Although the fault may cut across all known and potential aquifers, there are several reasons why the fault may not be a potential conduit for downward migration of contaminants. First, faults in evaporites (Queen, Seven Rivers formations) typically "heal" or self-seal by flowage and recrystallization of gypsum and anhydrite. Second, the net hydrostatic head of the shallow and deep artesian aquifers is upward and would prevent any downward advective flow.

Based on logs of numerous shallow boreholes in the refinery area, (see Discharge Plan, submitted to NMOCD 1984) it is apparent that the refinery is situated over shallow subcrops (5-20 feet in depth) of the Seven Rivers Formation of the Artesia Group. The Seven Rivers Formation consists of carbonates, evaporites (gypsum and anhydrite) and clayey shales in thin, discontinuous and interfingering beds.

The overburden thickens east of the refinery as it approaches the Pecos River valley. The alluvial fill may be up to 250 feet thick in the valley itself (east of NM Route 229). Welder (1983) indicates that 150 feet of valley fill underlies the City of Artesia, although more site-specific data (see Discharge Plan, Navajo Refining Company, 1984) indicate that the valley fill (and ground water) do not extend under the refinery site.

4.2 SOILS

The Artesia region is located on a broad, gently sloping plateau that has developed as a result of in-situ weathering of flat-lying carbonate and evaporitic bedrock. Localized areas of valley fill (Pecos River Valley and major arroyos) form the only other significant substrate. Soil properties vary as a result of differing grain size, land slope and available moisture. Plates 7 and 8 shows the distribution of soil types in the Artesia area. Table 4-1 shows physical and engineering properties of soils in this area. The refinery site proper is located in an area of Karro Loams (USSCS, 1971). These soils are developed on deeply weathered calcareous rocks, and are moderately permeable. Much of the refinery site area has been filled, graded and leveled, leaving little natural soil in place.

The effluent ditch (Plates 1 and 2) parallels Eagle Creek, and is constructed in soils of the Pima Series. These dark, calcareous loams have developed on carbonate bedrock and carbonate-rich alluvial material. They are moderately permeable (0.2-0.8 inches/hour) and have a high water-holding capacity (0.18-0.20 inches/inch).

The evaporation ponds are built on soils of the Arno and Harkey series which develop on fine, silty alluvium in the Pecos River Valley (Plate 7). These soils have low to moderate permeabilities (0.05-2.5 inches/hour) and high water holding capacity (0.17-0.19 inches/inch).

Data for horizontal permeability are not available. Stratified soils and sedimentary rocks generally exhibit a vertical/horizontal permeability

Table 4-1
Soil Properties

Soil series and map symbols	Depth to bedrock, hard caliche, or gypsum	Depth from surface	Classification		
			USDA texture	Unified	AASHO
	Inches	*Inches*			
Active dune land: AD	More than 60.	0-60	Fine sand	SP	A-3
Anthony: AE, Aa, Ah	More than 60.	0-60	Stratified sandy loam and loamy sand.	SM	A-1 or A-2
* Arno: AH, Ak, An (For Harkey part of AH and Ak, see Harkey series.)	More than 60.	0-14	Silty clay loam	CL	A-6
		14-60	Silty clay	CH	A-7
Atoka: Ao, At	20 to 36.	0-8	Loam	ML	A-4
		8-33	Loam and light clay loam	CL	A-6
		33	Hard, fractured caliche.		
Berino: BA, BB, BD, BP (For Pajarito part of BP, see Pajarito series; the Dune land part of BD is too variable for reliable evaluation.)	More than 60.	0-17	Loamy fine sand and fine sand	SM	A-2
		17-50	Sandy clay loam	SC	A-6
Bippus	More than 60.	0-48	Silty clay loam and clay loam	CL	A-6
		48	Weakly cemented caliche.		
Cacique: CA	12 to 36.	0-17	Loamy sand and sandy loam	SM	A-2
		17-24	Sandy clay loam	SC	A-6
		24	Indurated, fractured caliche.		
Cottonwood: CR (For Reeves part of CR, see Reeves series.)	Soft to hard gypsum below a depth of 9 inches.	0-9	Loam	ML-CL	A-4
		9	Gypsum.		
Dev: DP (For Pima part of DP, see Pima series.)	More than 60.	0-15	Gravelly loam	GM	A-1 or A-2
		15-60	Very gravelly loam	GP	A-1
Ector: EC, EE, ER (For Reagan part of ER, see Reagan series.)	1 to 18.	0-6	Stony loam	SM-ML	A-4
		6	Limestone bedrock.		
Gypsum land: GA, GC, GR, Gs (For Cottonwood part of GC and Gs, see Cottonwood series; for Reeves part of GR, see Reeves series.)	Soft or hard gypsum at a depth of 0 to 10 inches.	0-19	Gypsiferous earth	ML	A-4
		19	Gypsum.		
* Harkey: Ha, Hk	More than 60.	0-87	Very fine sandy loam, loam, and silt loam.	ML	A-4
* Karro: KA, KL, Kr, Ku, Kv	More than 60.	0-20	Loam	ML-CL	A-4
		24-60	Clay loam	CL	A-6
Kermit: KM (For Berino part of KM, see Berino series.)	More than 60.	0-60	Fine sand	SP-SM	A-3
Kimbrough: KO, KS, KT (For Stegall part of KS and KT, see Stegall series.)	2 to 15.	0-9	Loam	ML	A-4
		9	Caliche.		
Largo: LA, LG, LN (The Stony land part of LN is too variable for reliable evaluation.)	More than 60.	0-65	Stratified loam and silt loam	ML-CL	A-4
Likes: LS	More than 60.	0-60	Loamy fine sand	SM	A-1
Mobeetie: MO	More than 60.	0-60	Fine sandy loam	SM	A-4

Table 4-1
(Continued)

Soil series and map symbols	Percentage passing sieve—			Permeability	Available water capacity
	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 200 (0.074 mm.)		
				Inches per hour	*Inches per inch of soil*
Active dune land: AD	100	100	0-5	>10. 0	0. 06-0. 08
Anthony: AE, Aa, Ah	100	100	15-25	2. 5-5. 0	0. 10-0. 12
* Arno: AH, Ak, An (For Harkey part of AH and Ak, see Harkey series.)	100 100	100 100	90-95 90-95	0. 05-0. 20 0. 05-0. 20	0. 18-0. 20 0. 15-0. 17
Atoka: Ao, At	100 100	100 100	60-75 70-80	0. 8-2. 5 0. 8-2. 5	0. 16-0. 18 0. 17-0. 19
Berino: BA, BB, BD, BP (For Pajarito part of BP, see Pajarito series; the Dune land part of BD is too variable for reliable evaluation.)	100 100	100 100	10-20 35-45	5. 0-10. 0 0. 2-0. 8	0. 06-0. 08 0. 14-0. 16
Bippus	100	100	85-95	0. 2-0. 8	0. 18-0. 20
Cacique: CA	100 100	100 100	20-35 35-50	5. 0-10. 0 0. 8-2. 5	0. 10-0. 12 0. 14-0. 16
Cottonwood: CR (For Reeves part of CR, see Reeves series.)	100	100	60-75	0. 8-2. 5	0. 16-0. 18
Dev: DP (For Pima part of DP, see Pima series.)	35-75 15-45	30-70 10-40	15-20 5-10	0. 8-2. 5 >10. 0	0. 11-0. 13 0. 06-0. 08
Ector: EC, EE, ER (For Reagan part of ER, see Reagan series.)	55-85	50-80	40-60	0. 8-2. 5	0. 11-0. 13
Gypsum land: GA, GC, GR, Gs (For Cottonwood part of GC and Gs, see Cottonwood series; for Reeves part of GR, see Reeves series.)	100	100	60-70	0. 8-2. 5	0. 16-0. 18
* Harkey: Ha, Hk	100	100	60-75	0. 8-2. 5	0. 17-0. 19
* Karro: KA, KL, Kr, Ku, Kv	100 100	100 100	60-75 70-80	0. 8-2. 5 0. 8-2. 5	0. 16-0. 18 0. 18-0. 20
Kermit: KM (For Berino part of KM, see Berino series.)	100	100	5-10	>10. 0	0. 06-0. 08
Kimbrough: KO, KS, KT (For Stegall part of KS and KT, see Stegall series.)	95-100	90-95	50-65	0. 8-2. 5	0. 16-0. 18
Largo: LA, LG, LN (The Stony land part of LN is too variable for reliable evaluation.)	100	100	60-70	0. 8-2. 5	0. 17-0. 19
Likes: LS	98	97	10-20	5-10. 0	0. 08-0. 10
Mobeetie: MO	100	100	40-50	2. 5-5. 0	0. 13-0. 15

Table 4-1
(Continued)

Soil series and map symbols	Reaction	Electrical conductivity (Ec × 10^3) Mmho./cm. at 25° C.	Corrosivity (Untreated steel pipe)	Shrink-swell potential
Active dune land: AD	pH 6.6-7.3	0-1.0	Low	Low.
Anthony: AE, Aa, Ah	7.4-7.8	0-1.0	Low	Low.
* Arno: AH, Ak, An (For Harkey part of AH and Ak, see Harkey series.)	7.9-8.4 7.9-8.4	4.0-8.0 8.0-12.0	High High	Moderate. High.
Atoka: Ao, At	7.4-7.8 7.4-7.8	0-2.0 0-2.0	Moderate Moderate	Low to moderate. Moderate.
Berino: BA, BB, BD, BP (For Pajarito part of BP, see Pajarito series; the Dune land part of BD is too variable for reliable evaluation.)	6.6-7.3 6.6-7.3	0-1.0 0-4.0	Low Moderate	Low. Moderate.
Bippus	7.4-8.4	0-4.0	Moderate	Moderate.
Cacique: CA	6.6-7.3 6.6-7.3	0-1.0 0-4.0	Low Moderate	Low. Moderate.
Cottonwood: CR (For Reeves part of CR, see Reeves series.)	6.6-7.8	8.0-15.0	High	Low to moderate.
Dev: DP (For Pima part of DP, see Pima series.)	7.4-7.8 ----------	0-2.0 0-1.0	Moderate Low	Low. Low.
Ector: EC, EE, ER (For Reagan part of ER, see Reagan series.)	7.4-7.8	0-4.0	Moderate	Low.
Gypsum land: GA, GC, GR, Gs (For Cottonwood part of GC and Gs, see Cottonwood series; for Reeves part of GR, see Reeves series.)	6.6-7.8	>15.0	High	Low.
* Harkey: Ha, Hk	7.4-7.8	2.0-12.0	Moderate to high.	Low.
* Karro: KA, KL, Kr, Ku, Kv	7.9-8.4 7.9-8.4	4.0-10.0 8.0-15.0	High High	Moderate. Moderate.
Kermit: KM (For Berino part of KM, see Berino series.)	6.6-7.3	0-1.0	Low	Low.
Kimbrough: KO, KS, KT (For Stegall part of KS and KT, see Stegall series.)	6.6-7.8	0-4.0	Moderate	Low.
Largo: LA, LG, LN (The Stony land part of LN is too variable for reliable evaluation.)	7.4-7.8	0-4.0	Moderate	Low to moderate.
Likes: LS	6.6-7.8	0-1.0	Low	Low.
Mobeetie: MO	7.4-8.4	0-1.0	Low	Low.

Table 4-1

(Continued)

Soil series and map symbols	Depth to bedrock, hard caliche, or gypsum	Depth from surface	Classification		
			USDA texture	Unified	AASH
	Inches	*Inches*			
Pajarito: PA, PD (The Dune land part of PD is too variable for reliable evaluations.)	More than 60.	0-60	Loamy fine sand and fine sandy loam.	SM	A-1 or A
* Pima: PM, Pe, Pn, Pv	More than 60.	0-60	Silt loam to silty clay loam	CL	A-6
Potter: PS (For Simona part of PS, see Simona series.)	2 to 12.	0-10 10	Gravelly loam Fractured, indurated caliche.	SM	A-2
Reagan: RA, RE, Rc, Rd (For Upton part of RE, see Upton series.)	More than 60.	0-60	Loam and light clay loam	CL	A-4 or A-
Rf	More than 60.	0-60	Loam and light clay loam	CL	A-4
Reeves: RG, RM, Rl, Rn, Rt (For Reagan part of RM, see Reagan series; for Gypsum land part of RG, see Gypsum land.)	Soft or hard gypsum at a depth of 10 to 36 inches.	0-32 32	Heavy loam and light clay loam. Gypsum.	CL	A-4 or A-
Rr	Soft or hard gypsum at a depth of 20 to 36 inches.	0-31 31	Heavy loam and light clay loam. Gypsum.	CL	A-4
Russler: RS, RU, Rv (For Ector part of RU, see Ector series.)	Soft or hard gypsum at a depth of 45 inches or more.	0-11 11-52 52	Loam Clay loam Gypsiferous earths.	ML-CL CL	A-4 A-6
Simona: SA, SG, SM, SN (For Bippus part of SM, see Bippus series; for Wink part of SN, see Wink series.)	10 to 24.	0-19 19	Gravelly fine sandy loam Indurated, fractured caliche.	SM	A-4
Stegall	18 to 40.	0-22 22	Clay loam and heavy clay loam. Indurated, fractured caliche.	CL	A-6
Tonuco: TC, TF, TN, TO (For Berino part of TO, see Berino series.)	6 to 20.	0-15 15	Loamy fine sand Indurated, fractured caliche.	SM	A-1
Upton: UG, UR, US, Uo, Up, Ut (For Reagan part of UR, see Reagan series; for Simona part of US, see Simona series.)	2 to 20.	0-9 9	Gravelly loam Indurated, fractured caliche.	SM	A-2
Wink: WK	More than 69.	0-60	Loamy fine sand and fine sandy loam.	SM	A-1 or A-2

Table 4-1
(Continued)

Soil series and map symbols	Reaction	Electrical conductivity (Ec × 10³) Mmho./cm. at 25° C.	Corrosivity (Untreated steel pipe)	Shrink-swell potential
Pajarito: PA, PD (The Dune land part of PD is too variable for reliable evaluations.)	pH 6. 6–7. 8	0–1. 0	Low	Low.
* Pima: PM, Pe, Pn, Pv	7. 4–7. 8	0–4. 0	Moderate	Moderate.
Potter: PS (For Simona part of PS, see Simona series.)	7. 4–7. 8	0–4. 0	Moderate	Low.
Reagan:				
RA, RE, Rc, Rd (For Upton part of RE, see Upton series.)	7. 4–8. 4	2. 0–8. 0	Moderate to high.	Moderate.
Rf	7. 4–8. 4	4. 0–15. 0	High	Moderate.
Reeves:				
RG, RM, Rl, Rn, Rt (For Reagan part of RM, see Reagan series; for Gypsum land part of RG, see Gypsum land.)	7. 4–7. 8	4. 0–8. 0	High	Moderate.
Rr	7. 4–7. 8	4. 0–12. 0	High	Moderate.
Russler: RS, RU, Rv (For Ector part of RU, see Ector series.)	7. 4–7. 8 7. 4–7. 8	8. 0–15. 0 8. 0–15. 0	High High	Low. Moderate.
Simona: SA, SG, SM, SN (For Bippus part of SM, see Bippus series; for Wink part of SN, see Wink series.)	7. 4–7. 8	0–1. 0	Low	Low.
Stegall	6. 6–7. 8	0–4. 0	Moderate	Moderate.
Tonuco: TC, TF, TN, TO (For Berino part of TO, see Berino series.)	6. 6–7. 3	0–1. 0	Low	Low.
Upton: UG, UR, US, Uo, Up, Ut (For Reagan part of UR, see Reagan series; for Simona part of US, see Simona series.)	7. 4–7. 8	0–4. 0	Moderate	Low.
Wink: WK	7. 4–7. 8	0–4. 0	Low to moderate.	Low

Table 4-1
(Continued)

Soil series and map symbols	Percentage passing sieve—			Permeability	Available water capacity
	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 200 (0.074 mm.)		
				Inches per hour	*Inches per inch of soil*
Pajarito: PA, PD (The Dune land part of PD is too variable for reliable evaluations.)	100	100	20–30	5. 0–10. 0	0. 13–0. 15
* Pima: PM, Pe, Pn, Pv	100	100	85–95	0. 2–0. 8	0. 18–0. 20
Potter: PS (For Simona part of PS, see Simona series.)	75–85	75–85	20–30	0. 8–2. 5	0. 11–0. 13
Reagan:					
RA, RE, Rc, Rd (For Upton part of RE, see Upton series.)	100	100	60–75	0. 8–2. 5	0. 17–0. 19
Rf	100	100	60–75	0. 8–2. 5	0. 17–0. 19
Reeves:					
RG, RM, Rl, Rn, Rt (For Reagan part of RM, see Reagan series; for Gypsum land part of RG, see Gypsum land.)	100	100	60–75	0. 8–2. 5	0. 17–0. 19
Rr	100	100	60–75	0. 8–2. 5	0. 17–0. 19
Russler: RS, RU, Rv (For Ector part of RU, see Ector series.)	100 100	100 100	60–75 70–80	0. 8–2. 5 0. 2–0. 8	0. 16–0. 18 0. 18–0. 20
Simona: SA, SG, SM, SN (For Bippus part of SM, see Bippus series; for Wink part of SN, see Wink series.)	100	100	40–50	2. 5–5. 0	0. 09–0. 11
Stegall	100	100	70–80	0. 2–0. 8	0. 18–0. 20
Tonuco: TC, TF, TN, TO (For Berino part of TO, see Berino series.)	100	100	15–25	5. 0–10. 0	0. 09–0. 11
Upton: UG, UR, US, Uo, Up, Ut (For Reagan part of UR, see Reagan series; for Simona part of US, see Simona series.)	75–85	75–85	20–30	0. 8–2. 5	0. 11–0. 13
Wink: WK	100	100	20–35	2. 5–5. 0	0. 12–0. 14

ratio of 1/20. It is anticipated that the saturated horizontal hydraulic conductivity of these soils is approximately 20 times the vertical hydraulic conductivity.

4.3 REGIONAL HYDROGEOLOGY

Artesia is located in the Roswell-Artesia artesian water basin (Welder, 1983). The principal ground water reservoirs are the semi-confined aquifer in the upper Queen Formation, an unconfined water-table aquifer in the Pecos Valley fill and the artesian San Andres aquifer. Local perched water-bearing units with small storage capacities also occur in isolated stratigraphic traps in the upper Seven Rivers Formation. With the exception of some wells completed in the valley alluvium immediately adjacent to the Pecos River, all wells in the Artesia area exhibit some degree of artesian head. Deep (800-1200 feet) artesian wells, which are completed in the Grayburg-San Andres formations, have static water levels 50-80 feet below ground level. The San Andres aquifer is confined by shales and evaporites of the lower Queen Formation.

Shallow, semi-confined aquifer wells (150-250 feet) produce from the upper sands of the Queen Formation and are confined by aquitards of anhydrite, gypsum and shale in the overlying Seven Rivers Formation (Plate 9). Water levels in these shallow wells range from 40 - 60 feet below ground level (Plate 10).

According to available data at the office of the State Engineer, the only wells which tap the shallow, perched or confined "gyp water" reservoirs in stratigraphic traps in the upper Seven Rivers Formation are Navajo monitor wells. The ground water in these zones is effectively isolated from both major aquifers. In very shallow wells (20 feet), these perched zones exhibit 3 to 5 feet of artesian head.

The regional potentiometric surfaces of the San Andres and Valley Fill aquifers are shown in Figures 4-1 and 4-2. The two potentiometric surfaces have very similar elevations (about 3300' msl), with the deep artesian aquifers' surface slightly above the shallow aquifers surface.

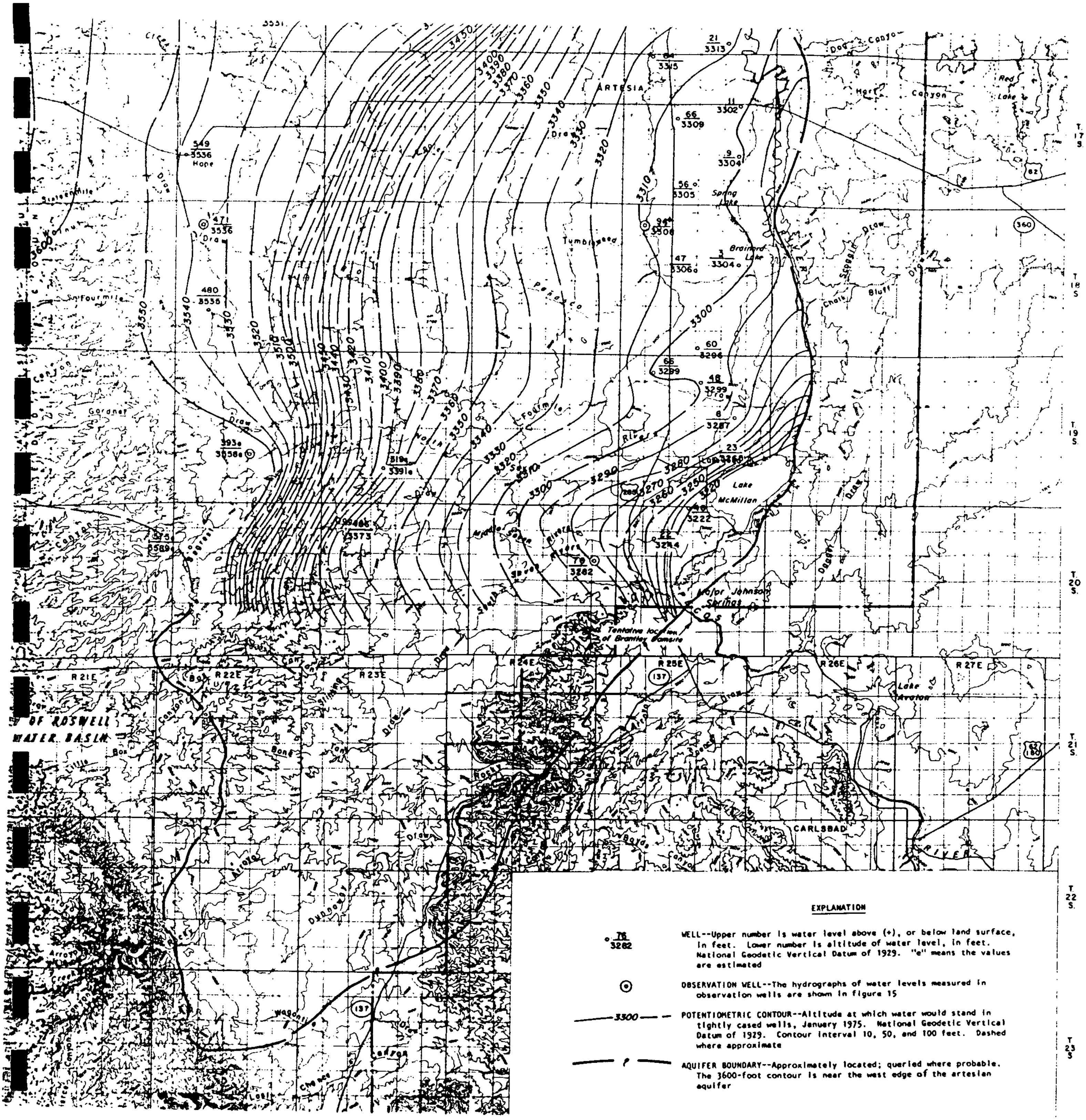


Figure 4-1 Potentiometric surface of San Andres Aquifer (Welder, 1983)

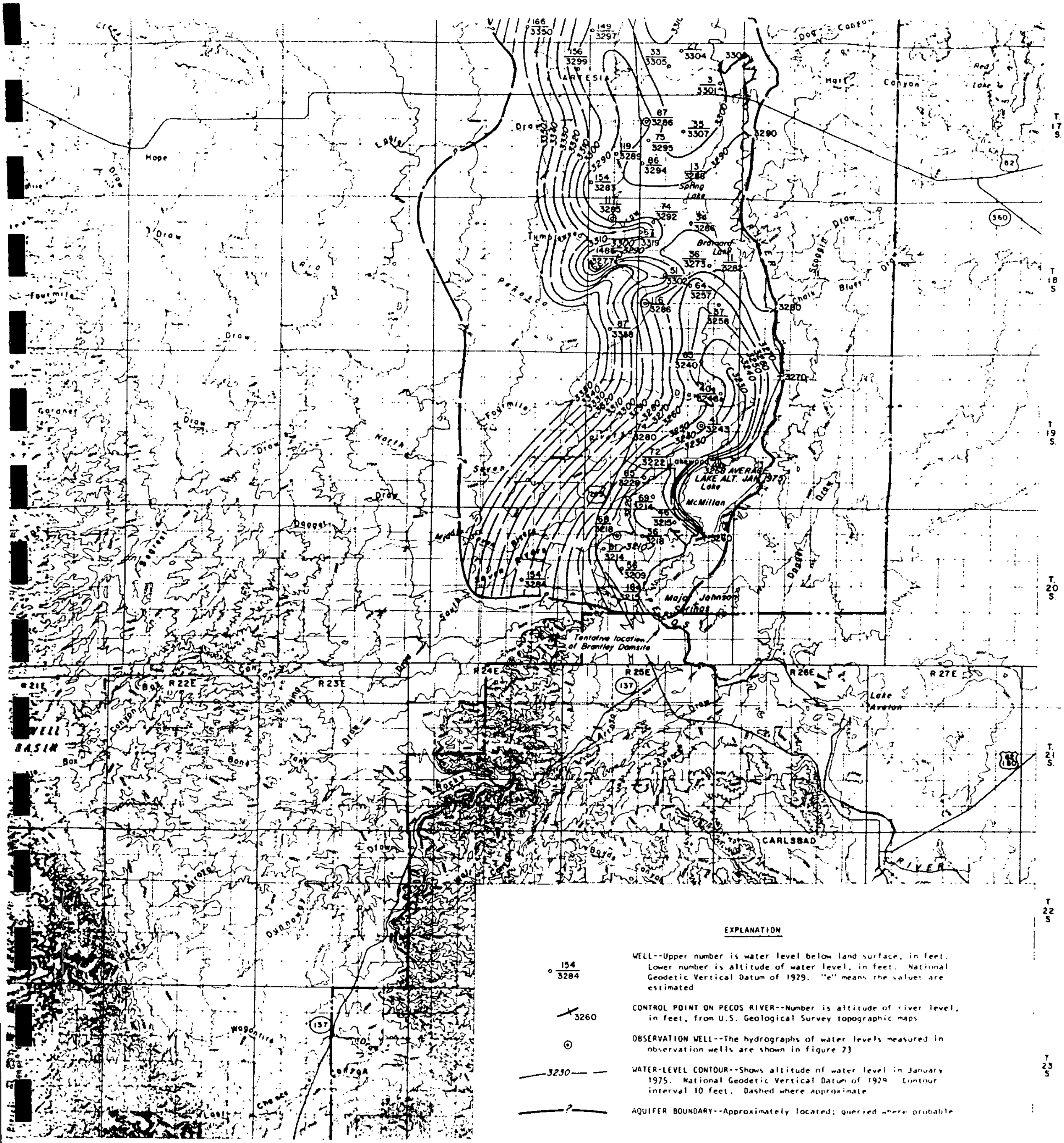


Figure 4-2 Potentiometric surface of shallow aquifer (Welder, 1983)

These two major aquifers produce water for irrigation, industrial and domestic purposes. Water quality is variable, ranging from 500 to over 5000 ppm total dissolved solids, and in general, the more saline waters are found at greater depths and/or to the east (Welder, 1983).

4.4 LOCAL HYDROGEOLOGY

Ground water in the Artesia area occurs in four general zones.

- The San Andres artesian aquifer
- The unconfined valley-fill aquifer
- A semi-confined zone in the upper Queen Formation
- Isolated confined and semi-confined zones in the upper Seven Rivers Formation

The San Andres artesian aquifer is the major source of ground water in the Artesia area and supports most of the large local agricultural industry. Artesian water, ranging from 500 to 5000 ppm TDS, is found in the San Andres and Grayburg formations (Permian) at depths of 850 to 1250 feet below the surface (Kelley, 1971). This aquifer system is recharged along San Andres outcrops in the Sacramento Mountains west of Artesia. In the early 1900's many wells in this aquifer flowed 1000 to 3000 gallons per minute (gpm). Extensive withdrawals have now lowered the head to approximately 50 to 80 feet below the land surface (Figure 4-1) The artesian aquifer is confined by the impermeable (or very slightly permeable) carbonates, shales and evaporites which comprise much of the overlying Queen and Seven Rivers formations. Its potentiometric surface is typically slightly above the Queen aquifer's potentiometric surface (Welder, 1983).

The Queen aquifer, which has been described as a "water table" aquifer, is, in fact, a second artesian aquifer. With the exception of wells drilled in the valley fill immediately adjacent to the Pecos River, nearly all wells with completion depths of 200 to 250 feet exhibit 100 to 150 feet of artesian head. These wells typically produce from sands in the upper Queen Formation that are confined by the thick anhydrites and shales (aquitards) of the overlying Seven Rivers Formation. Relatively impermeable shales and evaporites several hundred feet thick separate the upper Queen sands from the underlying San Andres aquifer.

The Queen aquifer potentiometric surface (Plate 10) typically slopes gently to the east and southeast, and follows the regional stratigraphic dips. East of the Artesia area, where extensive agricultural development exists, the potentiometric surface forms a trough due to significant withdrawals from the shallow aquifer. The Queen aquifer's potentiometric surface is typically below the San Andres' potentiometric surface (Figure 4-1), indicating that any interconnection (along faults or poorly completed wells) would cause flow upward from the deep to the shallow aquifer. The configuration of the shallow aquifer is locally complicated by large, seasonal irrigation withdrawals. Although considerable local variation is observed, the shallow aquifer generally provides water of quality adequate for domestic and irrigation use (500-5000 ppm TDS).

Poor-quality (>10,000 ppm TDS) ground water exists in a water-table aquifer in the alluvial fill of the Pecos River Valley. This aquifer underlies the evaporation ponds and much of the effluent ditch. It is bounded east of the Pecos by outcrops of the Artesia Group (see Plates 4 and 5) and to the west by the "zero edge" of the valley fill (Plate 4). The location of this "zero edge" is unclear in drillers' logs but it is probably coincident with the break in slope on the western edge of the Pecos Valley as is consistent with Plate 4. West of the "zero edge", the uppermost ground water is perched in permeable zones in the Seven Rivers Formation. As Plate 1 shows, this topographic break occurs along the 3310 foot elevation contour, subparallel to and approximately 1/2 mile east of NM Route 292. The boundary trends approximately north-south through the central part of Sections 2, 11, and 14, T. 17.S, R. 26 E. It appears that the valley-fill aquifer underlies the eastern 1/3 of the effluent ditch, and a "perched water" zone underlies the western 2/3 of the ditch.

The valley fill aquifer is interconnected with the Pecos River, and exchanges water with the river depending on seasonal flow. During high-flow events (floods or planned releases from upstream dams), water moves from the river to the aquifer. During periods of low flow, water discharges from the aquifer to the stream. Discharge to the Pecos is evidenced by a baseflow gain in the reach above and adjacent to Artesia (Welder, 1983).

In some areas (e.g., under the refinery) there is evidence indicating the existence of isolated, discontinuous perched-water zones, which lie on top of clay or anhydrite lenses in the Seven River Formation above the confined Queen aquifer. These small, stratigraphically trapped accumulations of ground water are highly variable in areal extent, volume, saturated thickness and quality. One such confined body of water underlies part of the Navajo Refinery site.

The configuration of the perched-water unit under the Navajo site and the upper end of the ditch is revealed by over 40 monitoring wells installed by Navajo Refining Company (Plate 11). Lithologic drillers' logs show that water is encountered in weathered and fractured anhydrite (so called "gypsum sand") at depths of 15 to 30 feet, and typically rises to levels 3 to 5 feet above the saturated unit. This water-bearing unit is confined above by layers of gypsum, anhydrite and caliche, and below by continuous layers of clay and anhydrite.

Plate 12 shows that this perched gypsum/anhydrite/sand unit may be composed of several localized water-bearing zones at different depths. The local water bearing zones are generally less than 5 feet thick and may be hydraulically connected with each other to an unknown degree. Wells #19 and #34, and #29, #37, #39 and #40 show anomalies in the potentiometric surface in some areas, apparently due to the complex hydrologic connections in these units.

Navajo Refining Company maintains 4 evaporation ponds near the Pecos River, which are connected to the plant site by a conveyance channel paralleling Eagle Creek (Plates 1 and 2). These ponds, and the portions of the conveyance channel in Sections 12, 11 and the east 1/2 of Section 10 are located in Pecos Valley alluvium. Monitor wells installed by Navajo Refining Company show that ground water in the valley alluvium is typically 6 to 12 feet below the surface. Although the alluvium is generally silty sand, some 6 inch monitor wells can maintain pumping rates of 10 -15 gpm indicating the local presence of higher permeability material. Plate 13 shows the configuration of the water surface in this unit. As expected, flow is sub-parallel to the Pecos River Valley and water levels in this unit respond to the fluctuations of flow in the Pecos River. Recent data on water levels in this area are consistent with the data presented in Plate 13.

4.5 GROUND WATER QUALITY

Four separate hydrogeologic units are present in the area of the Navajo facility:

- The deep artesian aquifer (San Andres)
- The shallow artesian aquifer (upper Queen)
- The Pecos River Valley alluvium, and
- The perched water in the terrace regolith (Seven Rivers Formation) and surficial deposits.

The well-defined pressure regime in the confined aquifers (San Andres and the upper Queen) demonstrates that these units cannot be degraded by advective transport from surface sources (Section 4.4). Therefore, water quality data on these units was not collected for this study. Published data on the water quality of these units are available (NMEID, 1980).

The water chemistry of wells located the shallow Pecos Valley alluvium and perched water-bearing units which have the potential to be affected by Navajo Refinery is summarized in Appendix B of the 1984 Discharge Plan (previously submitted to NMOCD). Well locations are given in Plates 1 and 2 of this report. The water quality in the Pecos River Valley alluvial sand/silt aquifer is well defined near the evaporation ponds.

Comparison of ground water quality with water quality in the evaporation ponds reveals that, in terms of the major cations/ anions and metals, the water quality in the lagoons is better than or equal to ground water quality. Neither are suitable for irrigation, domestic or industrial purposes.

Water quality in the perched water-bearing unit under the refinery process area is also well defined (Discharge Plan, Appendix B). The water quality in this unit is somewhat better than the Pecos Valley alluvium. It should be noted that the ground water in this perched, water-bearing zone beneath the refinery is under some artesian pressure. The lithologic logs of the monitoring wells indicate that the soils in the aquitards above the unit are locally stained due to hydrocarbon spills within the boundaries of Navajo Refinery. High hydrocarbon or TDS content in samples from these wells is probably a result of local hydrocarbon contamination in isolated permeable zones, or artesian water in the well bore coming into contact with hydrocarbons in the soil.

The shallow, perched-water unit is locally discontinuous on the refinery site and no known drinking water wells are completed in this unit. It does not appear to be connected with any of the other aquifers, and it appears very unlikely that any possible hydrocarbon staining would affect any other ground water. The impermeable aquitards of the lower Seven Rivers Formation would prevent any significant migration towards major aquifers (Queen, San Andres).

SECTION 5.0

5.0 GROUND WATER MONITORING PROGRAM

A ground water monitoring network has been installed to investigate potential impacts to ground water from the effluent ditch and the evaporation pond. Seven well locations (Plate 2) near the ponds were selected on the basis of previous investigations of hydraulic gradients. Well locations along the conveyance ditch (Plate 1) were selected on the basis of soil types, local hydrogeology and logistical considerations. Wells were designed to immediately detect ground water contamination if leachates are migrating from the waste management units. Well design and location were discussed with NMEID technical personnel and an agreement on the number and design of wells was obtained prior to initiating site work.

5.1 GROUND WATER MONITORING SYSTEM

Navajo Refining Company has begun to monitor water levels in existing wells, and has installed nine new RCRA-style monitoring wells. A pump test was conducted for determination of the physical properties of the saturated zone. After an initial site investigation, two existing wells near the Pecos River were selected and equipped with automatic water-level recorders to collect data to assist in the investigation of the relationship between the valley-fill aquifer and the Pecos River. Records from these wells will be compared with USGS gaging-station records to determine if, and to what degree, ground water levels vary with river flow. Specific conductance of ground and river water may also be monitored during the proposed investigation. Water levels in selected existing and proposed wells will also be monitored on a monthly basis to determine if seasonal changes in the hydraulic gradient exist and the lateral extent of these changes.

Plates 1 and 2 show the locations of the new monitor wells (MW series). The 7 wells located adjacent to the evaporation ponds are situated such that there will always be at least 2 upgradient and 2 downgradient wells, regardless of seasonal changes in hydraulic gradient. There is only one available location for monitor wells along the conveyance ditch where wells may be emplaced between the ditch and Eagle Creek. This location is shown on Plate 1.

All new wells were constructed of 2.0 inch 304 stainless steel (Figure 5-1). This material has excellent strength and is essentially inert in ground water with the chemical characteristics observed in the Artesia area.

All wells have 10.0 foot screens, completed with the top of the sand pack and screen located 1 or 2 feet above the seasonal-high water table. Well bores were sealed with a bentonite-concrete grout and down-ward sloping concrete pads to protect the well heads (Figure 5-1).

All wells were installed by use of an air-rotary rig. All tools and well materials were thoroughly steam-cleaned prior to use and installation. Temporary casing was used to install a sand pack. Following installation, all wells were developed by pumping until produced waters were free of excessive silt and specific conductance and pH were stable. Approximately 120 to 180 gallons were pumped from all wells during development.

Well heads are secured with locking caps and protected by a steel guard casing. This ensures the physical safety of the well, and will prevent any contamination from surface sources. Well lithologic logs and completion diagrams for the MW series are presented in Appendix C.

On July 17 and 18, 1986 a pump test was conducted in the valley-fill aquifer adjacent to Pond #1. A 6-inch PVC well was installed for the pump test. Results of analysis of the pump test indicate a transmissivity of 0.0097 ft^2/sec, or 6240 gallons/day/ft^2. The specific yield is 0.20.

Data was recorded from the pumped well and from 2 piezometers and 1 existing observation well. Subsequent investigation indicated that the

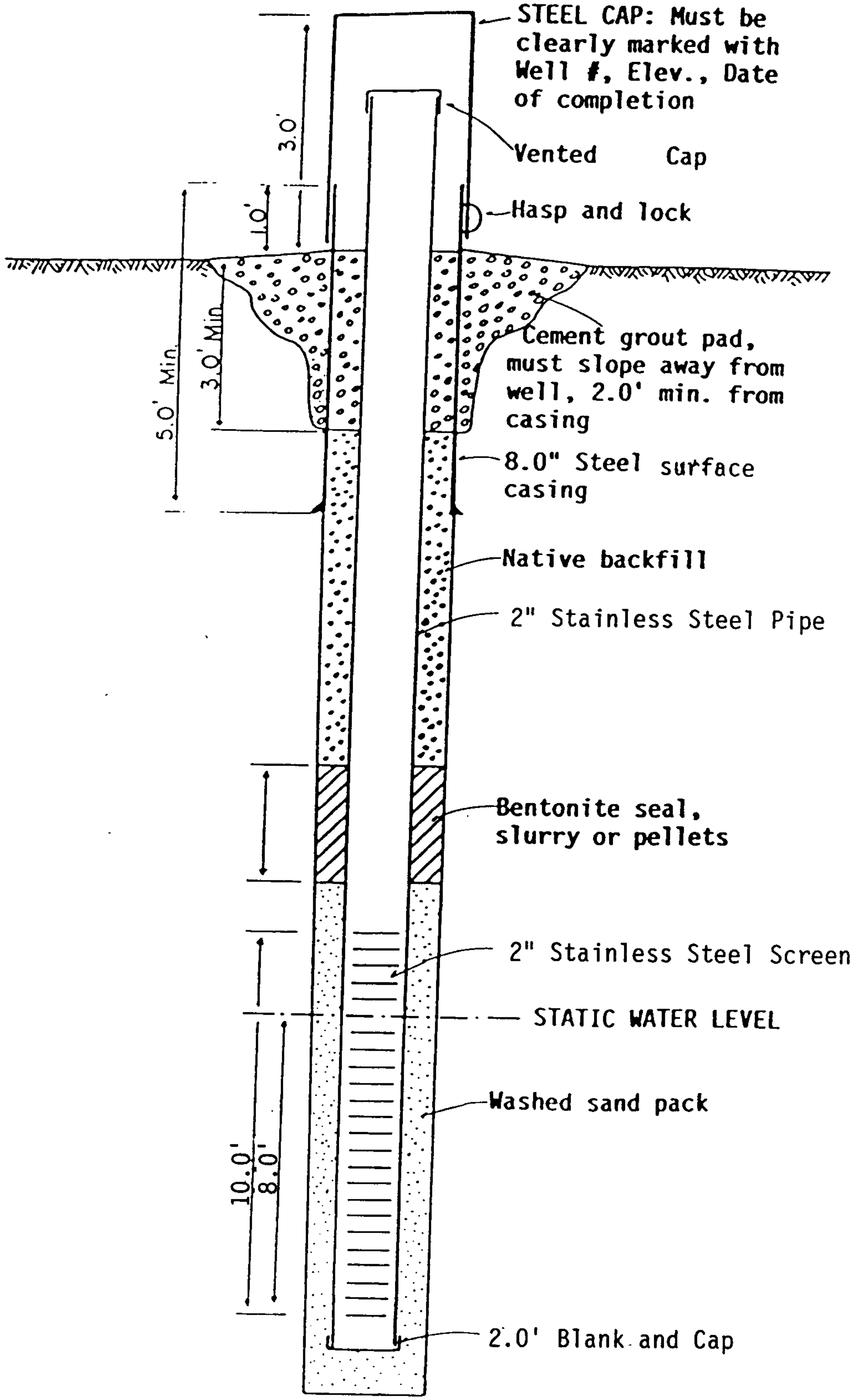


FIGURE 5-1
TYPICAL MONITOR WELL DESIGN

observation well (Navajo Well #13) may have an inefficient screen; data from this well was not used in the analysis.

Time-distance-drawdown data was analyzed according to methods described by Lohman (1972) which include corrections for partial penetration of water-table aquifers. Raw data, plots and calculations are included as Appendix D.

Pump discharge was monitored by a totalizing flow meter, and water levels were measured to the nearest 0.01 foot by an electronic water-level probe. Pump discharge was diverted to the evaporation ponds, located over 200 feet away from the pump test wells.

The calculated transmissivity of 6240 $g/d/ft^2$ is a reasonable value for silty sand ($1<K<10^4$ $g/d/ft^2$) or clean sand ($10<K<10^5$ $g/d/ft^2$; Freeze and Cherry, p. 29). The value for specific yield (0.20) is also reasonable for these materials.

5.2 GROUND WATER SAMPLING AND ANALYSIS

5.2.1 Sampling Equipment

The equipment that Navajo Refining Company will use in the field investigation for monitoring and collecting representative ground water samples is detailed in Table 5-1.

5.2.2 Sampling Techniques

5.2.2.1 Water Level Measurement

Prior to collecting any ground water samples, the depth to water in the well bore will be measured and recorded in the field log book. The procedures to be used in measuring water levels are as follows:

1. Plastic sheeting is placed around the well to protect sampling equipment from possible contamination.
2. If the casing cap is not vented, the well must be allowed to stand open for at least 10 minutes to equilibrate to atmospheric pressure.

TABLE 5-1

EQUIPMENT CHECKLIST

- 200 foot fiberglass, plastic or steel measuring tape with a weighted bottom
- electronic water-level indicator
- distilled water and wash bottles
- steam cleaner or methanol for cleansing
- paper towels or clean rags
- plastic sheeting
- bottom-filling stainless steel bailer
- Bennett, Model 180, submersible sampling pump driven by a Speedaire, Model 3Z869B, gasoline-powered air compressor
- graduated bucket
- hose to direct pump discharge away from the well
- sample containers with the appropriate volume of preservatives added to the containers by Rocky Mountain Analytical Laboratory
- waterproof marking pen
- pH meter
- thermometer
- field specific conductivity meter
- field sample log book
- pen
- ice and ice chest for samples
- sample analysis forms
- strapping tape and chain of custody seals

3. The electronic water-level indicator (sounder) or tape is cleaned with distilled water and dried with a clean paper towel, and coiled on the plastic sheet.

An electronic sounder is used in the following manner. When the sounder contacts ground water, a circuit is closed resulting in a "beep" from the sounder or a strong reading on an ammeter. The measurement is the depth to ground water. After determining the depth to water, the measuring device should be lowered to the bottom of the well, and the total depth (TD) below the casing top recorded.

5.2.2.2 Well Evacuation

The sampling pump (if used) will be steam cleaned and placed at the top of the water table (determined from electronic sounder) before well evacuation is begun. The pump is constructed of stainless steel, and is air-operated. Air contacts the ejected water, but is not released in the well bore. Wells also may be purged by bailing with a steam-cleaned stainless steel bailer or by a suction pump which has been properly cleaned. At least three casing volumes of standing water will always be removed from the well bore prior to collecting ground water samples. All samples will be collected by bailing with a stainless steel bailer. During bailing, the bailer will be slowly and carefully inserted into the well to prevent agitation of ground water. The following method may be used to calculate the volume of water which must be removed from the well prior to sampling.

The 2.0" (nominal) well-screen has a true inside diameter of 1.90". This corresponds to a casing volume of 0.02 cubic feet, or 0.15 gallons, per foot of water-filled casing. To calculate a 3-casing volume purge amount, use the formula:

[(depth to water) - (total depth)] x 0.15 gallons/foot x 3 = gallons to be purged

The exact amount to be purged will, or course, vary with the specific water level at the time of sampling. Wells smaller than 2 inch diameter may be used in the course of the investigation. During well evacuation, the temperature and specific conductance will be periodically measured to ensure these parameters have stabilized prior to sample collection.

5.2.2.3 Sample Collection, Preservation Field Analyses

Samples for pH, conductivity and temperature will be collected directly from the pump's discharge line following purging of a well. A 1500 ml glass flask which has been cleaned with laboratory soap, rinsed with distilled water and rinsed three times with well water will be filled for field determination of specific conductance, pH and temperature prior to collecting other samples. These values will be recorded in the log book and the sample will be discarded.

Ground water samples for inorganic and organic constituents will be collected with a bottom-filling stainless steel bailer that has been thoroughly steam cleaned, rinsed with acetone, and finally rinsed with distilled water. Samples for volatile organic constituents are placed in VOA glass containers (septum vials) and completely filled so that no head space or bubbles are present in the sample. Unfiltered samples will be collected from all sampling points. All samples will be appropriately containerized and preserved according to the specifications of Table 2-1. As each sample is collected, it will be logged, sealed and entered on a chain-of-custody form.

5.2.2.4 Analytical Protocols

Ground water samples collected on June 4, 1986 for inorganic and organic constituents were shipped to Rocky Mountain Analytical Laboratory for analysis. RMA will continue to provide analytical support for the remainder of the project.

Analytical parameters for the initial ground water monitoring samples consisted of volatile organic constituents (Table 5-2), semi-volatile compounds (Table 5-3) and heavy metals (Table 5-4). Samples were collected from three down-gradient wells and one upgradient well in the area of Pond #1 and from the two newly installed wells located between the waste conveyance ditch and Eagle Creek.

5.3 QUALITY ASSURANCE/QUALITY CONTROL

To assure reliable, precise and accurate analyses, splits of randomly-chosen ground water samples may be taken and sent to a second laboratory. Field blanks and equipment blanks may also be used to check on cross contamination in the field. Duplicate splits and blanks will be handled, containerized, labeled and shipped in exactly the same manner as all other samples. These QA/QC samples will be submitted to the laboratories in a "blind" manner; the laboratories will not know which samples are blanks or duplicates. These samples and the blanks will be analyzed for BTEX (benzene, toluene, ethyl benzene, xylenes).

If there are significant discrepancies between regular and QA/QC samples, Navajo may elect to re-sample selected wells. Field blanks were analyzed in the initial sampling but duplicate samples were not submitted for analysis.

TABLE 5-2
VOLATILE ORGANIC PARAMETERS*

Acetone
Chloromethane
Bromomethane
Vinyl chloride
Chloroethane
Methylene chloride
Trichlorofluoromethane
1,1-Dichloroethene
1,1-Dichloroethane
trans-1,2-Dichloroethene
Chloroform
1,2-Dichloroethane
1,1,1-Trichloroethane
Carbon tetrachloride
Bromodichloromethane
1,2-Dichloropropane
trans-1,3-Dichloropropene
Trichloroethene
Benzene
Dibromochloromethane
1,1,2-Trichloroethane
cis-1,3-Dichloropropene
2-Chloroethylvinyl ether
Bromoform
1,1,2,2-Tetrachloroethane
Tetrachloroethene
Toluene
Chlorobenzene
Ethyl benzene
1,3-Dichlorobenzene
1,2-Dichlorobenzene
1,4-Dichlorobenzene

*All Parameters Analyzed Using SW-846 Method 8240

TABLE 5-3
SEMI-VOLATILE ORGANIC PARAMETERS*

1,3-Dichlorobenzene
1,4-Dichlorobenzene
Hexachloroethane
Bis(2-chloroethyl) ether
1,2-Dichlorobenzene
Bis(2-chloroisopropyl) ether
N-Nitroso-di-n-propyl amine
Nitrobenzene
Hexachlorobutadiene
1,2,4-Trichlorobenzene
Isophorone
naphthalene
Bis(2-chloroethoxy) methane
Hexachlorocyclopentadiene
2-Chloronaphthalene
Acenaphthylene
Acenaphthene
Dimethyl phthalate
2,6-Dinitrotoluene
Fluorene
4-Chlorophenyl phenyl ether
2,4-Dinitrotoluene
Diethylphthalate
N-Nitrosodiphenylamine
Hexachlorobenzene
4-Bromophenyl phenyl ether
Phenanthrene
Anthracene
Dibutyl phthalate
Fluoranthene
Pyrene
Benzidine

*All parameters analyzed using SW-846 method 8250

TABLE 5-3 (Continued)

Butyl benzyl phthalate
Bis(2-ethylhexyl) phthalate
Chrysene
Benzo(a)anthracene
3,3'-Dichlorobenzidine
Di-n-octyl phthalate
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-c,d)pyrene
Dibenzo(a,h)anthracene
Benzo(ghi)perylene
N-Nitrosodimethyl amine
2-Chlorophenol
2-Nitrophenol
Phenol
2,4-Dimethylphenol
2,4-Dichlorophenol
2,4,6-Trichlorophenol
4-Chloro-3-methylphenol
2,4-Dinitrophenol
2-Methyl-4,6-dinitrophenol
Pentachlorophenol
4-Nitrophenol

TABLE 5-4
APPENDIX VIII METAL PARAMETERS

	SW-846 METHOD	EPA ICP METHOD
Antimony	7041	200.7
Arsenic	7060	200.7
Barium	7081	200.7
Beryllium	7091	200.7
Cadmium	7131	200.7
Calcium	N/A	200.7
Chromium	7191	200.7
Cobalt	N/A	200.7
Copper	7211	200.7
Iron	N/A	200.7
Lead	7421	200.7
Mercury	7470 & 7471	N/A
Nickel	7521	200.7
Potassium	N/A	200.7
Selenium	7740	200.7
Silver	7761	200.7
Sodium	N/A	200.7
Thallium	7841	200.7
Vanadium	7911	200.7
Zinc	7951	200.7

SECTION 6.0

6.0 GROUND WATER QUALITY ASSESSMENT AND CORRECTIVE ACTION

6.1 RESULTS OF INITIAL GROUND WATER SAMPLING

Chemical analyses of samples taken from the newly-installed wells adjacent to the evaporation ponds and the conveyance ditch and several other ground water monitoring points are presented in tabular form in Appendix E. Analysis of the results reveals several important characteristics of the aquifer:

- The total dissolved solids content of ground water in the area of the evaporation ponds is generally greater than 10,000 mg/l. Thus, this ground water is not suitable for domestic, irrigation or industrial use.
- Sodium, calcium and magnesium are the dominant cations and chloride and sulfate are the dominant anions in ground water.
- "Priority pollutant base/neutral organic compounds" (PAH's) were below detectable limits in ground water samples from selected wells.
- "Priority pollutant acid organics" (phenolic compounds) were below detectable limits in all wells except well 13 where 19 ppb of 2,4-Dimethylphenol was detected.
- Well 13 showed a significantly different total dissolved solids content than adjacent wells and a significantly different response in the test pumping. This suggests that this well may be poorly constructed and unsuitable for water quality monitoring.
- "Priority pollutant volatile organics" (GC/MS Scan) detected ethylbenzene in wells MW-6 and Navajo well #13. Acetone was also detected in MW-6; this suggests contamination of the sample from bailer cleaning or some other sampling or laboratory source.
- Using EPA method 602 for purgeable organics, toluene and ethylbenzene were detected in several wells near the ponds. These constituents were not detected in wells adjacent to the ditch.
- "Priority pollutant metals" were below established maximum concentration limits (40 CFR 264.94 and Appendix III of 40 CFR 265) except for arsenic which is slightly elevated in wells MW-3, MW-6 and Well #13.

6.2 GROUND WATER QUALITY ASSESSMENT PROGRAM

It is apparent from the results of the initial ground water sampling of wells in the pond area that a significant increase in hazardous constituents in downgradient wells is highly probable. Therefore, Navajo proposes to commence a phased investigation of the evaporation pond area which will be consistent with a ground water quality assessment program (40 CFR 265.93.d.) and item 15 of Exhibit A of the consent agreement.

Resampling of two ground water monitoring wells which were sampled in August is presently being conducted (MW-6 and MW-4). Samples will be split and sent to Rocky Mountain Analytical Laboratory and Assaigai Analytical Laboratory. EPA method 8020 will be employed to test for aromatic volatile organics in these wells. The program described below will commence within 20 days of confirmation of elevated levels of volatile organics in ground water and NMEID approval of the approach described below.

A ground water quality assessment program in the area of the conveyance ditch is not presently planned.

6.2.1 Phase I: Definition of Lateral Extent of Any Contamination

A shallow ground water sampling program near the ponds is planned to define the lateral extent of any organic contamination. Toluene and ethylbenzene have been detected in ground water near the evaporation ponds. Aromatic organic constituents are also present in pond sludges with concentrations ranging from 3.7 ppm (ortho plus para xylenes in the eastern portion of Pond #1) to 12 ppm (Toluene in the western portion of Pond #1). Using GC chromatography, these same constituents (BTEX) will be analyzed in the proposed ground water sampling program. Although other constituents were detected in pond sludges (e.g. PAH's) the mobility and solubility of the aromatic hydrocarbons coupled with their concentration in pond sludges make these species ideal in defining the geometry of any contaminant plume.

Ground water will be sampled in the following manner:

1) A fully steam cleaned steel drive-point piezometer (1 1/4 inch diameter) will be augered and/or driven to the top of the water table. These points are to be used as temporary sampling piezometers and may be removed after chemical analyses of the sample is complete and ground water elevations obtained.

2) Three casing volumes of fluid will be removed from the drive-point as described in Section 5.2.2.2.

3) If an offsite laboratory is employed, two forty milliliter septum vials will be filled for VOC analyses (BTEX) and one quart polyethylene container will be filled for specific conductance and/or TDS determination according to the protocols outlined in Section 5.2.2.3. If a mobile laboratory is employed (e.g., Tracer Research), the sampling and analytical protocol for BTEX analyses will be submitted prior to initiation of the program.

Because no fluids (air or water) are to be used in the emplacement of the drive points, the points will not be developed prior to initial sampling. The purpose of these points is to define the lateral extent of any hydrocarbon contamination (BTEX) which may be emanating from the pond. Some of these points may serve as permanent monitor wells for water level measurements.

It is anticipated that as many as 45 temporary drive points may be required to define the lateral extent of the plume. In order to minimize the number of points required, sampling and analysis will proceed immediately after installation of the points. Analytical data will be available within 24 hours of well installation or, if a mobile laboratory is employed, results will be immediately available. The analytical data will be evaluated in the field and the exact location and number of points will depend upon the analytical results.

The well point installation strategy is outlined below:

1) Points will be installed at 500 foot intervals down-gradient from the evaporation ponds, until samples from

two consecutive points show non-detectable levels of aromatic organic constituents.

2) A drive point will be installed midway between the point which shows detectable aromatic hydrocarbons and the first point which does not show volatile hydrocarbons.

3) Midway between the ponds and the first point which does not show aromatic hydrocarbons, a line of points, perpendicular to ground water flow will be installed on 500 foot centers.

4) Drive points will be installed midway between the point which shows detectable hydrocarbons and the point which does not show detectable hydrocarbons.

5) Drive points will be installed on 500 foot centers along a line perpendicular to ground water flow at the downgradient edge of hydrocarbon detection to insure that the downgradient extent of any contamination is accurately defined.

6) Depth to ground water will be measured in each drive point after sampling and 2 hours of "water level stabilization" after sampling.

Completion of this phase of the investigation will result in a series of concentration maps for each aromatic organic constituent and for conductance and a detailed potentiometric surface map. The concentration maps will define the lateral limits of any contaminated ground water. The potentiometric surface map will be employed in later work elements relating to the rate of migration of any contaminated ground water.

6.2.2 Phase II: Definition of Vertical Extent of Any Contamination

If a plume of contaminated ground water is present, at least two nested drive point clusters will be installed. One cluster will be located immediately adjacent to the evaporation ponds. A second drive point cluster will be installed in the area of highest concentration of aromatic hydrocarbons or about 500 feet downgradient from the ponds if the highest concentration of volatile hydrocarbons is adjacent to the ponds. If aromatic hydrocarbons are detected in samples of deeper ground water, a third piezometer cluster will be installed downgradient and outside of known hydrocarbon contamination.

The well point cluster will consist of 2 inch stainless steel (304) points with 2-3 foot screened openings at the water table, ten feet below the water table, twenty feet below the water table and, if necessary, at ten foot increments thereafter until two consecutive depth samples show that aromatic hydrocarbons are below detectable limits.

The stainless steel drive points may be employed as permanent RCRA-style ground water monitoring wells. GCL's experience with driven wells and gravel-packed wells in the area of the evaporation ponds shows that driven wells can be developed to the same degree as gravel-packed wells.

Samples for specific conductance and/or TDS will be obtained from each point. Depth to water will also be measured at each point.

6.3 CORRECTIVE ACTION

If the assessment program confirms that hazardous constituents are in ground water as a result of Navajo activities, Navajo will prepare and submit a plan for corrective action as negociated with NMEID.

SECTION 7.0

7.0 IMPLEMENTATION SCHEDULE

The following section outlines the schedule that Navajo Refining Company will follow in implementing the remaining field investigations and describes those milestones that will be achieved during its course. This schedule is detailed in Appendix A.

7.1 GROUND WATER SAMPLING AND ANALYSIS

The first ground water sampling activity was completed on August 6, 1986. Subsequent ground water monitoring of the pond area is presented in Section 6.0. On a monthly basis (November, December, January) the two RCRA-style wells near the conveyance ditch will be sampled and analyzed for those parameters detected in ground water in the evaporation pond area (arsenic, ethylbenzene, toluene, phenols).

If any of these compounds are detected in the monthly samples, a complete analysis exactly the same as that performed in August, 1986, will be initiated.

If the water quality assessment confirms the existence of ground water contamination in the pond area or along the wastewater conveyance ditch, Navajo Refining Company will prepare and submit a corrective program designated to remove, treat or prevent further migration of contaminants if necessary to prevent damage to human health and the environment.

SECTION 8.0

8.0 REPORTING

8.1 MONTHLY PROGRESS REPORTS

Navajo Refining Company will submit monthly progress reports on the 15th day of each month following installation of the ground water monitoring wells. Reports will detail the activities and milestones that have occurred during the previous calendar month.

8.2 FINAL PROJECT REPORT

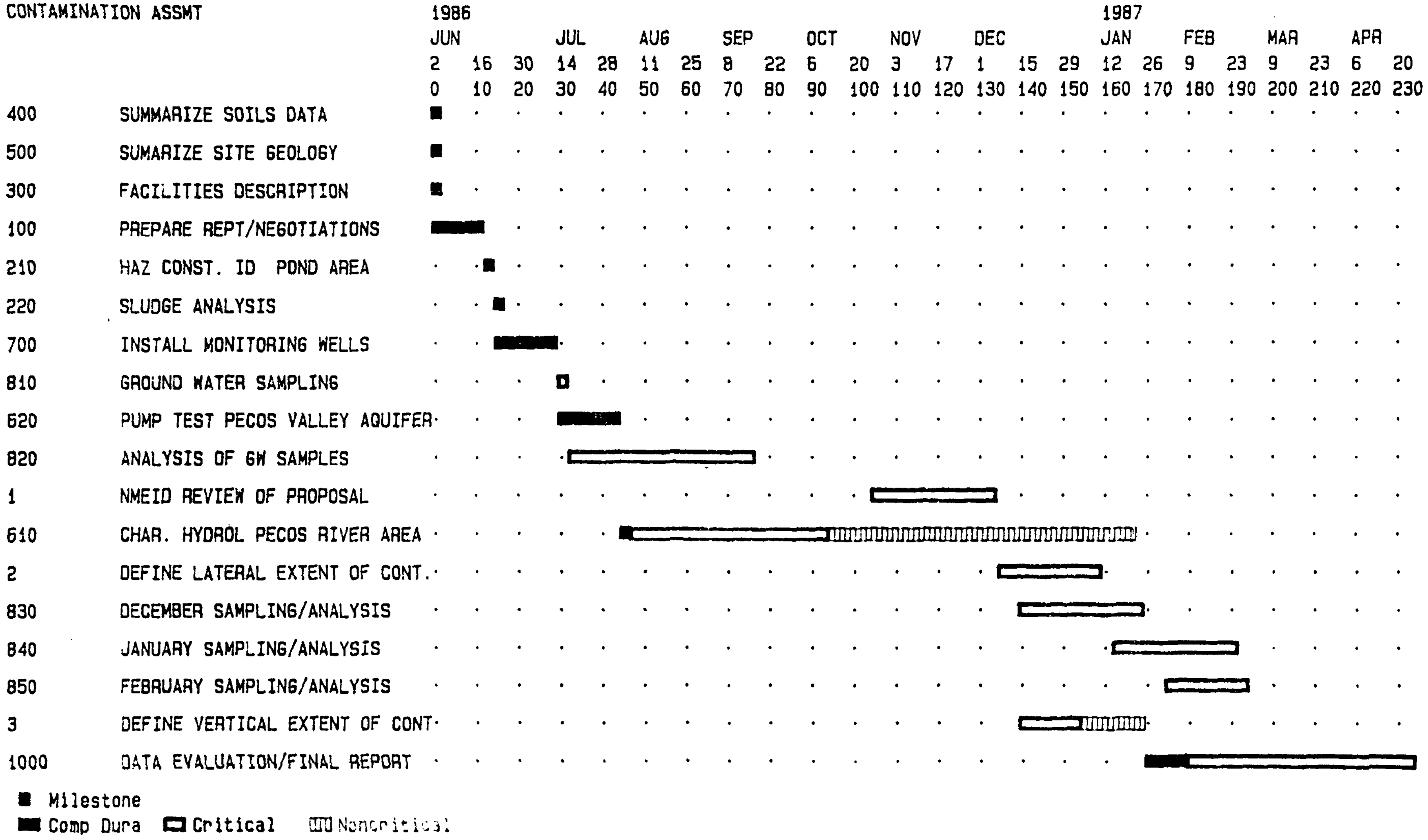
Navajo Refining Company will submit its Final Project Report within 45 days after completion of the field investigation. The Project Report will summarize the findings of the field investigation and present conclusions and recommendations based on analysis of all data collected.

APPENDIX A

APPENDIX A

NMEID RECOMMENDED WORK ITEMS FOR NAVAJO REFINERY CONTINUING RELEASE STUDY

GANTT CHART REPORT - Current Date: 10-22-86
Summarize Level: 11 Wildcard WBS: ????????? Resource Number: 0
CONTAMINATION ASSMT



NMEID RECOMMENDED WORK ITEMS FOR NAVAJO REFINERY CONTINUING RELEASE STUDY

[BRACKETED TEXT IS BASED UPON NOTES
FROM NAVAJO/GCL/NMEID MEETING]

(1) The location, and amounts of all chemical and other wastes identified by EPA as hazardous constituents in 40 Code of Federal Regulations part 261 which have been stored, treated or disposed of or which may be located on the site [Pond #1 and conveyance ditch]

(2) A description of the facility in which such waste/constituents were or are being stored, treated or disposed of, together with engineering plans, specifications and drawings, if any, of the facility used for such storage, treatment or disposal. If such plans, specifications or drawings are unavailable, please submit any other information available regarding the existence and characteristics of liners, leachate collection systems, or other waste containment systems [Short narrative with any plans and specifications]

(3) The manner in which such waste/constituents were stored, treated or disposed of, including whether all or a part of such waste/ constituents were or are containerized or non-containerized and the depth of burial of any waste [Short narrative]

(4) A determination of soils depth, type, characteristics and areal distribution [Use existing SCS data, class I survey if available]

(5) Determination of horizontal and vertical permeabilities of soils at the site [Use existing SCS data].

(6) Definition of location, type, transmissivity, bedding, structure and other characteristics of bedrock and/or other confining strata [Based upon existing data]

(7) Determination of strike and dip of bedrock; and location and attitude of any faults [Available geologic maps]

(8) Determination of direction and velocity of ground water flow in all water-bearing zones in an area likely to be affected by migration of constituents from the site, considering soils and bedrock characteristics, and the location of aquifers most likely to be affected which are or may be a source of public or private water supply [Site study and pump test]

(9) Determination of areas of discharge and recharge for ground water in the area likely to be affected by migration of constituents from the site [Site study]

(10) Determination of interaction between ground water and Pecos River [Monitor water levels in wells and river]

(11) Establishment of a network of monitoring wells, including recommendations as to the location, depth, and construction thereof, designed to monitor ground water elevations and water quality [By June 30, 1985]

(12) A sampling and analysis program for monitoring ground water, both on-site and off-site, which describes frequency of sampling and sampling and analytical procedures

(13) A proposed schedule for the implementation of the items set forth above

(14) The means and frequency of reporting to NMEID the implementation of the items set forth above, and the results of the sampling, analysis and monitoring program as the same may be approved

(15) Proposed plan to define contaminant plume, if one exists

(16) Proposed corrective action, if necessary

APPENDIX B

APPENDIX B

SAMPLE DESCRIPTION INFORMATION

I. INTRODUCTION

On June 6, 1986, Rocky Mountain Analytical Laboratory received three sludge samples from Navajo Refinery. These samples were collected by GeoScience. The analyses performed on these samples were for the refinery Appendix VIII constituents (metals and organics), plus additional parameters.

The analytical parameters selected were based on recent communication with EPA concerning RCRA monitoring requirements for petroleum companies. The parameters selected were based on a subset of Appendix VIII hazardous constituents commonly referred to as the "Skinner" list. Communications from EPA in late 1984 contained various versions of this list. During this time RMAL, under contract to the American Petroleum Institute, performed several studies evaluating analytical methods proposed for measuring the constituents in these various lists. Due in part to efforts by RMAL and others, the EPA in early 1985 revised this list. The documents which were used by RMAL in defining the analytical parameters are listed in a bibliography at the end of this report. This list, as revised, consisted of 12 metals and 46 organic compounds and is presented in Table 1. The organic compounds are further subdivided into volatile and semivolatile (extractable) compounds.

All samples were shipped by air freight to RMAL's Denver, Colorado laboratory. Each sample was assigned a unique RMAL sample number as shown in the enclosed Sample Description Information sheet. These sample numbers were used throughout the project to track and control the analytical work and are used in this document for reporting the results from each analyses.

TABLE 1. APPENDIX VIII HAZARDOUS CONSTITUENT SUBSET FOR PETROLEUM REFINERY STUDIES*

Metals

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Cobalt
- Lead
- Mercury
- Nickel
- Selenium
- Silver
- Vanadium

Volatile Organics

- Benzene
- Carbon Disulfide
- Chlorobenzene
- Chloroform
- 1,2-Dibromoethane
- 1,2-Dichloroethane
- 1,4-Dioxane
- Methyl ethyl ketone
- Styrene
- Ethyl Benzene
- Toluene
- Xylenes
  - Xylenes, m
  - Xylenes, o & p

Base/Neutral Organics

- Anthracene
- Benz(a)anthracene
- Benzo(b)fluoranthene

Base/Neutral Organics (Cont.)

- Benzo(j)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Bis(2-ethylhexyl)phthalate
- Butyl benzyl phthalate
- Chrysene
- Dibenz(a,h)acridine
- Dibenz(a,h)anthracene
- Di-n-butyl phthalate
- Dichlorobenzenes
  - o-Dichlorobenzene
  - m-Dichlorobenzene
  - p-Dichlorobenzene
- Diethyl phthalate
- 7,12-Dimethylbenz(a)anthracene
- Dimethyl phthalate
- Di-n-octyl phthalate
- Fluoranthene
- Indene
- Methyl chrysene
- 1-Methylnaphthalene
- Naphthalene
- Phenanthrene
- Pyrene
- Pyridine
- Quinoline

Acid Organics

- Benzenethiol
- Cresols
  - o-Cresol
  - p&m-Cresol
- 2,4-Dimethylphenol
- 2,4-Dinitrophenol
- 4-Nitrophenol
- Phenol

---

*"Petitions to Delist Hazardous Wastes, A Guidance Manual," EPA/530-SW-85-003, April, 1985.

SAMPLE DESCRIPTION INFORMATION

for

GeoScience Consultants

RMA Sample No.	Sample Description	Sample Type	Date Sampled	Date Received
61555-01	8606041350	Sludge	06/04/86	06/06/86
61555-02	8606041625	Sludge	06/04/86	06/06/86
61555-03	8606041715	Sludge	06/04/86	06/06/86

July 9, 1986

FOR APPENDIX B

GCL Note: Sample 8606041350 taken from the east pond area

Sample 8606041625 taken from the middle pond area

Sample 8606041715 taken from west pond area

Pages 4 and 8 of laboratory report to be submitted in final draft

II. RESULTS

The analytical results are presented in the data tables in this section. The data are organized into the tables described below:

- Metals,
- Volatile Organics,
- Base/Neutral Organics, and
- Acid Organics.

For the metals tables, the result and detection limit is presented for each sample. The term ND is used to indicate the parameter was not detected at the detection limit shown.

The term BDL (Below Detection Limit) is used in the organic results tables to indicate that the compound is not present at the detection limit shown. The detection limits for the Appendix VIII organic compounds were obtained from a study of the analytical methods performed by RMAL under contract to the American Petroleum Institute (API)[1]. Analytical standards are not available for three compounds. These compounds cannot be measured; they have been listed in the results tables and have been footnoted to show that standards were not available.

As explained in more detail in the analytical methodology section, the samples analyzed for volatile organics were screened prior to analysis in order to optimize the detection limit for each sample and minimize instrumental problems associated with analyzing samples containing relatively high concentrations. This process resulted in high dilutions for several samples containing high concentrations of the target compounds. For these samples, the detection limits for compounds not detected are proportionately high. Also, the compounds which were reported close to (less than two times) the detection limits may be suspect.

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[1] "Recovery and Detection Limits of Organic Compounds in Petroleum Refinery Wastes", January 25, 1985.

ANALYTICAL RESULTS

for

GeoScience Consultants

METALS

Parameter	Units	61555-01		61555-02		61555-03	
Antimony	mg/kg	ND	(0.4)	ND	(0.4)	ND	(0.4)
Arsenic	mg/kg	14	(0.4)	15	(2.)	11	(2.)
Barium	mg/kg	96	(0.5)	92	(1)	75	(1)
Beryllium	mg/kg	0.6	(0.1)	0.4	(0.2)	0.4	(0.2)
Cadmium	mg/kg	ND	(0.5)	ND	(1)	ND	(1)
Chromium	mg/kg	250	(0.5)	410	(1)	820	(1)
Cobalt	mg/kg	3.8	(0.3)	3.6	(0.6)	4.0	(0.6)
Copper	mg/kg	310	(0.3)	360	(0.6)	89	(0.6)
Lead	mg/kg	38	(2)	61	(4)	31	(4)
Mercury	mg/kg	0.52	(0.05)	0.38	(0.05)	0.06	(0.05)
Nickel	mg/kg	9.4	(1)	11	(2)	7.5	(2)
Selenium	mg/kg	4	(1)	ND	(0.4)	ND	(2)
Silver	mg/kg	ND	(0.3)	ND	(0.6)	ND	(0.6)
Thallium	mg/kg	ND	(2)	ND	(0.8)	ND	(4)
Vanadium	mg/kg	18	(0.2)	15	(0.4)	12	(0.4)
Zinc	mg/kg	62	(0.4)	190	(0.8)	330	(0.8)

ND = Not detected.   Detection limits in parentheses.

ANALYTICAL RESULTS

for

GeoScience Consultants

VOLATILE ORGANICS

Refinery Organics	Units	61555-01		61555-02		61555-03	
Benzene	ug/kg	BDL	(1500)	BDL	(2000)	2000	(2000)
Carbon disulfide	ug/kg	BDL	(1500)	BDL	(2000)	BDL	(2000)
Chlorobenzene	ug/kg	BDL	(1500)	BDL	(2000)	BDL	(2000)
Chloroform	ug/kg	BDL	(1500)	BDL	(2000)	BDL	(2000)
1,2-Dibromoethane	ug/kg	BDL	(6000)	BDL	(8000)	BDL	(8000)
1,2-Dichloroethane	ug/kg	BDL	(1500)	BDL	(2000)	BDL	(2000)
1,4-Dioxane	ug/kg	BDL	(30000)	BDL	(40000)	BDL	(40000)
Methyl ethyl ketone	ug/kg	BDL	(15000)	BDL	(20000)	BDL	(20000)
Styrene	ug/kg	BDL	(1500)	BDL	(2000)	BDL	(2000)
Ethyl Benzene	ug/kg	6700	(1500)	4500	(2000)	8700	(2000)
Toluene	ug/kg	3900	(1500)	5600	(2000)	12000	(2000)
Xylene, m	ug/kg	5100	(1500)	5400	(2000)	10000	(2000)
Xylenes,o & p	ug/kg	3700	(1500)	4500	(2000)	9100	(2000)

Additional Compounds							
Acetone	ug/kg	BDL	(15000)	BDL	(20000)	BDL	(20000)
Methylene chloride	ug/kg	BDL	(3000)	BDL	(4000)	BDL	(4000)
Tetrachloroethene	ug/kg	BDL	(1500)	BDL	(2000)	BDL	(2000)

BDL = Below detection limit.   Detection limits in parentheses.

ANALYTICAL RESULTS
for
GeoScience Consultants

BASE/NEUTRAL ORGANICS

Refinery Organics	Units	61555-01		61555-02		61555-03	
Anthracene	ug/kg	5300	(3200)	BDL	(11000)	8500	(8000)
Benzo(a)anthracene	ug/kg	4600	(3200)	BDL	(11000)	13000	(8000)
Benzo(b)fluoranthene	ug/kg	BDL	(3200)	BDL	(11000)	9200	(8000)
Benzo(j)fluoranthene	ug/kg	-	-	-	-	-	-
Benzo(k)fluoranthene	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Benzo(a)pyrene	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Bis(2-ethylhexyl)phthalate	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Butylbenzyl phthalate	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Chrysene	ug/kg	8500	(3200)	27000	(11000)	30000	(8000)
Dibenz(a,h)acridine*	ug/kg	-	-	-	-	-	-
Dibenz(a,h)anthracene	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Di-n-butyl phthalate	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
o-Dichlorobenzene	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
m-Dichlorobenzene	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
p-Dichlorobenzene	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Diethyl phthalate	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
7,12-Dimethylbenz(a)anthrac	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Dimethyl phthalate	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Di-n-octyl phthalate	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Fluoranthene	ug/kg	7800	(3200)	24000	(11000)	16000	(8000)
Indene	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Methyl chrysene*	ug/kg	-	-	-	-	-	-
1-Methylnaphthalene	ug/kg	34000	(3200)	39000	(11000)	59000	(8000)
Naphthalene	ug/kg	4200	(3200)	BDL	(11000)	8100	(8000)
Phenanthrene	ug/kg	74000	(3200)	120000	(11000)	110000	(8000)
Pyrene	ug/kg	14000	(3200)	35000	(11000)	33000	(8000)
Pyridine**	ug/kg	ND	-	ND	-	ND	-
Quinoline	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Additional Compounds							
Acenaphthene	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Acenaphthylene	ug/kg	BDL	(3200)	BDL	(11000)	BDL	(8000)
Fluorene	ug/kg	17000	(3200)	27000	(11000)	21000	(8000)

BDL = Below detection limit. ND = Not detected. Detection limits in parentheses.
*No analytical standard available. **Not recovered using Method 8270.

ANALYTICAL RESULTS

for

GeoScience Consultants

ACID ORGANICS

Parameter	Units	61555-01		61555-02		61555-03	
Benzenethiol**	ug/kg	ND	-	ND	-	ND	-
o-Cresol	ug/kg	4900	(3200)	5500	(4000)	7700	(1600)
p & m-Cresol	ug/kg	BDL	(3200)	5800	(4000)	10000	(1600)
2,4-Dimethylphenol	ug/kg	BDL	(3200)	BDL	(4000)	4100	(1600)
2,4-Dinitrophenol	ug/kg	BDL	(16000)	BDL	(20000)	BDL	(8000)
4-Nitrophenol	ug/kg	BDL	(16000)	BDL	(20000)	BDL	(8000)
Phenol	ug/kg	4400	(3200)	5200	(4000)	12000	(1600)

BDL = Below detection limit. Detection limits in parentheses.
**Not recovered using Method 8270.

QUALITY ASSURANCE DATA FOR SURROGATE RECOVERIES

GeoScience Consultants

Parameters	% Recovery		
	61555-01	61555-02	61555-03
Volatiles-QC Limit[a]			
1,2-Dichloroethane-D_4	106	100	99
Toluene	101	103	102
Bromofluorobenzene(BFB)	128	99	101
Base/Neutral Compounds-QC Limits: 50-120%[b]			
Nitrobenzene-D_5	90	84	96
2-Fluorobiphenyl	90	88	94
Terphenyl-D_{14}	95	92	99
Pyrene-D_{10}	80	31*	18*
Acids-QC limits: 40-115%[b]			
Phenol-D_5	59	44	56
2-Fluorophenol	70	53	62
2,4,6-Tribromophenol	100	83	86

Notes

*Value outside recovery limit in Refinery Handbook.
a = QC limits not established; EPA Las Vegas limits for these surrogates in soil samples range from 70-121%.
b = EPA Las Vegas limits for these surrogates in soil samples range from 18-137%.

III. ANALYTICAL METHODOLOGY

The methods for the metals and organic compounds were derived from three sources of EPA methods, 1) the methods promulgated in 40 CFR 136 for priority pollutants, 2) the methods published in SW-846 and 3) methods developed by the EPA-EMSL/LV for Superfund investigations, as well as several documents published by the EPA and RMAL in 1984 and 1985. These methods all use the same generic technology as summarized below:

- Metals, acid digestion followed by analysis by ICP supported by graphite furnace AA,
- Volatile Organics, purge and trap GC/MS, and
- Semivolatile (base/neutral and acid) organics, solvent extraction followed by capillary column GC/MS.

The EPA (40 CFR 136, SW-846 and Superfund) methods were, to a large degree, developed and validated to determine the priority pollutants in a broad spectrum of environmental samples. Between October 1983 and July 1985 the EPA released three methods manuals and a "Guidance Manual" which were compendiums of modified SW-846 methods specifically adapted for the analysis of Appendix VIII constituents in petroleum refining wastes (not water samples). The most useful of these documents was an October, 1984 draft methods manual which unfortunately was never formally distributed by EPA, apparently in order to avoid a conflict with a proposed rule in the October 1, 1984 Federal Register. However, even this document (as discussed by an RMAL review for API in December, 1984) lacked many important details that are critical to the successful analysis of environmental samples impacted by petroleum refineries.

Thus, although the methods used by RMAL were based on these various EPA documents, the actual details of each method were implemented by RMAL as explained in more detail below. The various documents which were used to establish RMAL's approach are listed in a bibliography. The discussion below references method numbers in SW-846. However, it should be noted that several different versions of these methods are cited in the various EPA documents. In addition to the documents listed in the bibliography, RMAL has continued a dialogue through phone conversations and meetings with EPA/OSW to ensure that this approach is in line with the Agency's expectations. Much of RMAL's approach is being incorporated in pending Agency promulgations.

Total Metals

Metals were determined using inductively coupled plasma-atomic emission spectroscopy (ICP) for barium, beryllium, cadmium, chromium, cobalt, lead, nickel, silver, vanadium and zinc (Method 6010). Graphite furnace atomic absorption (AA) spectroscopy was used for the determinations of antimony (Method 7041), arsenic (Method 7060), selenium (Method 7740) and thallium (Method 7841). Cold vapor atomic absorption spectroscopy was used to determine mercury (Method 7470). Prior to analysis, the samples were prepared using Method 3050.

The ICP was preprogrammed to perform off peak background correction on both the high and low wavelength sides of the analytical peaks of interest as appropriate. One hundred interelemental corrections were also automatically applied to the analysis. A matrix spike is analyzed as a quality control check for the ICP analyses. Every sample analyzed by graphite furnace AA was spiked with the metal of interest and reanalyzed to check for possible interferences.

Volatile Organics

Volatile organic compounds were determined by purge and trap gas chromatography/mass spectrometry (GC/MS) using Method 8240 with the appropriate sample introduction procedure. The appropriate procedure was determined using a screening procedure consisting of a liquid-liquid extraction with hexadecane followed by direct injection of an aliquot of the extract into a gas chromatograph with flame ionization detection (GC/FID). All volatile samples were screened in this way before GC/MS analysis. The GC/FID screening results were evaluated to determine the amount of sample to use that provides the lowest detection limits possible without overloading the GC/MS system. Samples containing low levels of organics were analyzed using a modification developed by EPA Region X and EMSL/Cincinnati for soil and sediment samples containing low levels of volatile organics. The procedure is quite similar to Method 624 except that a water slurry of the solid material is purged. This procedure is used by the EPA in their contract lab program for Superfund analyses. Samples containing higher levels of organic species were analyzed using the sample introduction technique described in Method 8240. This procedure was used as written except that tetraglyme (tetraethylene glycol dimethyl ether) was used instead of polyethylene glycol as the extracting agent before the purge and trap procedure, as recommended in the July, 1985 Refinery Guidance Manual.

Semivolatile Organics

Semivolatile organics were determined by capillary column GC/MS using SW-846 Method 8270. Soil samples were extracted using SW-846 Sonication Method 3550. After extraction, the samples were subjected to Method 3530 to separate the extract into acidic and basic fractions. The basic fraction was then cleaned up using Method 3570 to generate aliphatic and aromatic fractions. GC/MS analyses were then performed on the acidic and aromatic fractions.

Identification and quantitation of the target compounds determined by GC/MS were performed according to the process described in Methods 8240 and 8270. In summary, this process has the following features:

- Multipoint calibration for each compound to establish instrument response using multiple internal standards,
- Identification of compounds using a computerized reverse search with selected key fragment ions, and
- Quantitation using the previously determined response factors.

QUALITY CONTROL

For refinery waste sample analyses quality control analyses consist of the following activities:

- multipoint standard calibration,
- analysis of blanks,
- analysis of spiked and duplicate samples,
- analysis of a standard reference materials,
- daily calibration, including mass spectrometer tuning checks (BFB and DFTPP), where appropriate, and
- addition of surrogate spikes into each sample for GC/MS analyses.

More specific information about these activities is presented in Table 2. The relevant quality control data generated on this project are presented in the enclosed QC tables.

TABLE 2. SUMMARY OF QC ACTIVITIES PERFORMED FOR REFINERY SAMPLES

for

GeoScience Consultants

Parameter Group	QC Activity	Frequency
Metals and Inorganic parameters	Duplicate Sample	5%
Metals and Inorganic parameters	Spike Sample	5%
Volatile Organics	Surrogate Spikes	Each sample
Volatile Organics	Blank Analysis	Daily
Base/Neutral Organics	Surrogate Spikes	Each sample
Base/Neutral Organics	Duplicate Analysis	10%
Base/Neutral Organics	Blank Analysis	10%
Acid Organics	Surrogate Spikes	Each sample
Acid Organics	Duplicate Analysis	10%
Acid Organics	Blank Analysis	10%
Volatile Aromatics	Duplicate Analyses	10%

V. BIBLIOGRAPHY

A. Documents Pertaining to Appendix VIII Constituents

1) January, 1984 letter form Myles Morse pertaining to delisting petitions as well as land treatment demonstrations, including sampling procedures and data requirements.

2) March, 1984 letter to delisting petitioners from Barbara Bush revising target parameters.

3) April, 1984 memo from John Skinner to Permit Branch Chiefs concerning land treatment containing target parameters and analytical methods.

4) May, 1984 memo from John Skinner clarifying previous memo.

5) September, 1984 letter to Petitioners from Barbara Bush distributing Refinery Handbook.

6) November, 1984 letter from Eileen Claussen to all delisting petitioners describing new RCRA requirements.

7) May 3, 1985 RMAL Memo.

8) January 8, 1985 RMAL letter to Eileen Claussen, EPA-OSW.

B. Documents Pertaining to Analytical Methods

1) "Handbook for the Analysis of Petroleum Refinery Residuals and Waste", October, 1984 - prepared by Radian Corporation for EPA/OSW.

2) "Evaluation of the Applicability of the SW-846 Manual To Support All RCRA Subtitle C Testing", December 20, 1984 - prepared by Rocky Mountain Analytical Laboratory for API.

3) "Comments on the 'Handbook for the Analysis of Petroleum Refinery Residuals and Waste, October, 1984'", December 12, 1984 - prepared by Rocky Mountain Analytical Laboratory for API.

4) "Comments on the 'Handbook for the Analysis of Petroleum Refinery Residuals and Waste, April 2, 1984", August 15, 1984 - prepared by Rocky Mountain Analytical Laboratory for API.

5) "Handbook for the Analysis of Petroleum Refinery Residuals and Waste", April 2, 1984 - prepared by S-Cubed for EPA/OSW.

6) EPA document "Guidance for the Analysis of Refinery Wastes", July 5, 1985.

7) "Recovery and Detection Limits of Organic Compounds in Petroleum Refinery Wastes", January 25, 1985.

8) SW-846 - "Test Methods for Evaluating Solid Waste, Physical Chemical Methods" USEPA, 2nd Edition, 1982.

9) 40CFR136 - "Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act."

Report of Chemical Analysis

Consulting Geotechnical, Materials and Environmental Engineers
Geologists, Scientists and Chemists

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To: Geoscience Consultants, Ltd.
500 Copper Avenue N.W., Suite 325
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Attn: Mr. Trent A. Thomas

Project No: 686-036
Date Received: 6/06/86
Date Reported: 7/18/86
Submitted By: Mr. Thomas, GCL

Sample Description/Code: 8606041715, Bottom Sludge, Pond No. 1, Navajo Refinery, R-KCI 6-10143-1

SUMMARY OF ANALYSIS

Determination	Analytical Method	Results	Miscellaneous
Volatile Organics	EPA 624[1]	See Attached	Aqueous Phase
Acid Extractables	EPA 625[1]	See Attached	Aqueous Phase
Solids Content	EPA 160.3[2]	86.8 % wt	
Arsenic	EPA 7060[3]	11.2 mg/kg	Total[4]
Barium	EPA 7080	52.0 mg/kg	Total
Beryllium	EPA 7090	0.46 mg/kg	Total
Cadmium	EPA 7130	0.46 mg/kg	Total
Chromium	EPA 7190	636 mg/kg	Total

Special Comments:
1. Federal Register, Vol. 49, October, 1984.
2. EPA 600/4-79-020, March, 1983.
3. EPA SW-846, April, 1984.
4. The metal contents are on dry weight basis of the sludge sample.

Raba-Kistner Consultants, Inc.

by Francis Y. Huang
Francis Y. Huang, Ph.D., CPC

Report of Chemical Analysis

Consulting Geotechnical, Materials and Environmental Engineers
Geologists, Scientists and Chemists

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Attn: Mr. Trent A. Thomas

Project No: 686-036
Date Received: 6/06/86
Date Reported: 7/18/86
Submitted By: Mr. Thomas, GCL

Sample Description/Code: 8606041715, Bottom Sludge, Pond No. 1, Navajo Refinery, R-KCI 6-10143-1

SUMMARY OF ANALYSIS

Determination	Analytical Method	Results	Miscellaneous
Lead	EPA 7420	37.0 mg/kg	Total
Mercury	EPA 7471	0.06 mg/kg	Total
Silver	EPA 7760	0.70 mg/kg	Total
Zinc	EPA 7950	22.9 mg/kg	Total

Special Comments:

Raba-Kistner Consultants, Inc.
by Francis Y. Huang
Francis Y. Huang, Ph.D., CPC

Austin / El Paso / San Antonio

Project No. 686-036
R-KCI Lab No. 6-10143-1

(PURGEABLES)
(EPA Method 624)

Compound	Concentration (ug/L)	Method Detection Limits (ug/L)
Chloromethane	N.D.	5.0
Bromomethane	N.D.	5.0
Vinyl Chloride	N.D.	10.0
Chloroethane	N.D.	5.0
Methylene Chloride	N.D.	2.8
Trichlorofluoromethane	N.D.	5.0
1,1-Dichloroethene	N.D	2.8
1,1-Dichloroethane	N.D.	4.7
Trans-1,2-Dichloroethene	N.D.	1.6
Chloroform	N.D.	1.6
1,2-Dichloroethane	N.D.	2.8
1,1,1-Trichloroethane	N.D.	3.8
Carbon Tetrachloride	N.D.	2.8
Bromodichloromethane	N.D.	2.2
1,2-Dichloropropane	N.D.	6.0
Trans-1,3-Dichloropropene	N.D.	5.0
Trichloroethene	N.D	1.9
Dibromochloromethane	N.D.	3.1
1,1,2-Trichloroethane	N.D	5.0
cis-1,3-Dichloropropene	N.D.	5.0
Benzene	11.8	4.4
2-Chloroethylvinyl Ether	N.D.	5.0
Bromoform	N.D.	4.7
1,1,2,2-Tetrachloroethane	N.D.	6.9
Tetrachloroethene	N.D	4.1
Toluene	72.4	6.0
Chlorobenzene	N.D.	6.0
Ethylbenzene	N.D.	7.2
Xylenes	N.D.	5.0

N.D. = Not Detected

Note: Aliphate hydrocarbons were found in the sample.

Raba-Kistner Consultants, Inc.

by Francis Y. Huang

Francis Y. Huang, Ph.D., CPC

Project No. 686-036
R-KCI Lab No. 6-10143-1

ACID EXTRACTABLES
(EPA METHOD 625)

Compound	Concentration (ug/L)	Method Detection Limits (ug/L)
4-Chloro-3-Methylphenol	N.D.	3.0
2-Chlorophenol	N.D.	3.3
2,4-Dichlorophenol	N.D.	2.7
2,4-Dimethylphenol	N.D.	2.7
2,4-Dinitrophenol	N.D.	20.0
2-Methyl-4,6-Dinitrophenol	N.D.	10.0
2-Nitrophenol	N.D.	3.6
4-Nitrophenol	N.D.	2.4
Pentachlorophenol	N.D.	3.6
Phenol	N.D.	1.5
2,4,6-Trichlorophenol	N.D.	2.7

N.D. = Not Detected

Raba-Kistner Consultants, Inc.

by Francis Y. Huang
Francis Y. Huang, Ph.D., CPC

APPENDIX C

APPENDIX C

MW SERIES WELL LITHOLOGIC LOGS AND COMPLETION DIAGRAMS

GCL

WELL LOGGING FORM

Page 1 of 1

Client NAVAJO REFINERY Well Number MW-1

1/4 1/4 1/4 1/4 S 12 T 17S R 26E State NEW MEXICO

County EDDY Contractor LARRY'S DRILLING

Spud Date 6-18-86 Completion Date 6-18-86

Logs Run LITHOLOGY Logged By SELKE

Elevation Spud In (Fm.)

Remarks Steam cleaned rig and tools prior to drilling- drill w/ air rotary and temp. casing

DEPTH	LITHO.	RECOV.	RUN	FROM	TO	SAMPLE DEPTH	REMARKS
0	▤						0-20' v.fn.gr., brown silty clay v. tight formation- drilled borehole to 40'- 1hr. to recover
5	▤						
10	▤						
15	▤						
20							
25							
30							
35							
40							
45							

Sand

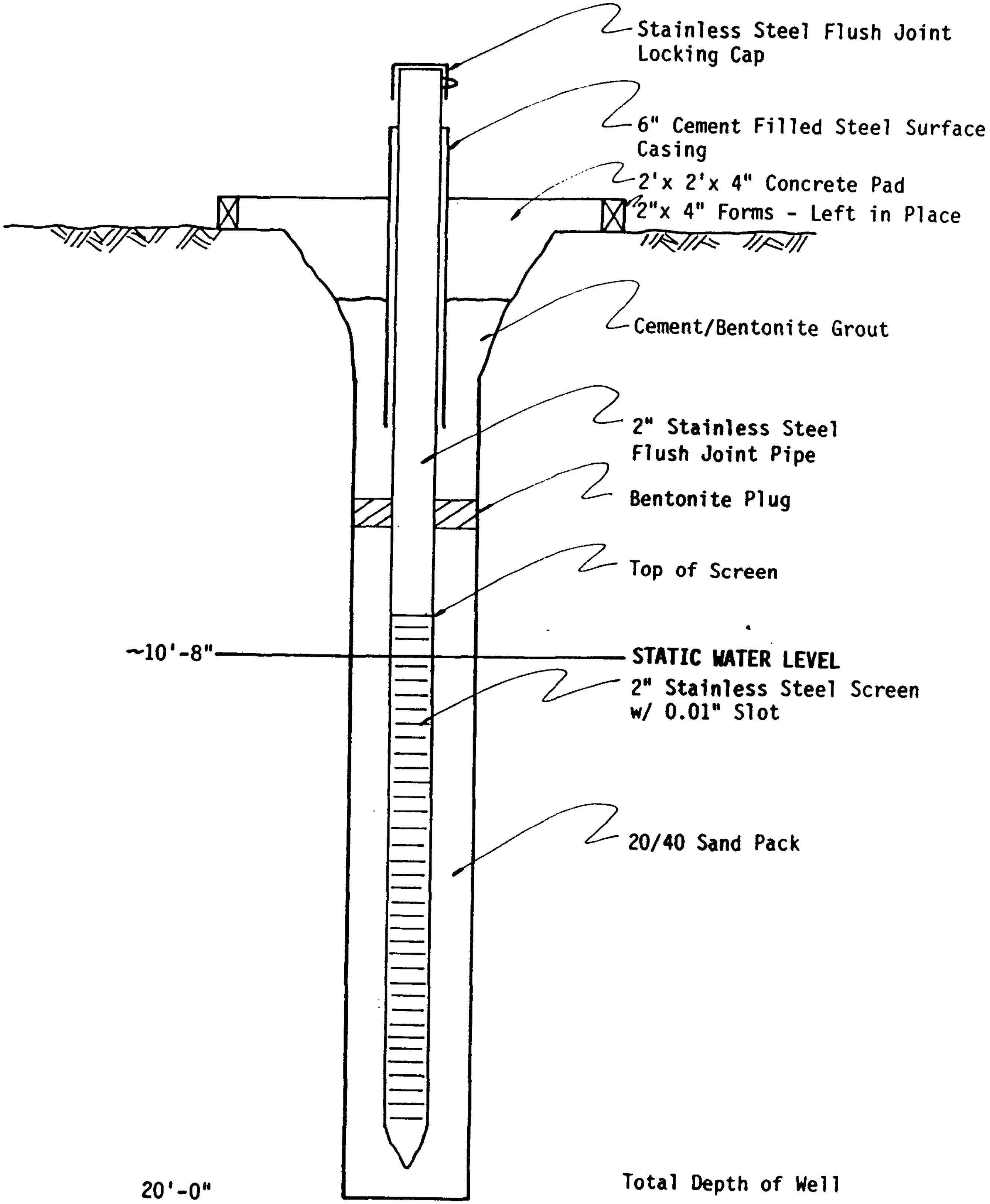
Silt

Clay

Silty Clay

Clayey Silt

Gravel



WELL COMPLETION DIAGRAM
FOR MW-1

GCL

WELL LOGGING FORM

Page 1 of 1

Client NAVAJO REFINERY Well Number MW- 2

___1/4___1/4___1/4___1/4 S___T___R___ State NEW MEXICO

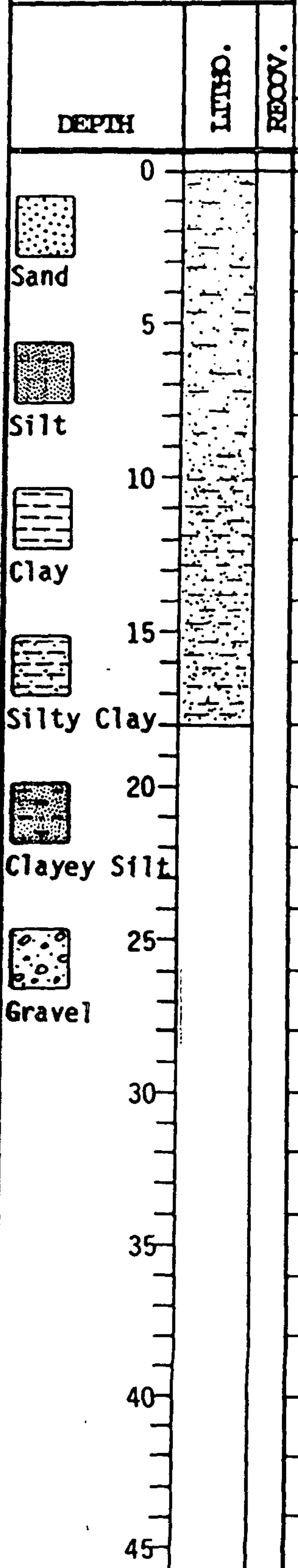
County EDDY Contractor LARRY'S DRILLING

Spud Date 6-18-86 Completion Date 6-18-86

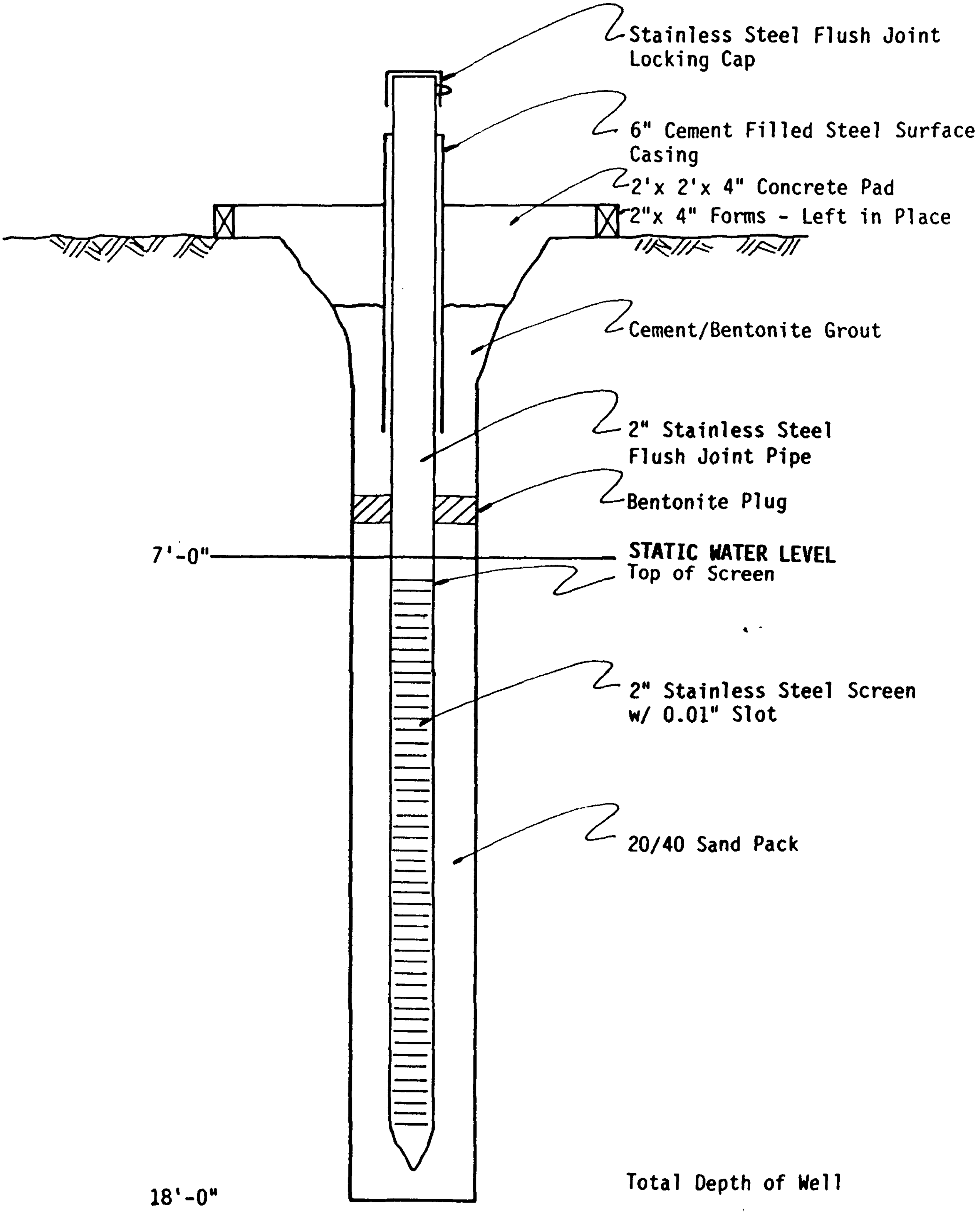
Logs Run LITHOLOGY Logged By SELKE

Elevation ______ Spud In (Fm.) ______

Remarks Steam cleaned rig and tools prior to drilling-
drilled with air rotary and temp. casing



RUN	FROM	TO	SAMPLE DEPTH	REMARKS
				0-18' very fine gr., brown, clayey silt and silty clay



WELL COMPLETION DIAGRAM
FOR MW-2

GCL

WELL LOGGING FORM

Page 1 of 1

Client NAVAJO REFINERY Well Number MW-3

1/4 1/4 1/4 1/4 S 12 T 17S R 26E State NEW MEXICO

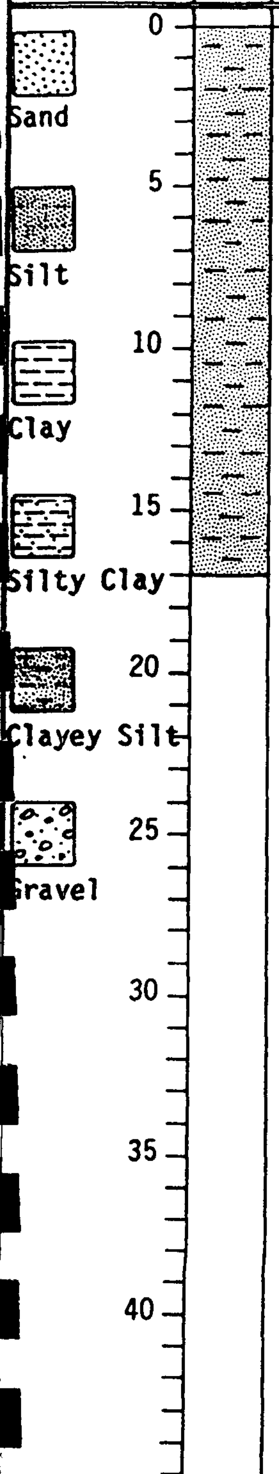
County EDDY Contractor LARRY'S DRILLING

Spud Date 6-17-86 Completion Date 6-17-86

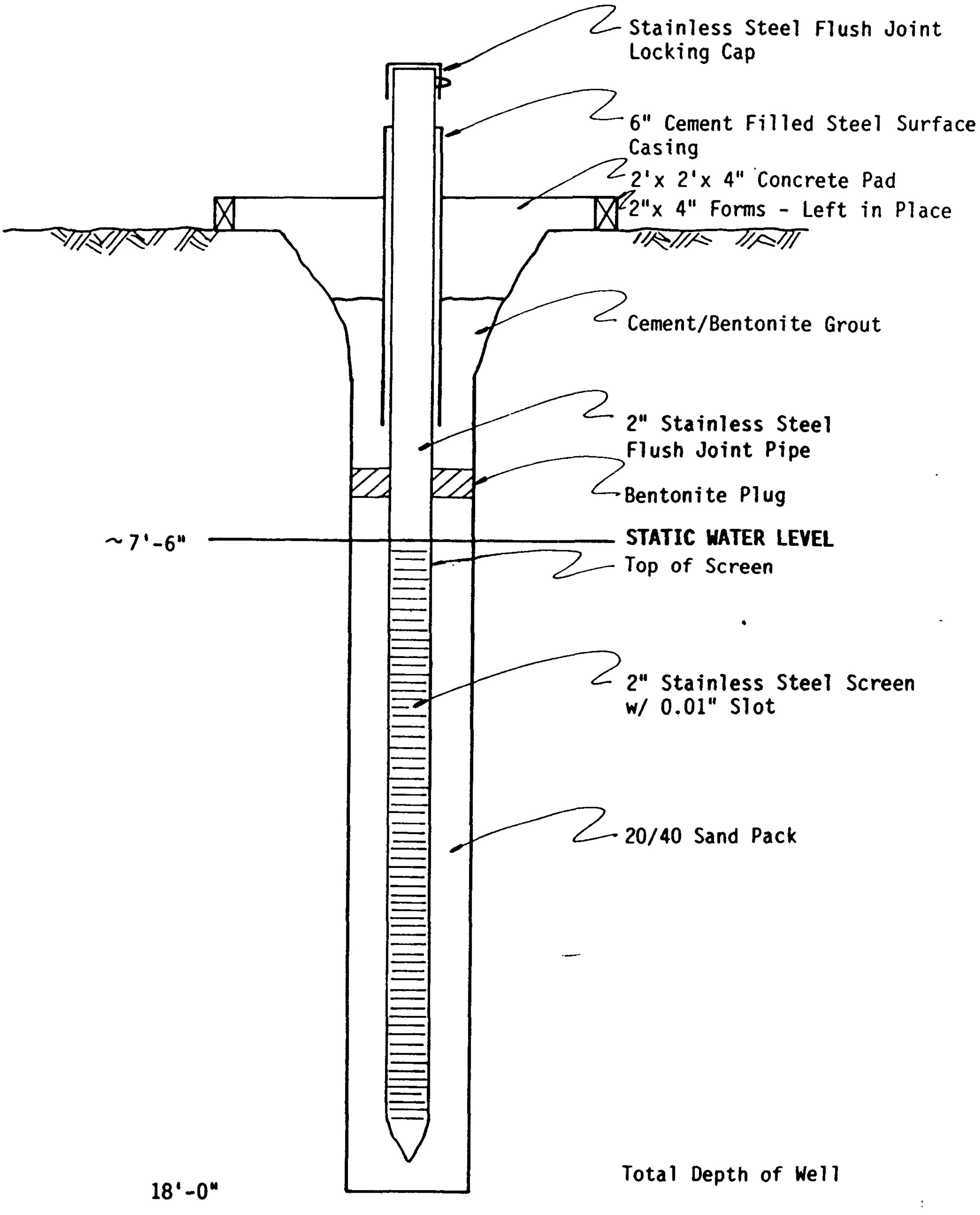
Logs Run LITHOLOGY Logged By SELKE

Elevation Spud In (Fm.)

Remarks I/R TH-60 Drill Rig and all tools steam cleaned prior to drilling-drill w/ air rotary and temp. casing 2" stainless steel well casing-.010" slot 20/40 sand pack



DEPTH	LITHO.	RECOV.	RUN	FROM	TO	SAMPLE DEPTH	REMARKS
							0-17' v.fn.gr.,clayey silt, brown



WELL COMPLETION DIAGRAM

FOR MW-3

GCL

WELL LOGGING FORM

Page 1 of 1

Client NAVAJO REFINERY **Well Number** MW- 4

___ 1/4 ___ 1/4 ___ 1/4 ___ 1/4 **S** 12 **T**17S **R**26E **State** NEW MEXICO

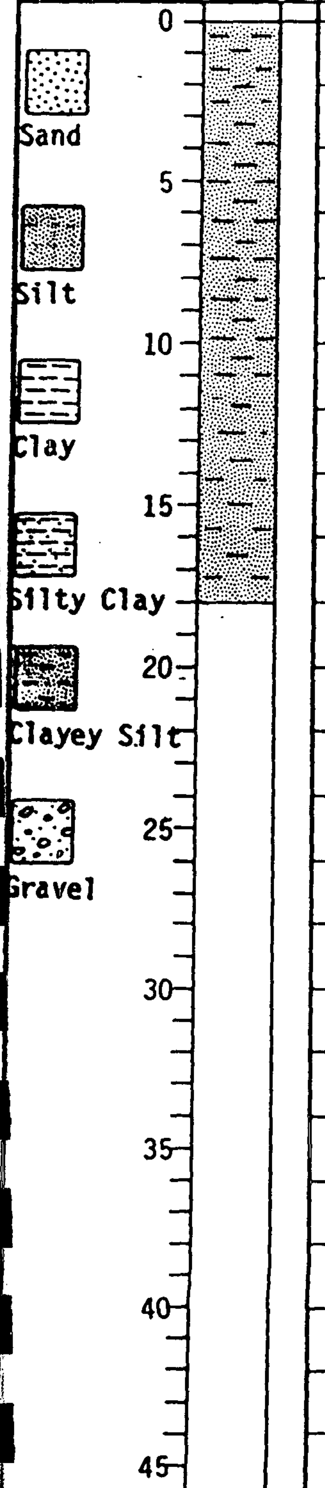
County EDDY **Contractor** LARRY'S DRILLING

Spud Date 6-17-86 **Completion Date** 6-17-86

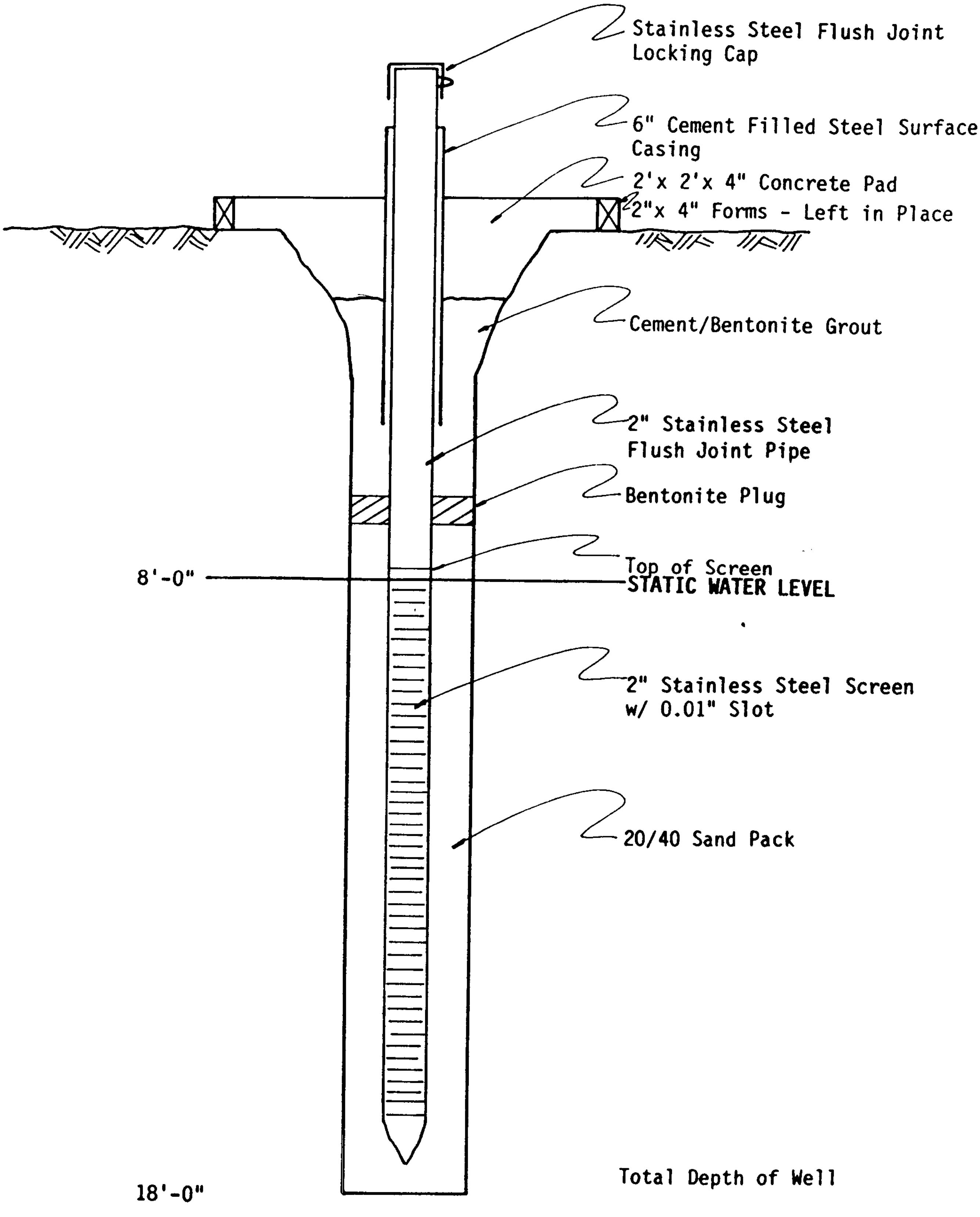
Logs Run LITHOLOGY **Logged By** SELKE

Elevation ___ **Spud In (Fm.)** ___

Remarks Steam cleaned rig and tools prior to setting up drill with air rotary and temp. casing



DEPTH	LITHO.	RECOV.	RUN	FROM	TO	SAMPLE DEPTH	REMARKS
							0-18' v.fn.gr.,brown, clayey silt



WELL COMPLETION DIAGRAM

FOR MW-4

GCL

WELL LOGGING FORM

Page 1 of 1

Client NAVAJO REFINERY **Well Number** MW- 5

1/4 1/4 1/4 1/4 S T R **State** NEW MEXICO

County EDDY **Contractor** LARRY'S DRILLING

Spud Date 6-19-86 **Completion Date** 6-19-86

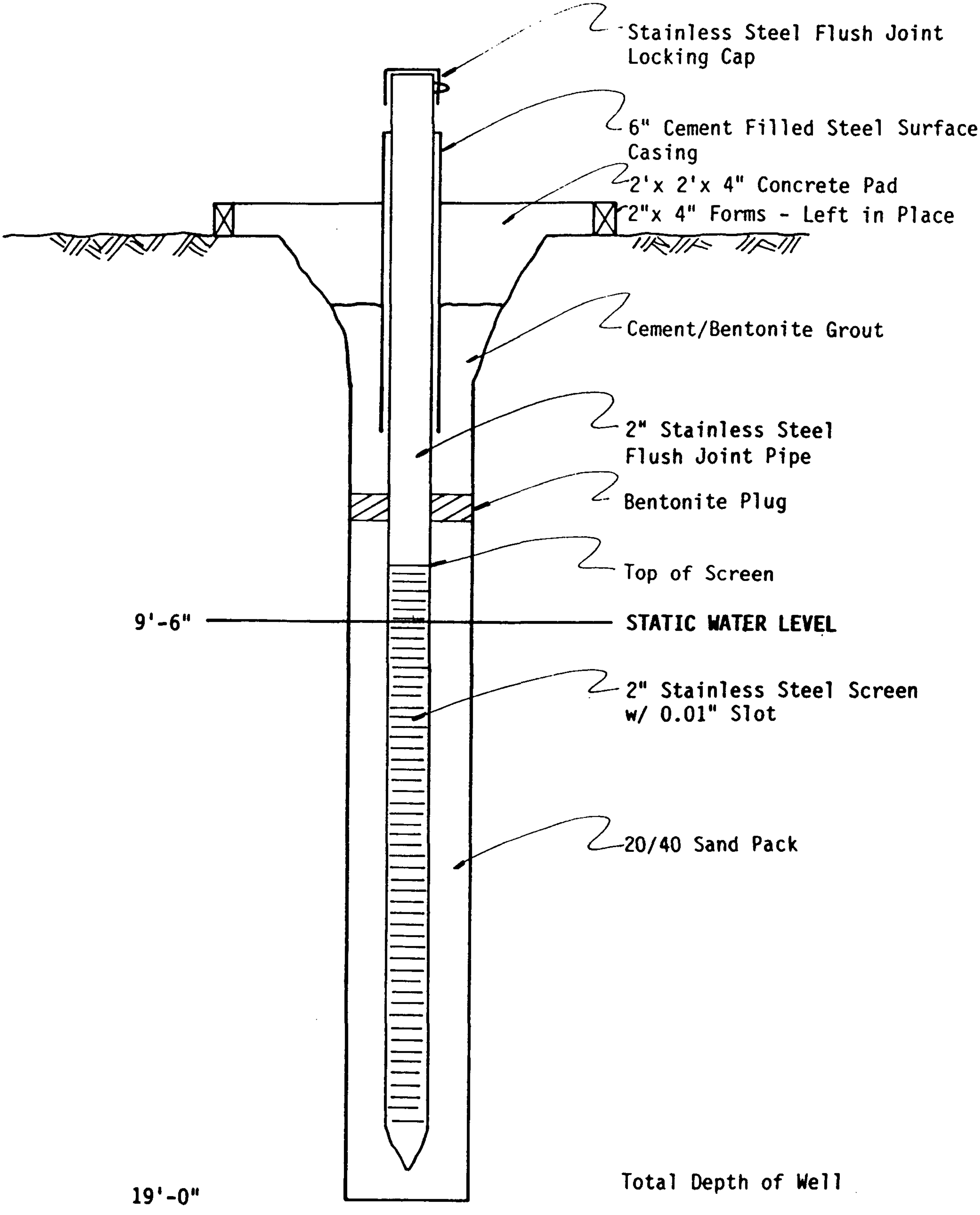
Logs Run LITHOLOGY **Logged By** SELKE

Elevation **Spud In (Fm.)**

Remarks Steam cleaned rig and tools prior to drilling-drilled with air rotary- no temporary casing

- ▒ Sand
- ▓ Silt
- ☰ Clay
- ▤ Silty Clay
- ▦ Clayey Silt
- ⁘ Gravel

DEPTH	LITHO.	RECOV.	RUN	FROM	TO	SAMPLE DEPTH	REMARKS
0	▤						0-19' v.fn.gr., brown silty clay, very strong petroliferous odor soils are discolored black beginning at approx. 13'
5	▤						
10	▤						
15	▤						
20							
25							
30							
35							
40							
45							



WELL COMPLETION DIAGRAM

FOR MW-5

GCL

WELL LOGGING FORM

Page 1 of 1

Client NAVAJO REFINERY Well Number MW- 6

1/4 1/4 1/4 1/4 S T R State NEW MEXICO

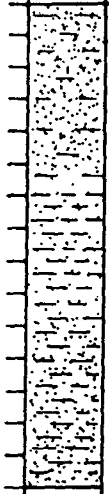
County EDDY Contractor LARRY'S DRILLING

Spud Date 6-19-86 Completion Date 6-19-86

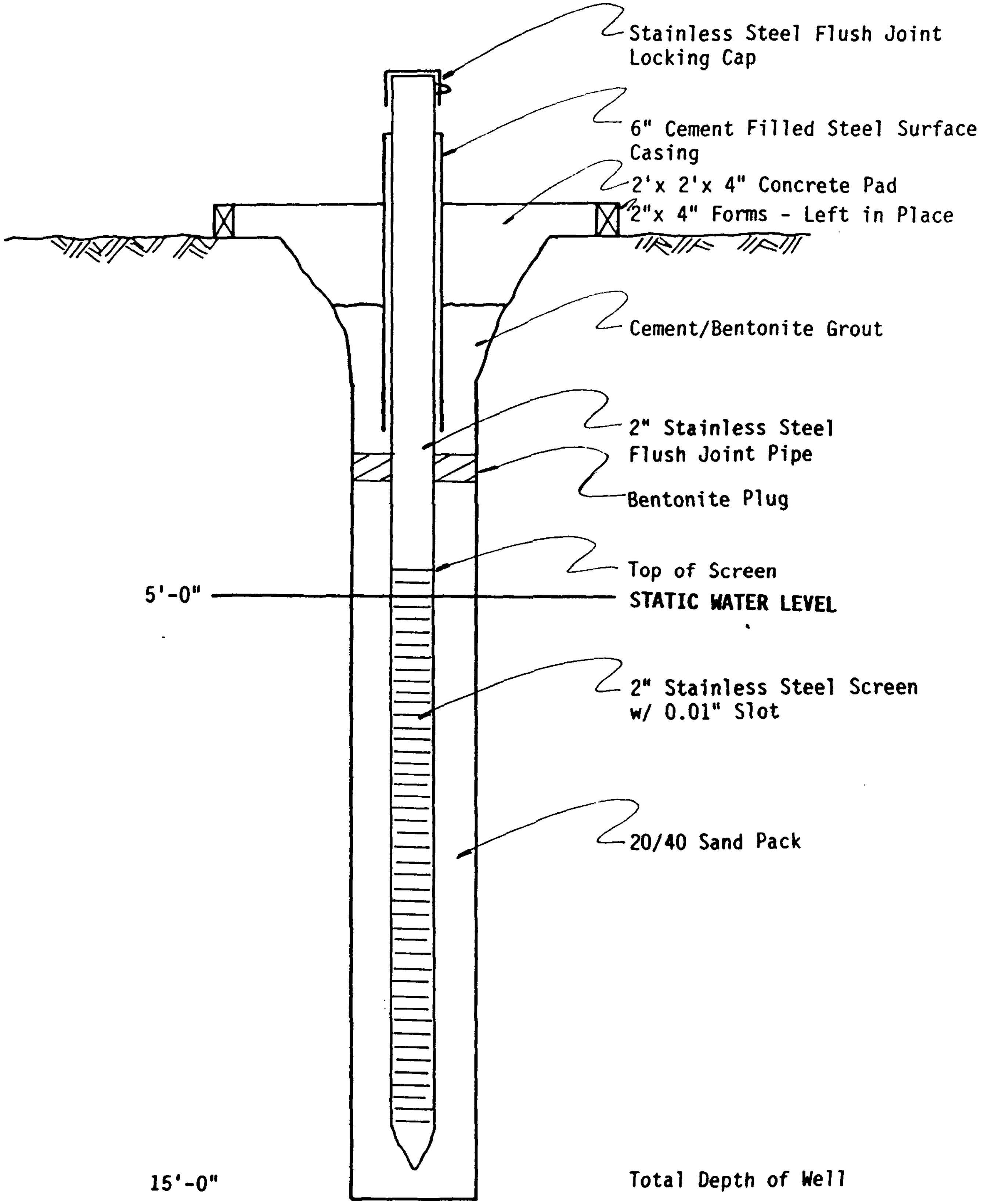
Logs Run LITHOLOGY Logged By SELKE

Elevation Spud In (Fm.)

Remarks Steam cleaned rig and tools prior to drilling- drilled with air rotary

DEPTH	LITHO.	RECOV.	RUN	FROM	TO	SAMPLE DEPTH	REMARKS
0							0-15' brown, v.fn.gr., silty clay and clayey silt at approx. 14' the clay is colored black, green, gray and is extremely petroliferous
5							
10							
15							
20							
25							
30							
35							
40							
45							

- ░ Sand
- ▒ Silt
- ☰ Clay
- ▤ Silty Clay
- ▓ Clayey Silt
- ⁘ Gravel



WELL COMPLETION DIAGRAM

FOR MW-6

GCL

WELL LOGGING FORM

Page 1 **of** 1

Client NAVAJO REFINERY **Well Number** MW-7

1/4 1/4 1/4 1/4 S T R **State** NEW MEXICO

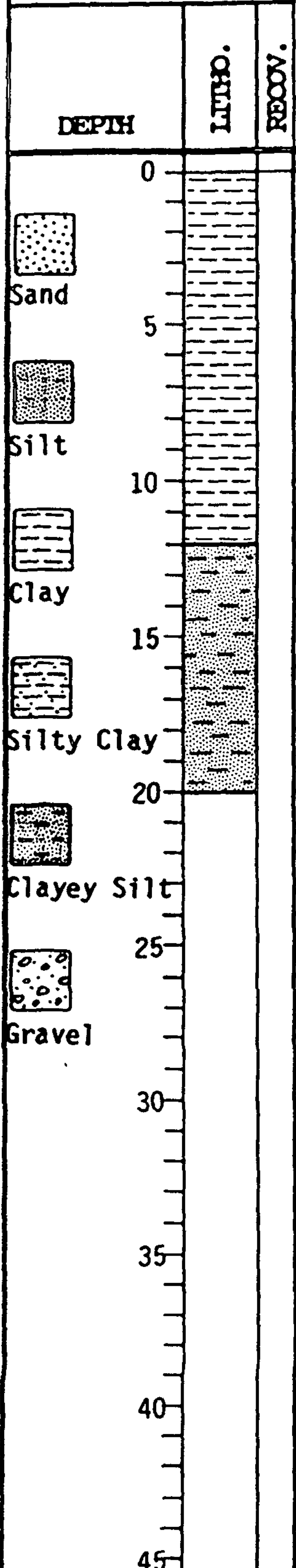
County EDDY **Contractor** LARRY'S DRILLING

Spud Date 6-19-86 **Completion Date** 6-19-86

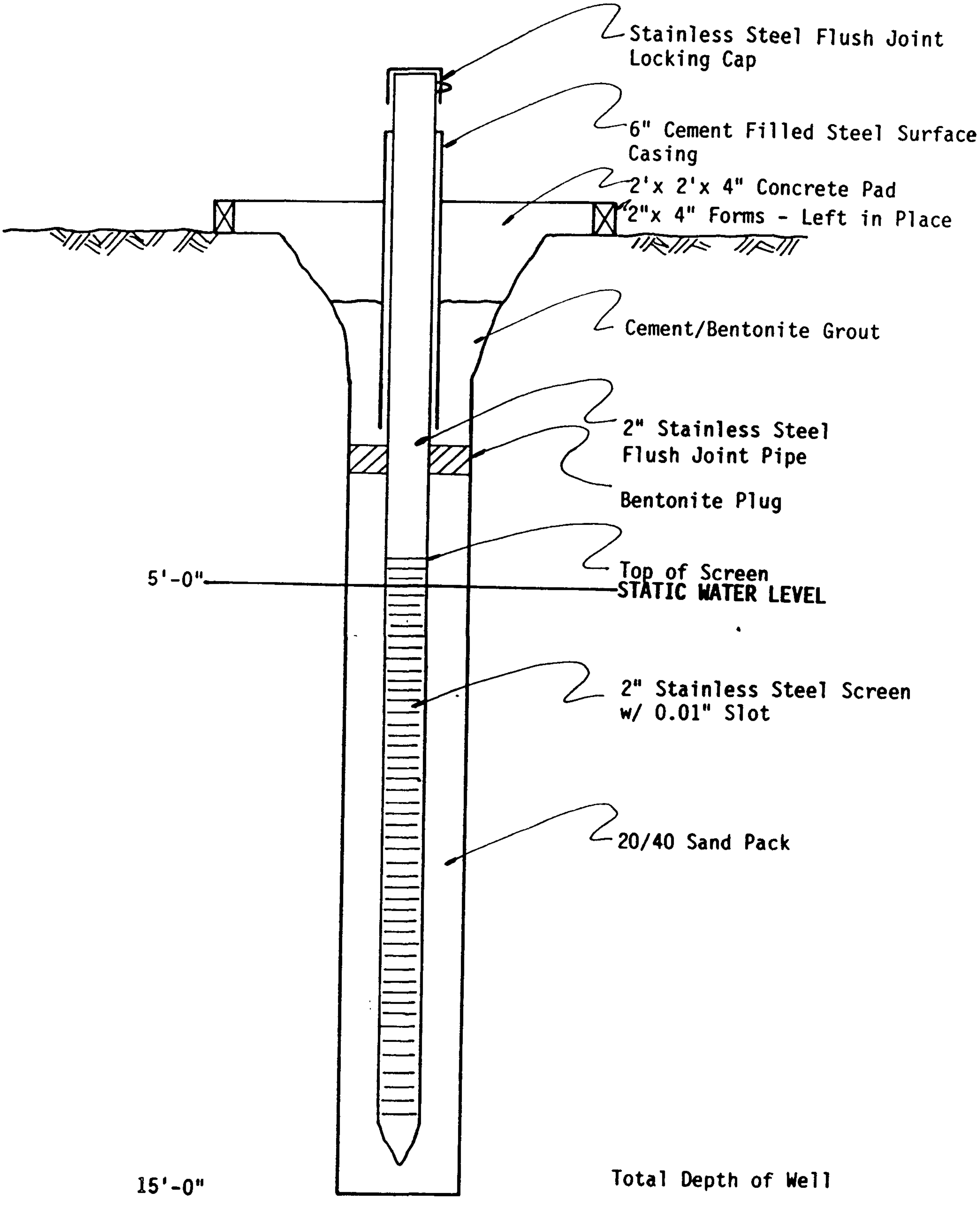
Logs Run LITHOLOGY **Logged By** SELKE

Elevation **Spud In (Fm.)**

Remarks Steam cleaned rig and tools prior to drilling-drilled with air rotary- no temp casing necessary



RUN	FROM	TO	SAMPLE DEPTH	REMARKS
				0-12' v.stiff, brown clay
				at 7' clay is slightly moist and plastic
				12-20' v. fn. gr., brown clayey silt petroliferous odor



WELL COMPLETION DIAGRAM

FOR MW-7

GCL

WELL LOGGING FORM

Page 1 of 1

Client NAVAJO REFINERY Well Number MW- 8

1/4 1/4 1/4 1/4 S T R State NEW MEXICO

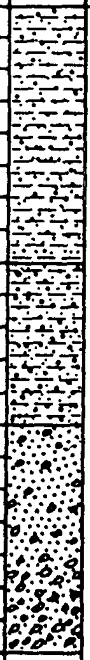
County EDDY Contractor LARRY'S DRILLING

Spud Date 6-20-86 Completion Date 6-20-86

Logs Run LITHOLOGY Logged By SELKE

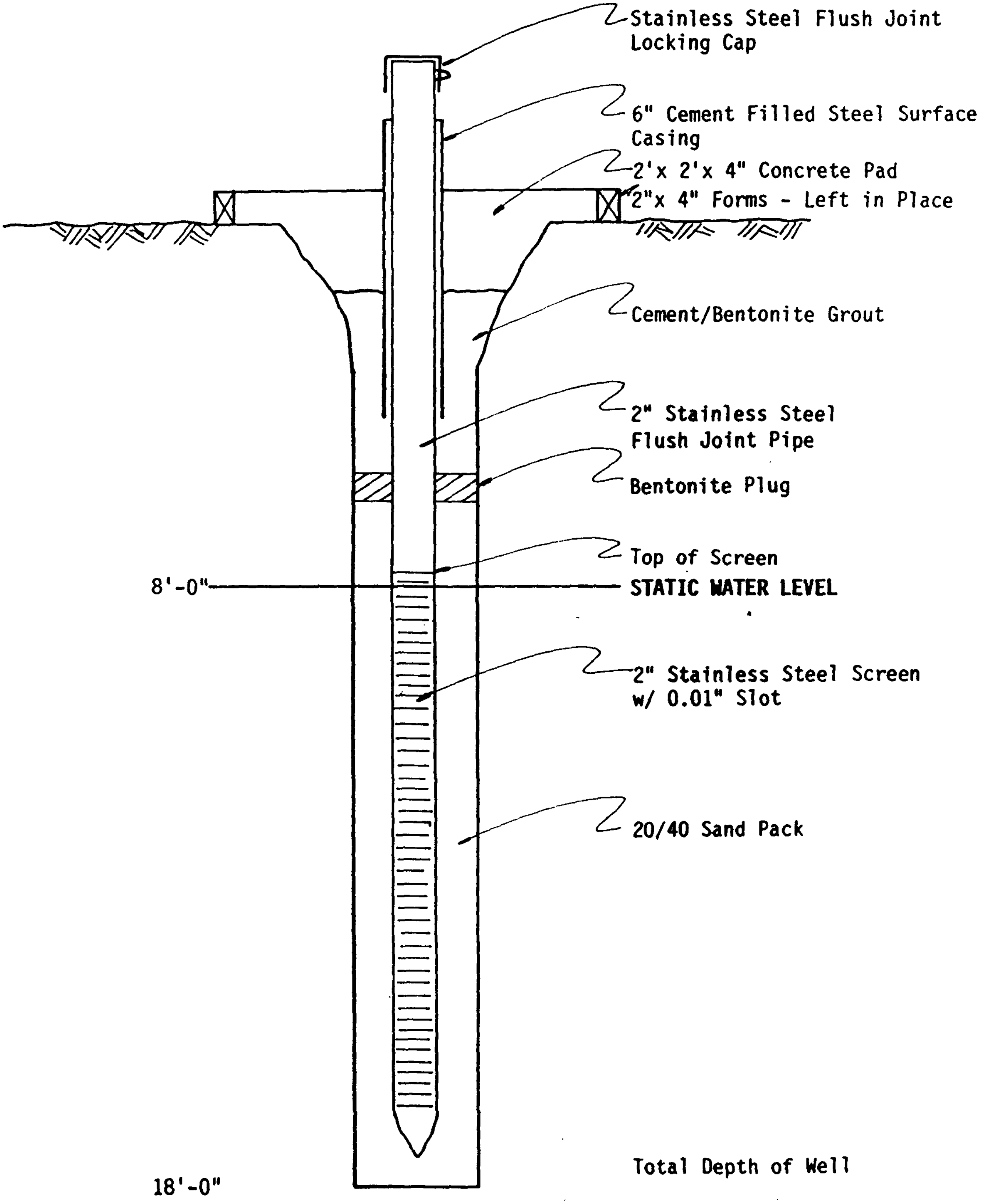
Elevation Spud In (Fm.)

Remarks Steam cleaned rig and tools prior to drilling - drilled with air rotary



DEPTH	LITHO.	RECOV.	RUN	FROM	TO	SAMPLE DEPTH	REMARKS
0							0-8' Brown, silty sandy clay moist at approx. 8'
5							
							8-13' white to gray, sandy clay with moderate amounts of gravel(pea size)
10							
							13-20' lt. brown clayey sand (abund. clay) v. minor gravel at top w/ moderate to abundant gravel at bottom
15							
20							
25							
30							
35							
40							
45							

░ Sand
▓ Silt
☰ Clay
▤ Silty Clay
▩ Clayey Silt
⁘ Gravel



WELL COMPLETION DIAGRAM
FOR MW-8

GCL

WELL LOGGING FORM

Page 1 of 1

Client NAVAJO REFINERY Well Number MW- 9

1/4 1/4 1/4 1/4 S T R State NEW MEXICO

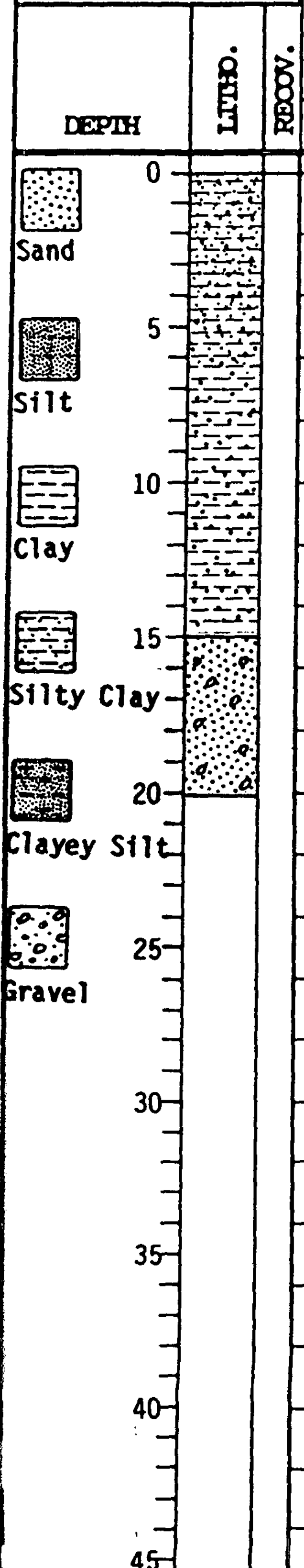
County EDDY Contractor LARRY'S DRILLING

Spud Date 6-20-86 Completion Date 6-20-86

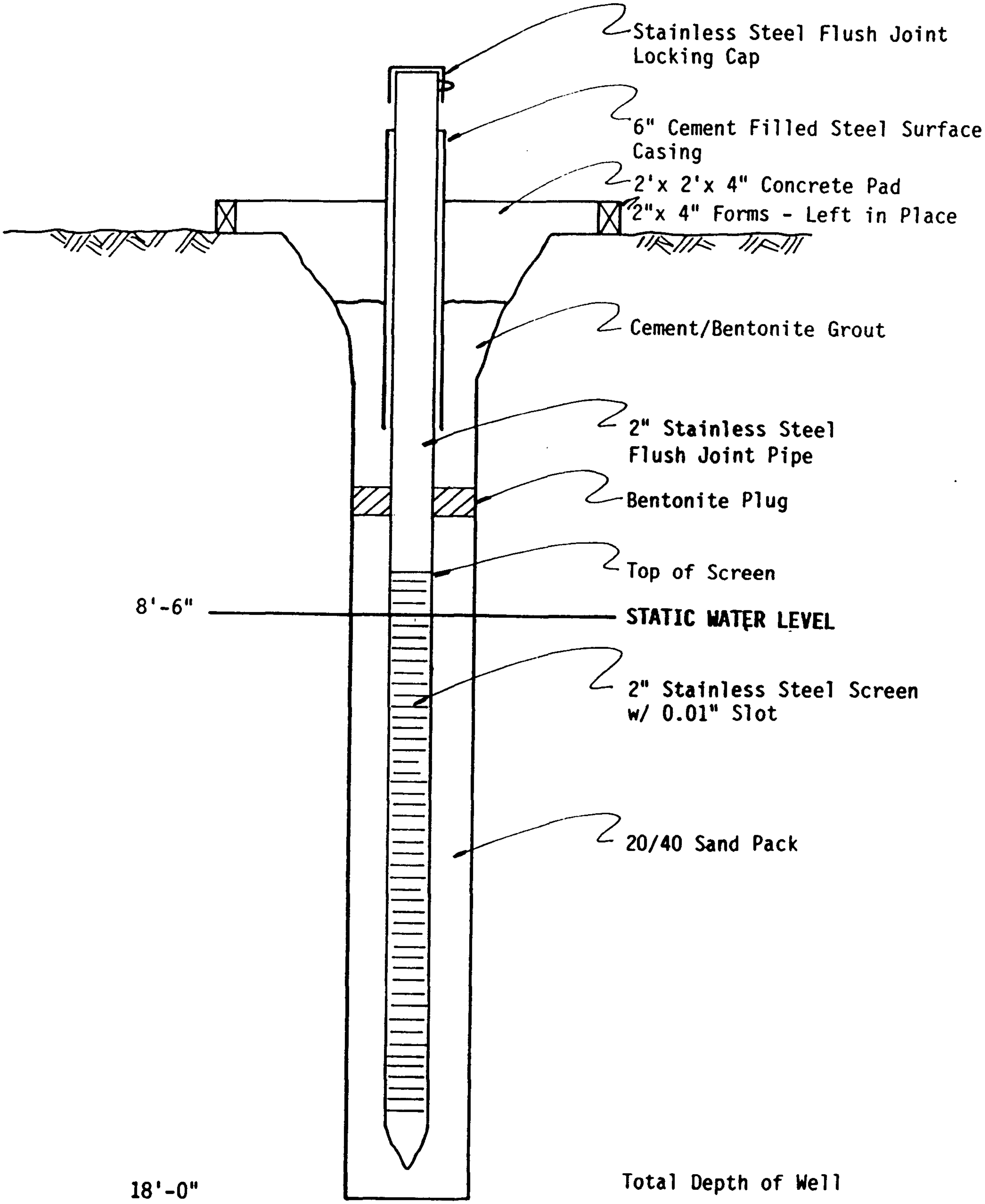
Logs Run LITHOLOGY Logged By SELKE

Elevation Spud In (Fm.)

Remarks Steam cleaned rig and tools prior to drilling- drilled with air rotary- no temporary casing



RUN	FROM	TO	SAMPLE DEPTH	REMARKS
				0-approx. 5' brown, silty , sandy clay
				approx. 5'-approx. 15' white to gray, sandy clay
				15-20' lt. brown, clayey sand w/ moderate amounts of fine grain gravel



WELL COMPETION DIAGRAM

FOR MW-9

GCL

WELL LOGGING FORM

Page 1 of 1

Client NAVAJO REFINERY Well Number Pumptest Well

1/4 1/4 1/4 1/4 S T R State NEW MEXICO

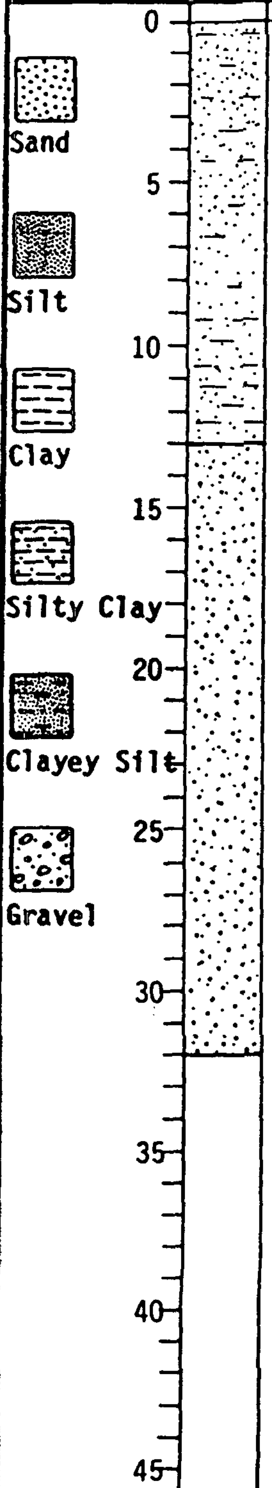
County EDDY Contractor LARRY'S DRILLING

Spud Date 6-20-86 Completion Date 6-20-86

Logs Run LITHOLOGY Logged By SELKE

Elevation Spud In (Fm.)

Remarks Steam cleaned rig and tools prior to drilling- drilled w/ air rotary- 4" PVC well casing-.010" slot 12/20 sand pack



DEPTH	LITHO.	RECOV.	RUN	FROM	TO	SAMPLE DEPTH	REMARKS
							0-13' brown, fn. gr.clayey silt and silty clay
							13-32' blackish, v.fn.gr. silt and sand

APPENDIX D

APPENDIX D

DATA SHEET FOR RECORDING PUMP TEST DATA

12,020
1,461
10,559 gal

Meter
14,611 ~~121,020~~ = ~~106,409~~ gal

$\bar{Q}$ = 6.5 gpm

DATA SHEET FOR RECORDING PUMP TEST DATA

County :

Location: Navajo

Observation well no.

Pumped well no. 1

Average Q 6.5 gpm r = 0 ft. r² =

Date	Hour	t (min)	log t/t' (min)	Δt t/t'	Depth to water	s (unadjusted)	~~Adjustment~~ Δs	s' (adjusted)	Q (gpm)	Remarks
7/17	0830				6.96				9.5	static
	0836	0								start
	0842	6	.78	6	9.45	2.49	-2.49			
	0853	17	1.23	11	9.61	2.65	-.16		9.6	
	0900	24	1.38	7	9.65	2.69	-.04			
	0914	38	1.58	14	9.74	2.78	-.09			
	0930	54	1.73	16	9.80	2.84	-.06			
	1100	144	2.16	90.	9.875	2.92	-.08		7.0	Added 50' hose
	1158	202	2.31	58	8.25	1.29	+1.63		7.0	for better discharge control
	1258	262	2.42	60	8.826	1.92	-0.63			
	1359	321	2.51	59	8.89	1.93	-.01			
	1456	440	2.64	119	8.95	1.99	-.06			
	1850	554	2.74	114	9.00	2.04	-.05			
	2100	744	2.87	190	9.08	2.12	-.08			
7/18	2400	924			9.15	2.19				
	0330	1134			9.17	2.21				
	0640	1324			9.23	2.26				
	0915	1479			9.23	2.26				
	1140	1624			9.26	2.29				
	1145				9.26					Pump off
	1146				8.125					Recovery
	1150				7.45					
	1152				7.39					
	1156				7.35					
	1200				7.31					

27 hr 9 min
= 1629 min
⇒ $\bar{Q}$ = 6.5 gpm

DATA SHEET FOR RECORDING PUMP TEST DATA

County :

Location:

Observation well no. 4

Pumped well no. 1

Average Q ____________ gpm r = __________ ft. r^2 = ________

Date	Hour	t (min)	Δt t' (min)	t/t'	Depth to water	s (unad-justed)	Adjust-ment Δs	s' (ad-justed)	Q (gpm)	Remarks
7/18	1205				7.28					
	1210		5		7.275					
	1215		5		7.26					
	1220		5		7.25					
	1235		15		7.22					
	1250		15		7.21					
	1305		15		7.19					
	1345				7.16					
	1530				7.13					
	1620				7.11					
7/19	0720				7.19					

DATA SHEET FOR RECORDING PUMP TEST DATA

County :

Location: Navajo

Observation well no. #1

Pumped well no.

Average Q ____ gpm r = 15.5' ft. r^2 = 240.25 log r^2 = 2.38

Date	Hour	t (min)	t' (min)	t/t'	Depth to water	s (unadjusted)	Adjustment Δs	s' (adjusted)	Q (gpm)	Remarks
7/17	0830				7.075				9.5	static
	0836	0			~~7.95~~	0				start
	0837				7.075					
	0837	1			7.075					
	0840	4			7.075					
	0849	13			7.075					
	0901	25			7.075					
	0913	37			7.075					
	0931	55			7.080	.005				
	1102	146			7.09	.015				added 50' hose
	1159	203			7.10	.025				
	1259	263			7.10	.025				
	1358	322			7.11	.035				
	1557	441			7.11	.035				
	1756	560			7.125	.05				
	2100	744			7.13	.055				
7/18	2400	924			7.15	.075				
	0330	1134			7.175	.10				
	0640	1324			7.20	.125				
	0915	1479			7.20	.125				
	1140	1624			7.21	.135				
	1147				7.21					Rec
	1153				7.21					
	1157				7.21					

Static = 7.075 Smax = 7.210 = .135

DATA SHEET FOR RECORDING PUMP TEST DATA

County :

Location:

Observation well no. 1

Pumped well no.

Average Q ____ gpm r = ____ ft. r^2 = ____

Date	Hour	t (min)	t' (min)	t/t'	Depth to water	s (unadjusted)	Adjustment Δs	s' (adjusted)	Q (gpm)	Remarks
7/18	1206				7.21					
	1211				7.21					
	1216				7.21					
	1221				7.21					
	1236				7.21					
	1251				7.21					
	1306				7.21					
	1346				7.21					
	1531				7.23					
	1920				7.24					
7/19	0720				7.31					

DATA SHEET FOR RECORDING PUMP TEST DATA

County :

Location:

Observation well no. Z

Pumped well no.

Average Q ______ gpm r = 23.2' ft. r^2 = 538.24 log r^2 = 2.73

Date	Hour	t (min)	Δt' (min)	Log t/t'	Depth to water	s (unadjusted)	Adjustment Δs	s' (adjusted)	Q (gpm)	Remarks
	0830	0			6.21		Δs			Static
	0836	0			6.21					Start.
	0841	5			6.21	0				
	0856	19			6.275	.07	-.07			
	0902	26			6.30	.09	-.02			
	0914	38			6.32	.11	-.02			
	0931	55			6.33	.12	-.01			
	1103	147			6.375	.17	-.05			
	1200	204			6.36	.15	+.02			
	1300	264			6.375	.17	-.02			
	1400	324			6.38	.17	0			
	1558	442			6.39	.18	-.01			
	1755	559			6.41	.20	-.02			
	2100	744			6.46	.25	-.05			
7/18	2400	924			6.50	.29	-.04			
	0330	1134			6.53	.32	-.03			
	0640	1324			6.55	.34	-.02			
	0915	1479			6.57	.36	-.02			
	1140	1624			6.58	.37				
	1148				6.58					Rec
	1154				6.57					
	1158				6.56					

Static = 6.210 Smf = 6.580
= .37'

DATA SHEET FOR RECORDING PUMP TEST DATA

County :

Location:

Observation well no. 2

Pumped well no.

Average Q ______ gpm r = ______ ft. r^2 = ______

Date	Hour	t (min)	t' (min)	t/t'	Depth to water	s (unadjusted)	Adjustment Δs	s' (adjusted)	Q (gpm)	Remarks
	1207				6.54					
	1212				6.52					
	1217				6.51					
	1222				6.51					
	1237				6.50					
	1252				6.49					
	1307				6.48					
	1347				6.47					
	1532				6.44					
	1820				6.425					
7/19	0720				6.45					

DATA SHEET FOR RECORDING PUMP TEST DATA

County :
Observation well no. 3
Location:
Pumped well no.

Average Q ____ gpm $r =$ 48.2′ ft. $r^2 =$ 2323.24 $\log r^2 = 2.37$

Date	Hour	t (min)	t′ (min)	t/t′	Depth to water	s (unadjusted)	Adjustment Δs	s′ (adjusted)	Q (gpm)	Remarks
5/0	0830		log t		6.43	s	Δs			static
	0857	21	1.43	27	6.48	.05	.005			
	0903	27	1.54	6	6.49	.06	.01			
	0915	39	1.65	12	6.50	.07	.01			
	0932	56	1.79	17	6.50	.07	0			
	1103	147	2.18	91	6.52	.09	.02			
	1200	204	2.32	57	6.52	.09	0			
	1301	265	2.43	61	6.525	.095	.005			
	1401	325	2.52	60	6.525	.095	0			
	1600	444	2.65	119	6.525	.095	0			
	1756	560	2.75	116	6.525	.095	0			
	2100	744	2.88	184	6.540	.11	.02			
7/18	2400	924			6.56	.13	.02			
	0330	1134			6.60	.17	.04			
	0640	1324			6.61	.18	.01			
	0915	1479			6.62	.19	.01			
	1140	1624			6.625	.195				
	1149				6.625					Rec Pump off @ 1145
	1155				6.61					
	1159				6.60					

Static = 6.430
Smax = 6.625
= .195

DATA SHEET FOR RECORDING PUMP TEST DATA

County :
Location:
Observation well no. 3
Pumped well no.

Average Q ________ gpm r = ________ ft. r^2 = ________

Date	Hour	t (min)	t' (min)	t/t'	Depth to water	s (unadjusted)	Adjustment Δs	s' (adjusted)	Q (gpm)	Remarks
	1208				6.59					
	1213				6.59					
	1218				6.58					
	1223				6.58					
	1238				6.58					
	1253				6.57					
	1308				6.57					
	1348				6.57					
	1533				6.57					
	1820				6.56					
7/19	0720				6.64					

Calculation of Transmissivity and Specific Yield

$$T = \frac{2.30Q \log\left(\frac{r_2}{r_1}\right)}{2(3.1416)\ (S_1' - S_2')}$$

Where:

T = transmissivity
Q = discharge
r = distance from pumped well to observation well

$$S' = S - (S^2/2m)$$

Where:

S = drawdown
m = effective aquifer thickness

Using Data from time = 1624 minutes:

r_1 = 23.2 ft
r_2 = 48.2 ft
s_1 = 0.37 ft
s_2 = 0.195 ft
s_1' = 0.369 ft
s_2' = 0.195 ft
Q = 0.0145 ft^3/second

$$T = \frac{2.3\ (0.0145)\ \log\left(\frac{48.2}{23.2}\right)}{2(3.1416)\ (.396 - .195)}$$

T = 0.0097 ft^2/second

$$0.0097\ ft^2/\text{second} \times 6.46 \times 10^5\ \frac{\text{gallons/d/}ft^2}{ft^2/\ \text{sec}}$$

= 6243 gallons/day/$foot^2$

Specific yield is determined as follows:

$$\text{from } \frac{r_e^2 S}{4Tt} = e^{-0.5772} = 0.562$$

$$\text{then } S = (4)(.562)\frac{Tt}{r_e^2}$$

Where:

S = specific yield
T = transmissivity
t = time
r_e = effective radius of the cone of depression

All of these terms are known except for r_e. This is determined from the accompanying graph of s' versus r. Note that r_e is read from the graph where the line connecting s_1 and s_2 intersects the s' = 0 line. This gives an r_e value of:

$$r_e = 105 \text{ feet.}$$

Converting 1624 minutes to seconds:
1624 x 60 = 97,440 seconds

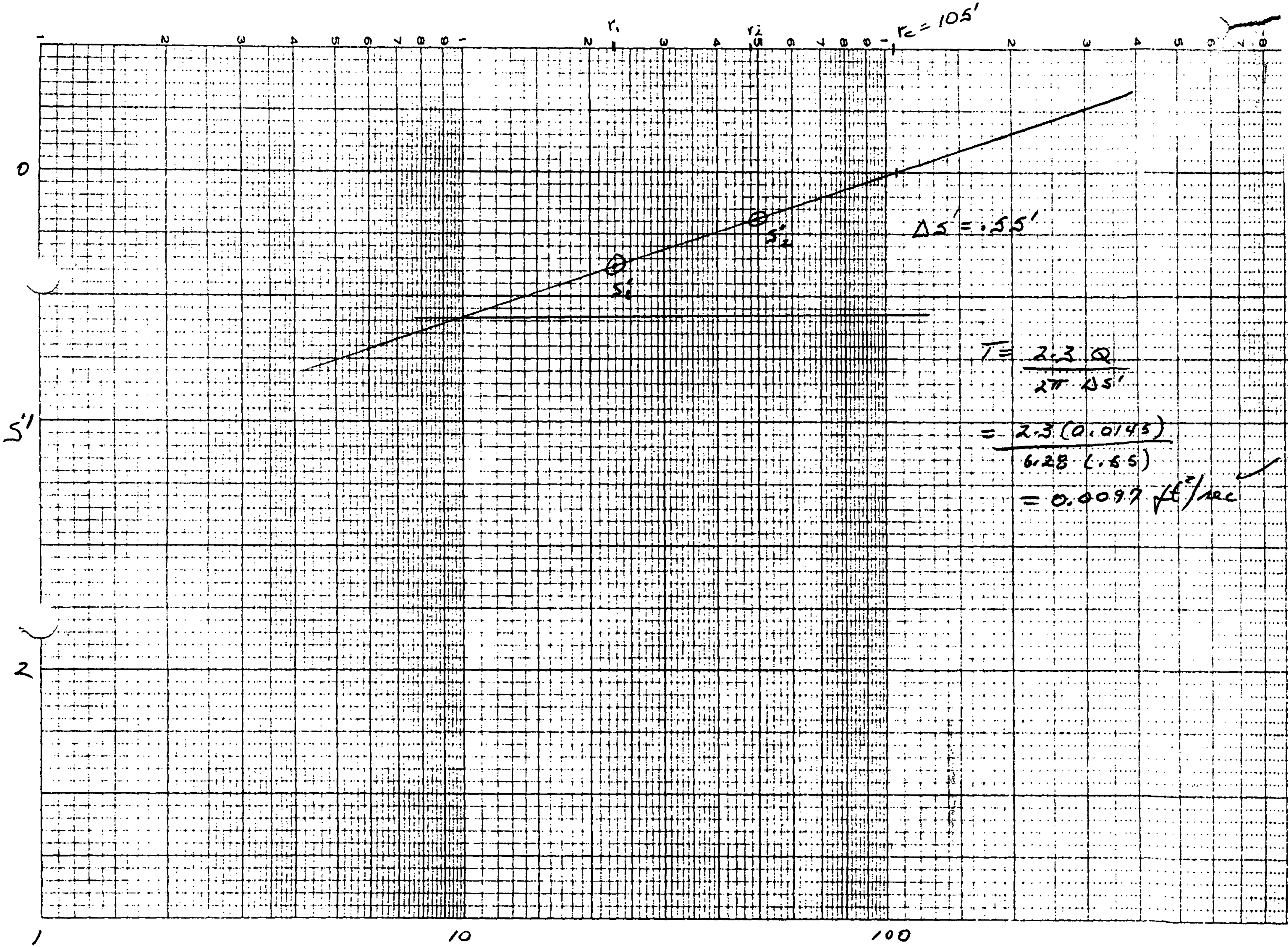
$$S = \frac{(4)(.562)(0.0097)(97{,}440)}{(105)^2}$$

$$S = 0.1927$$

or, $S = 0.2$

NO. 340-L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
3 CYCLES X 10 DIVISIONS PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



$\Delta s' = .55'$

$$T = \frac{2.3\,Q}{2\pi\,\Delta s'}$$

$$= \frac{2.3\,(0.0145)}{6.28\,(.55)}$$

$$= 0.0097\ \text{ft}^2/\text{sec}$$

APPENDIX E

APPENDIX E

CHEMICAL ANALYSES OF GROUND WATER SAMPLES

Rocky Mountain Analytical Laboratory
4955 Yarrow Street, Arvada, CO 80002 (303) 421-6611

A DIVISION OF
ENSECO
INCORPORATED

September 19, 1986

Trent Thomas
Geoscience Consultants, Ltd.
500 Copper N.W., Suite 325
Albuquerque, NM 87102

Dear Trent:

Enclosed are the results for the analysis of the 13 groundwater samples (Navajo Refinery) received August 12, 1986. An ion balance was performed on relevant samples and all had a percent difference of less than five percent. The ion balance results are also enclosed.

We experienced some difficulty with organic acid surrogate spike recoveries. Samples MW-9, MW-2, MW-3, MW-1 and Well Pit #2 all had more than one acid surrogate spike recovery below our QC limits. Repreparation and analysis was performed on these five samples and all still had low acid surrogate spike recoveries except for Well Pit #2, which had acceptable recoveries. Limited sample was available for the repreparation of Well Pit #2 (260 mLs vs. 1000 mLs). This suggests that there was a matrix effect on the recovery of the acid surrogate compounds when the sample was at full strength (1000 mLs).

Please do not hesitate to call if you have any questions.

Sincerely,

Brian J. Rahn
Project Coordinator
Inorganic Chemistry

Approved by:

Jerry L. Parr
Technical Director

BJR/JLP/bj
Enclosures

RMAL #61882

SAMPLE DESCRIPTION INFORMATION

for

Geoscience Consultants, Ltd.

RMA Sample No.	Sample Description	Sample Type	Date Sampled	Date Received
61882-01	MW-8 ✓	Water	08/06/86	08/12/86
61882-02	MW-9 ✓	Water	08/06/86	08/12/86
61882-03	MW-2 ✓	Water	08/06/86	08/12/86
61882-04	MW-6 ✓	Water	08/07/86	08/12/86
61882-05	MW-3 ✓	Water	08/07/86	08/12/86
61882-06	Equip Blank ✓	Water	08/07/86	08/12/86
61882-07	Field Blank ✓	Water	08/07/86	08/12/86
61882-08	MW-7 ✓	Water	08/07/86	08/12/86
61882-09	MW-5 ✓	Water	08/07/86	08/12/86
61882-10	MW-1 ✓	Water	08/07/86	08/12/86
61882-11	MW-4 ✓	Water	08/07/86	08/12/86
61882-12	#13 ✓	Water	08/07/86	08/12/86
61882-13	Well Pt #2 ✓	Water	08/07/86	08/12/86

September 19, 1986

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

MW 2

NORGANIC PARAMETERS

arameter	Units	61882-01		61882-02		61882-03		61882-04	
otal Dissolved Solids	mg/L	7420	(10)	NR	-	21600	(10)	10100	(10)
luoride	mg/L	2.0	(0.1)	NR	-	NR	-	5.5	(0.1)
hloride	mg/L	904	(3)	NR	-	NR	-	3080	(3)
itrate + Nitrite as N	mg/L	1.7	(0.1)	NR	-	NR	-	2.1	(0.1)
ulfate	mg/L	3430	(5)	NR	-	NR	-	3000	(5)
issolved Sulfide	mg/L	ND	(0.05)	ND	(0.05)	NR	-	ND	(0.05)
arb. Alk. as CaCO3 at pH 8.3	mg/L	ND	(5)	NR	-	NR	-	ND	(5)
icarb. Alk as CaCO3 at pH 4.5	mg/L	384	(5)	NR	-	NR	-	483	(5)
otal Kjeldahl Nitrogen as N	mg/L	0.9	(0.1)	NR	-	NR	-	5.2	(0.1)

arameter	Units	61882-05		61882-08		61882-09		61882-10	
otal Dissolved Solids	mg/L	8080	(10)	10500	(10)	27300	(10)	14900	(10)
luoride	mg/L	2.9	(0.1)	NR	-	NR	-	1.0	(0.1)
hloride	mg/L	1210	(3)	NR	-	NR	-	4250	(3)
itrate + Nitrite as N	mg/L	ND	(0.1)	NR	-	NR	-	ND	(0.1)
ılfate	mg/L	2760	(5)	NR	-	NR	-	3080	(5)
issolved Sulfide	mg/L	ND	(0.05)	NR	-	NR	-	0.07	(0.05)
arb. Alk. as CaCO3 at pH 8.3	mg/L	ND	(5)	NR	-	NR	-	ND	(5)
icarb. Alk as CaCO3 at pH 4.5	mg/L	1280	(5)	NR	-	NR	-	391	(5)
otal Kjeldahl Nitrogen as N	mg/L	0.3	(0.1)	NR	-	NR	-	2.6	(0.1)

D = Not detected. NR = Not requested. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

NORGANIC PARAMETERS

arameter	Units	61882-11		61882-12		61882-13	
otal Dissolved Solids	mg/L	13000	(10)	1200	(10)	5100	(10)
luoride	mg/L	NR	-	2.1	(0.1)	NR	-
hloride	mg/L	NR	-	202	(3)	NR	-
itrate + Nitrite as N	mg/L	NR	-	ND	(0.1)	NR	-
ulfate	mg/L	NR	-	257	(5)	NR	-
issolved Sulfide	mg/L	NR	-	0.29	(0.05)	NR	-
arb. Alk. as CaCO3 at pH 8.3	mg/L	NR	-	ND	(5)	NR	-
icarb. Alk as CaCO3 at pH 4.5	mg/L	NR	-	184	(5)	NR	-
otal Kjeldahl Nitrogen as N	mg/L	NR	-	7.2	(0.1)	NR	-

D = Not detected. NR = Not requested. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

RIORITY POLLUTANT METALS

arameter	Units	61882-01		61882-02		61882-04		61882-05	
ntimony	mg/L	0.006	(0.002)	ND	(0.002)	0.007	(0.002)	0.003	(0.002)
rsenic	mg/L	0.012	(0.002)	0.020	(0.002)	0.092	(0.002)	0.084	(0.002)
arium	mg/L	0.049	(0.01)	0.020	(0.01)	0.040	(0.01)	0.22	(0.01)
eryllium	mg/L	ND	(0.002)	ND	(0.002)	ND	(0.002)	ND	(0.002)
admium	mg/L	ND	(0.008)	ND	(0.008)	ND	(0.008)	ND	(0.008)
hromium	mg/L	ND	(0.01)	ND	(0.01)	0.019	(0.01)	0.02	(0.01)
obalt	mg/L	0.018	(0.06)	0.012	(0.06)	ND	(0.06)	0.007	(0.06)
opper	mg/L	ND	(0.03)	ND	(0.03)	ND	(0.03)	ND	(0.03)
ead	mg/L	ND	(0.04)	ND	(0.04)	ND	(0.04)	ND	(0.04)
ercury	mg/L	ND	(0.0001)	ND	(0.0001)	ND	(0.0001)	ND	(0.0001)
ickel	mg/L	0.039	(0.02)	0.048	(0.02)	ND	(0.02)	0.02	(0.02)
elenium	mg/L	ND	(0.04)	ND	(0.04)	ND	(0.04)	ND	(0.04)
ilver	mg/L	ND	(0.006)	ND	(0.006)	ND	(0.006)	ND	(0.006)
hallium	mg/L	ND	(0.04)	ND	(0.04)	ND	(0.04)	ND	(0.04)
anadium	mg/L	0.053	(0.004)	0.048	(0.004)	0.005	(0.004)	0.014	(0.004)
inc	mg/L	ND	(0.02)	ND	(0.02)	ND	(0.02)	ND	(0.02)

ISSOLVED MAJOR CATIONS

arameter	Units	61882-01		61882-02		61882-04		61882-05	
alcium	mg/L	635	(0.2)	NR	-	986	(0.2)	703	(0.2)
on	mg/L	1.7	(0.1)	NR	-	19	(0.1)	7.5	(0.1)
agnesium	mg/L	451	(0.2)	NR	-	248	(0.2)	296	(0.2)
otassium	mg/L	2.6	(0.6)	NR	-	9.0	(0.6)	7.2	(0.6)
odium	mg/L	637	(1)	NR	-	1990	(1)	1220	(1)

D = Not detected. NR = Not requested. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

RIORITY POLLUTANT METALS

arameter	Units	61882-10		61882-12	
rsenic	mg/L	ND	(0.002)	0.064	(0.002)
ntimony	mg/L	0.004	(0.002)	0.006	(0.002)
arium	mg/L	0.030	(0.025)	0.22	(0.05)
eryllium	mg/L	ND	(0.005)	ND	(0.001)
admium	mg/L	ND	(0.02)	ND	(0.004)
hromium	mg/L	ND	(0.025)	0.007	(0.005)
obalt	mg/L	ND	(0.015)	ND	(0.003)
opper	mg/L	ND	(0.03)	ND	(0.03)
ead	mg/L	ND	(0.1)	ND	(0.02)
ercury	mg/L	ND	(0.0001)	ND	(0.0001)
ickel	mg/L	0.10	(0.05)	ND	(0.01)
elenium	mg/L	ND	(0.04)	ND	(0.004)
ilver	mg/L	ND	(0.015)	ND	(0.003)
hallium	mg/L	ND	(0.04)	ND	(0.004)
anadium	mg/L	ND	(0.01)	0.011	(0.002
inc	mg/L	ND	(0.02)	ND	(0.02)

ISSOLVED MAJOR CATIONS

arameter	Units	61882-10		61882-12	
alcium	mg/L	900	(0.2)	143	(0.1)
on	mg/L	1.3	(0.1)	2.7	(0.05)
agnesium	mg/L	601	(0.2)	27	(0.1)
otassium	mg/L	9.1	(0.6)	9.3	(0.3)
odium	mg/L	2020	(1)	150	(0.5)

D = Not detected. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

PRIORITY POLLUTANT BASE/NEUTRAL ORGANICS

Parameter	Units	61882-01		61882-02		61882-03		61882-04	
Acenaphthene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Acenaphthylene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Anthracene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Benzidine	ug/L	BDL	(20)	BDL	(20)	NR	-	BDL	(20)
Benzo(a)anthracene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Benzo(a)pyrene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
3,4-Benzofluoranthene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Benzo(g,h,i)perylene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Benzo(k)fluoranthene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Bis(2-chloroethoxy)methane	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Bis(2-chloroethyl)ether	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Bis(2-chloroisopropyl)ether	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Bis(2-ethylhexyl)phthalate	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
4-Bromophenyl phenyl ether	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Butylbenzyl phthalate	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
2-Chloronaphthalene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
4-Chlorophenyl phenyl ether	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Chrysene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Dibenzo(a,h)anthracene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Dibenzofuran	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
2-Methylnaphthalene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
1,2-Dichlorobenzene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
1,3-Dichlorobenzene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
1,4-Dichlorobenzene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
3,3'-Dichlorobenzidine	ug/L	BDL	(20)	BDL	(20)	NR	-	BDL	(20)
Diethyl phthalate	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Dimethyl phthalate	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Di-n-butyl phthalate	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
2,4-Dinitrotoluene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
2,6-Dinitrotoluene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)

BDL = Below detection limits.   NR = Not requested.   Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

PRIORTIY POLLUTANT BASE/NEUTRAL ORGANICS (Cont.)

Parameter	Units	61882-01		61882-02		61882-03		61882-04	
Di-n-octyl phthalate	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
1,2-Diphenylhydrazine*	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Fluoranthene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Fluorene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Hexachlorobenzene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Hexachlorobutadiene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Hexachlorocyclopentadiene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Hexachloroethane	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
ndeno(1,2,3-cd)pyrene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
sophorone	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Naphthalene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Nitrobenzene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
N-Nitrosodimethylamine	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
N-Nitrosodi-n-propylamine	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
N-Nitrosodiphenylamine*	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Phenanthrene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
Pyrene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
,2,4-Trichlorobenzene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)

BDL = Below detection limits. NR = Not requested. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

PRIORITY POLLUTANT ACID ORGANICS

Parameter	Units	61882-01		61882-02		61882-03		61882-04	
2-Chlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
2,4-Dichlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
2,4-Dimethylphenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
4,6-Dinitro-o-cresol	ug/L	BDL	(10)	BDL	(10)	BDL	(5)	BDL	(5)
2,4-Dinitrophenol	ug/L	BDL	(10)	BDL	(10)	BDL	(10)	BDL	(10)
2-Methylphenol	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
4-Methylphenol	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
2-Nitrophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
4-Nitrophenol	ug/L	BDL	(10)	BDL	(10)	BDL	(10)	BDL	(10)
p-Chloro-m-cresol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
Pentachlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
Phenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
2,4,6-Trichlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)

BDL = Below detection limits.   NR = Not requested.   Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

RIORITY POLLUTANT VOLATILE ORGANICS

arameter	Units	61882-01		61882-02		61882-03		61882-04	
cetone	ug/L	BDL	(10)	BDL	(10)	NR	-	74	(10)
crolein	ug/L	BDL	(100)	BDL	(100)	NR	-	BDL	(100)
crylonitrile	ug/L	BDL	(100)	BDL	(100)	NR	-	BDL	(100)
enzene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
romoform	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
arbon tetrachloride	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
hlorobenzene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
hlorodibromomethane	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
hloroethane	ug/L	BDL	(10)	BDL	(10)	NR	-	BDL	(10)
-Chloroethylvinyl ether	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
hloroform	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
ichlorobromomethane	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
,1-Dichloroethane	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
,2-Dichloroethane	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
,1-Dichloroethylene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
,2-Dichloropropane	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
,3-Dichloropropylene (c&t)	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
thylbenzene	ug/L	BDL	(5)	BDL	(5)	NR	-	12	(5)
ethylbromide	ug/L	BDL	(10)	BDL	(10)	NR	-	BDL	(10)
ethylchloride	ug/L	BDL	(10)	BDL	(10)	NR	-	BDL	(10)
ethylene chloride	ug/L	BDL	(10)	BDL	(10)	NR	-	BDL	(10)
,1,2,2-Tetrachloroethane	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
etrachloroethylene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
oluene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
,2-trans-Dichloroethylene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
,1,1-Trichloroethane	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
,1,2-Trichloroethane	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
richloroethylene	ug/L	BDL	(5)	BDL	(5)	NR	-	BDL	(5)
inyl chloride	ug/L	BDL	(10)	BDL	(10)	NR	-	BDL	(10)

DL = Below detection limits. NR = Not requested. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

RIORITY POLLUTANT BASE/NEUTRAL ORGANICS

arameter	Units	61882-05		61882-08		61882-09		61882-10	
cenaphthene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
cenaphthylene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
nthracene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
enzidine	ug/L	BDL	(20)	NR	-	NR	-	BDL	(20)
enzo(a)anthracene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
enzo(a)pyrene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,4-Benzofluoranthene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
enzo(g,h,i)perylene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
enzo(k)fluoranthene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
is(2-chloroethoxy)methane	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
is(2-chloroethyl)ether	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
is(2-chloroisopropyl)ether	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
is(2-ethylhexyl)phthalate	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
-Bromophenyl phenyl ether	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
utylbenzyl phthalate	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
-Chloronaphthalene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
-Chlorophenyl phenyl ether	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
hrysene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
ibenzo(a,h)anthracene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
ibenzofuran	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,2-Dichlorobenzene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,3-Dichlorobenzene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,4-Dichlorobenzene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,3'-Dichlorobenzidine	ug/L	BDL	(20)	NR	-	NR	-	BDL	(20)
iethyl phthalate	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
imethyl phthalate	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
i-n-butyl phthalate	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,4-Dinitrotoluene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,6-Dinitrotoluene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)

DL = Below detection limits. NR = Not requested. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

PRIORITY POLLUTANT BASE/NEUTRAL ORGANICS (Cont.)

Parameter	Units	61882-05		61882-08		61882-09		61882-10	
Di-n-octyl phthalate	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
1,2-Diphenylhydrazine*	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
Fluoranthene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
Fluorene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
Iexachlorobenzene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
Iexachlorobutadiene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
Hexachlorocyclopentadiene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
Hexachloroethane	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
ndeno(1,2,3-cd)pyrene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
sophorone	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
-Methylnaphthalene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
Naphthalene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
Nitrobenzene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
N-Nitrosodimethylamine	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
N-Nitrosodi-n-propylamine	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
N-Nitrosodiphenylamine*	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
Phenanthrene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
Pyrene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,2,4-Trichlorobenzene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)

DL = Below detection limits. NR = Not requested. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

PRIORITY POLLUTANT ACID ORGANICS

Parameter	Units	61882-05		61882-08		61882-09		61882-10	
-Chlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
,4-Dichlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
,4-Dimethylphenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
,6-Dinitro-o-cresol	ug/L	BDL	(10)	BDL	(10)	BDL	(10)	BDL	(10)
,4-Dinitrophenol	ug/L	BDL	(10)	BDL	(10)	BDL	(10)	BDL	(10)
-Methylphenol	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
-Methylphenol	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
-Nitrophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
-Nitrophenol	ug/L	BDL	(10)	BDL	(10)	BDL	(10)	BDL	(10)
-Chloro-m-cresol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
Pentachlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
Phenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)
,4,6-Trichlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)	BDL	(5)

BDL = Below detection limits. NR = Not requested. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

RIORITY POLLUTANT VOLATILE ORGANICS

arameter	Units	61882-05		61882-08		61882-09		61882-10	
cetone	ug/L	BDL	(10)	NR	-	NR	-	BDL	(10)
crolein	ug/L	BDL	(100)	NR	-	NR	-	BDL	(100)
crylonitrile	ug/L	BDL	(100)	NR	-	NR	-	BDL	(100)
enzene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
romoform	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
arbon tetrachloride	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
hlorobenzene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
hlorodibromomethane	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
hloroethane	ug/L	BDL	(10)	NR	-	NR	-	BDL	(10)
-Chloroethylvinyl ether	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
hloroform	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
ichlorobromomethane	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,1-Dichloroethane	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,2-Dichloroethane	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,1-Dichloroethylene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,2-Dichloropropane	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,3-Dichloropropylene (c&t)	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
thylbenzene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
ethylbromide	ug/L	BDL	(10)	NR	-	NR	-	BDL	(10)
ethylchloride	ug/L	BDL	(10)	NR	-	NR	-	BDL	(10)
ethylene chloride	ug/L	BDL	(10)	NR	-	NR	-	BDL	(10)
,1,2,2-Tetrachloroethane	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
etrachloroethylene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
oluene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,2-trans-Dichloroethylene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,1,1-Trichloroethane	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
,1,2-Trichloroethane	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
richloroethylene	ug/L	BDL	(5)	NR	-	NR	-	BDL	(5)
inyl chloride	ug/L	BDL	(10)	NR	-	NR	-	BDL	(10)

DL = Below detection limits. NR = Not requested. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

RIORITY POLLUTANT BASE/NEUTRAL ORGANICS

arameter	Units	61882-11		61882-12	
cenaphthene	ug/L	NR	-	BDL	(5)
cenaphthylene	ug/L	NR	-	BDL	(5)
nthracene	ug/L	NR	-	BDL	(5)
enzidine	ug/L	NR	-	BDL	(20)
enzo(a)anthracene	ug/L	NR	-	BDL	(5)
enzo(a)pyrene	ug/L	NR	-	BDL	(5)
,4-Benzofluoranthene	ug/L	NR	-	BDL	(5)
enzo(g,h,i)perylene	ug/L	NR	-	BDL	(5)
enzo(k)fluoranthene	ug/L	NR	-	BDL	(5)
is(2-chloroethoxy)methane	ug/L	NR	-	BDL	(5)
is(2-chloroethyl)ether	ug/L	NR	-	BDL	(5)
is(2-chloroisopropyl)ether	ug/L	NR	-	BDL	(5)
is(2-ethylhexyl)phthalate	ug/L	NR	-	BDL	(5)
-Bromophenyl phenyl ether	ug/L	NR	-	BDL	(5)
utylbenzyl phthalate	ug/L	NR	-	BDL	(5)
-Chloronaphthalene	ug/L	NR	-	BDL	(5)
-Chlorophenyl phenyl ether	ug/L	NR	-	BDL	(5)
hrysene	ug/L	NR	-	BDL	(5)
ibenzo(a,h)anthracene	ug/L	NR	-	BDL	(5)
ibenzofuran	ug/L	NR	-	BDL	(5)
,2-Dichlorobenzene	ug/L	NR	-	BDL	(5)
3-Dichlorobenzene	ug/L	NR	-	BDL	(5)
4-Dichlorobenzene	ug/L	NR	-	BDL	(5)
3'-Dichlorobenzidine	ug/L	NR	-	BDL	(20)
iethyl phthalate	ug/L	NR	-	BDL	(5)
imethyl phthalate	ug/L	NR	-	BDL	(5)
i-n-butyl phthalate	ug/L	NR	-	BDL	(5)
4-Dinitrotoluene	ug/L	NR	-	BDL	(5)
6-Dinitrotoluene	ug/L	NR	-	BDL	(5)

L = Below detection limits. NR = Not requested. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

RIORITY POLLUTANT BASE/NEUTRAL ORGANICS (Cont.)

arameter	Units	61882-11		61882-12	
i-n-octyl phthalate	ug/L	NR	-	BDL	(5)
,2-Diphenylhydrazine*	ug/L	NR	-	BDL	(5)
luoranthene	ug/L	NR	-	BDL	(5)
luorene	ug/L	NR	-	BDL	(5)
exachlorobenzene	ug/L	NR	-	BDL	(5)
exachlorobutadiene	ug/L	NR	-	BDL	(5)
exachlorocyclopentadiene	ug/L	NR	-	BDL	(5)
exachloroethane	ug/L	NR	-	BDL	(5)
ndeno(1,2,3-cd)pyrene	ug/L	NR	-	BDL	(5)
sophorone	ug/L	NR	-	BDL	(5)
-Methylnaphthalene	ug/L	NR	-	BDL	(5)
aphthalene	ug/L	NR	-	BDL	(5)
itrobenzene	ug/L	NR	-	BDL	(5)
-Nitrosodimethylamine	ug/L	NR	-	BDL	(5)
-Nitrosodi-n-propylamine	ug/L	NR	-	BDL	(5)
-Nitrosodiphenylamine*	ug/L	NR	-	BDL	(5)
henanthrene	ug/L	NR	-	BDL	(5)
yrene	ug/L	NR	-	BDL	(5)
,2,4-Trichlorobenzene	ug/L	NR	-	BDL	(5)

DL = Below detection limits.   NR = Not requested.   Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

RIORITY POLLUTANT ACID ORGANICS

arameter	Units	61882-11		61882-12		61882-13	
-Chlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)
,4-Dichlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)
,4-Dimethylphenol	ug/L	BDL	(5)	19	(5)	BDL	(5)
,6-Dinitro-o-cresol	ug/L	BDL	(10)	BDL	(10)	BDL	(10)
,4-Dinitrophenol	ug/L	BDL	(10)	BDL	(10)	BDL	(10)
-Methylphenol	ug/L	NR	-	BDL	(5)	NR	-
-Methylphenol	ug/L	NR	-	BDL	(5)	NR	-
-Nitrophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)
-Nitrophenol	ug/L	BDL	(10)	BDL	(10)	BDL	(10)
-Chloro-m-cresol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)
entachlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)
henol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)
,4,6-Trichlorophenol	ug/L	BDL	(5)	BDL	(5)	BDL	(5)

DL = Below detection limits.   NR = Not requested.   Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

RIORITY POLLUTANT VOLATILE ORGANICS

arameter	Units	61882-11		61882-12	
cetone	ug/L	NR	-	BDL	(10)
crolein	ug/L	NR	-	BDL	(100)
crylonitrile	ug/L	NR	-	BDL	(100)
enzene	ug/L	NR	-	BDL	(5)
romoform	ug/L	NR	-	BDL	(5)
arbon tetrachloride	ug/L	NR	-	BDL	(5)
hlorobenzene	ug/L	NR	-	BDL	(5)
hlorodibromomethane	ug/L	NR	-	BDL	(5)
hloroethane	ug/L	NR	-	BDL	(10)
-Chloroethylvinyl ether	ug/L	NR	-	BDL	(5)
hloroform	ug/L	NR	-	BDL	(5)
ichlorobromomethane	ug/L	NR	-	BDL	(5)
,1-Dichloroethane	ug/L	NR	-	BDL	(5)
,2-Dichloroethane	ug/L	NR	-	BDL	(5)
,1-Dichloroethylene	ug/L	NR	-	BDL	(5)
,2-Dichloropropane	ug/L	NR	-	BDL	(5)
,3-Dichloropropylene (c&t)	ug/L	NR	-	BDL	(5)
thylbenzene	ug/L	NR	-	5	(5)
ethylbromide	ug/L	NR	-	BDL	(10)
ethylchloride	ug/L	NR	-	BDL	(10)
ethylene chloride	ug/L	NR	-	BDL	(10)
,1,2,2-Tetrachloroethane	ug/L	NR	-	BDL	(5)
etrachloroethylene	ug/L	NR	-	BDL	(5)
oluene	ug/L	NR	-	BDL	(5)
,2-trans-Dichloroethylene	ug/L	NR	-	BDL	(5)
,1,1-Trichloroethane	ug/L	NR	-	BDL	(5)
,1,2-Trichloroethane	ug/L	NR	-	BDL	(5)
richloroethylene	ug/L	NR	-	BDL	(5)
inyl chloride	ug/L	NR	-	BDL	(10)

DL = Below detection limits. NR = Not requested. Detection limits in parentheses.

ANALYTICAL RESULTS

for

Geoscience Consultants, Ltd.

URGEABLE ORGANICS - METHOD 602

arameter	Units	61882-03		61882-06		61882-07		61882-08	
enzene	ug/L	ND	(0.5)	ND	(0.5)	ND	(0.5)	ND	(0.5)
hlorobenzene	ug/L	ND	(1)	ND	(1)	ND	(1)	ND	(1)
thylbenzene	ug/L	ND	(1)	ND	(1)	ND	(1)	ND	(1)
oluene	ug/L	6.4	(1)	ND	(1)	ND	(1)	7.2	(1)
2-Dichlorobenzene	ug/L	ND	(2)	ND	(2)	ND	(2)	ND	(2)
3-Dichlorobenzene	ug/L	ND	(2)	ND	(2)	ND	(2)	ND	(2)
4-Dichlorobenzene	ug/L	ND	(2)	ND	(2)	ND	(2)	ND	(2)

arameter	Units	61882-09		61882-11		61882-13	
enzene	ug/L	ND	(5)	ND	(5)	ND	(5)
hlorobenzene	ug/L	ND	(10)	ND	(10)	ND	(10)
thylbenzene	ug/L	ND	(10)	39	(10)	ND	(10)
oluene	ug/L	58	(10)	140	(10)	70	(10)
2-Dichlorobenzene	ug/L	ND	(20)	ND	(20)	ND	(20)
3-Dichlorobenzene	ug/L	ND	(20)	ND	(20)	ND	(20)
4-Dichlorobenzene	ug/L	ND	(20)	ND	(20)	ND	(20)

D = Not detected. Detection limits in parentheses.

ION BALANCE RESULTS
for sample #61882-01

CATION ANALYSIS

ELEMENT	mg/L	meq/L
Ca	635.000	31.6865
Fe+2	1.700	0.0153
Fe+3	ND	0.0000
Mg	451.000	37.1173
K	2.600	0.0666
Na	637.000	27.7095
NH4	ND	0.0000
TOTAL	1727.300	96.5952

ANION ANALYSIS

ELEMENT	mg/L	meq/L
Cl	904.000	25.4928
F	2.000	0.0512
SO4	3430.000	71.3440
Alk	230.400	7.6800
NO2+NO3	1.700	0.1214
TOTAL	4568.100	104.6894

SUMMARY

% DIFFERENCE =-4.021
CATIONS + ANIONS (mg/L) =6295.400
TDS =%7420.000
HARDNESS =3436.600
CALCULATED THEORETICAL CONDUCTIVITY =%13244.0527
MEASURED CONDUCTIVITY = 1.0000
THEORETICAL/MEASURED CONDUCTIVITY RATIO =%13244.053
MEASURED CONDUCTIVITY/TDS RATIO = 0.000

ND - Not Detected

ION BALANCE RESULTS
for sample #61882-04

CATION ANALYSIS

ELEMENT	mg/L	meq/L
Ca	986.000	49.2014
Fe+2	19.000	0.1710
Fe+3	ND	0.0000
Mg	248.000	20.4104
K	9.000	0.2304
Na	1990.000	86.5650
NH4	ND	0.0000
TOTAL	3252.000	156.5782

ANION ANALYSIS

ELEMENT	mg/L	meq/L
Cl	3080.000	86.8560
F	5.500	0.1408
SO4	3000.000	62.4000
Alk	289.800	9.6600
NO2+NO3	2.100	0.1499
TOTAL	6377.400	159.2067

SUMMARY

% DIFFERENCE =-0.832
CATIONS + ANIONS (mg/L) =9629.400
TDS =%10100.000
HARDNESS =3481.800
CALCULATED THEORETICAL CONDUCTIVITY =%20425.8847
MEASURED CONDUCTIVITY = 1.0000
THEORETICAL/MEASURED CONDUCTIVITY RATIO =%20425.885
MEASURED CONDUCTIVITY/TDS RATIO = 0.000

ND - Not Detected

```
                          ION BALANCE RESULTS
                          for sample #61882-05


                            CATION ANALYSIS
ELEMENT                         mg/L                             meq/L
------------------------------------------------------------------------
Ca                            703.000                           35.0797
Fe+2                            7.500                            0.0675
Fe+3                               ND                            0.0000
Mg                            296.000                           24.3608
K                               7.200                            0.1843
Na                           1220.000                           53.0700
NH4                                ND                            0.0000

------------------------------------------------------------------------
TOTAL                        2233.700                          112.7623
------------------------------------------------------------------------


                             ANION ANALYSIS
ELEMENT                         mg/L                             meq/L
------------------------------------------------------------------------
Cl                           1210.000                           34.1220
F                               2.900                            0.0742
SO4                          2760.000                           57.4080
Alk                           768.000                           25.6000
NO2+NO3                            ND                            0.0000

------------------------------------------------------------------------
TOTAL                        4740.900                          117.2042
------------------------------------------------------------------------


                                SUMMARY
------------------------------------------------------------------------
% DIFFERENCE =-1.932
CATIONS + ANIONS (mg/L) =6974.600
TDS =%8080.000
HARDNESS =2971.100
CALCULATED THEORETICAL CONDUCTIVITY =%14385.3307
MEASURED CONDUCTIVITY =   1.0000
THEORETICAL/MEASURED CONDUCTIVITY RATIO =%14385.331
MEASURED CONDUCTIVITY/TDS RATIO =    0.000


ND - Not Detected
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                              ION BALANCE RESULTS
                              for sample #61882-10


                               CATION ANALYSIS
ELEMENT                          mg/L                                 meq/L
-----------------------------------------------------------------------------
Ca                             900.000                               44.9100
Fe+2                             1.300                                0.0117
Fe+3                                ND                                0.0000
Mg                             601.000                               49.4623
K                                9.100                                0.2330
Na                            2020.000                               87.8700
NH4                                 ND                                0.0000

-----------------------------------------------------------------------------
TOTAL                         3531.400                              182.4870
-----------------------------------------------------------------------------


                                ANION ANALYSIS
ELEMENT                          mg/L                                 meq/L
-----------------------------------------------------------------------------
Cl                            4250.000                              119.8500
F                                1.000                                0.0256
SO4                           3080.000                               64.0640
Alk                            234.600                                7.8200
NO2+NO3                             ND                                0.0000

-----------------------------------------------------------------------------
TOTAL                         7565.600                              191.7596
-----------------------------------------------------------------------------


                                   SUMMARY
-----------------------------------------------------------------------------
% DIFFERENCE =-2.478
CATIONS + ANIONS (mg/L) =%11097.000
TDS =%14900.000
HARDNESS =4714.100
CALCULATED THEORETICAL CONDUCTIVITY =%24321.3227
MEASURED CONDUCTIVITY =    1.0000
THEORETICAL/MEASURED CONDUCTIVITY RATIO =%24321.323
MEASURED CONDUCTIVITY/TDS RATIO =    0.000


ND - Not Detected
```

ION BALANCE RESULTS
for sample #61882-12

CATION ANALYSIS

ELEMENT	mg/L	meq/L
Ca	143.000	7.1357
Fe+2	2.700	0.0243
Fe+3	ND	0.0000
Mg	27.000	2.2221
K	9.300	0.2381
Na	150.000	6.5250
NH4	ND	0.0000
TOTAL	332.000	16.1452

ANION ANALYSIS

ELEMENT	mg/L	meq/L
Cl	202.000	5.6964
F	2.100	0.0538
SO4	257.000	5.3456
Alk	110.400	3.6800
NO2+NO3	ND	0.0000
TOTAL	571.500	14.7758

SUMMARY

% DIFFERENCE = 4.429
CATIONS + ANIONS (mg/L) = 903.500
TDS =%1200.000
HARDNESS = 468.200
CALCULATED THEORETICAL CONDUCTIVITY =1918.0087
MEASURED CONDUCTIVITY = 1.0000
THEORETICAL/MEASURED CONDUCTIVITY RATIO =%1918.009
MEASURED CONDUCTIVITY/TDS RATIO = 0.001

ND - Not Detected

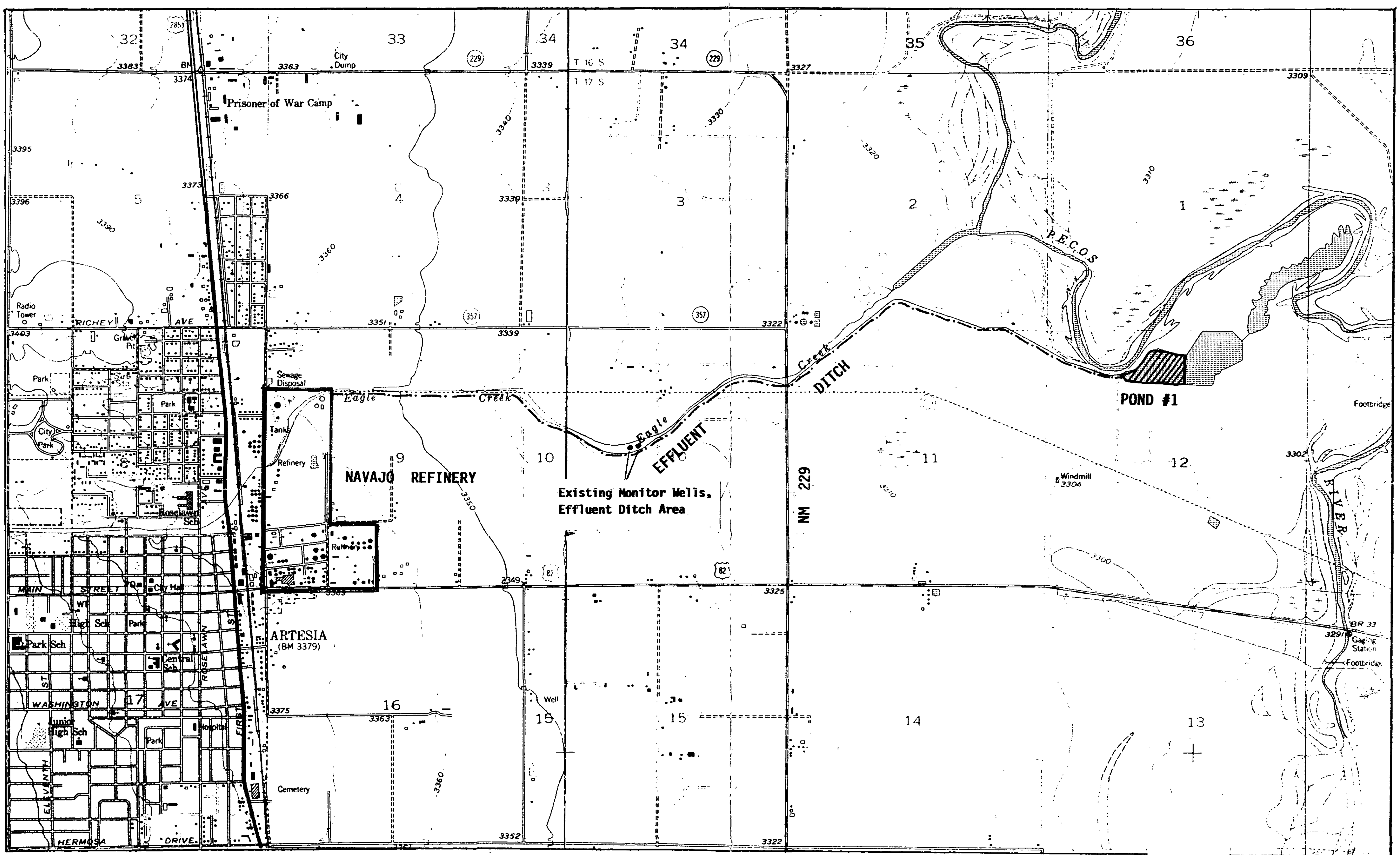
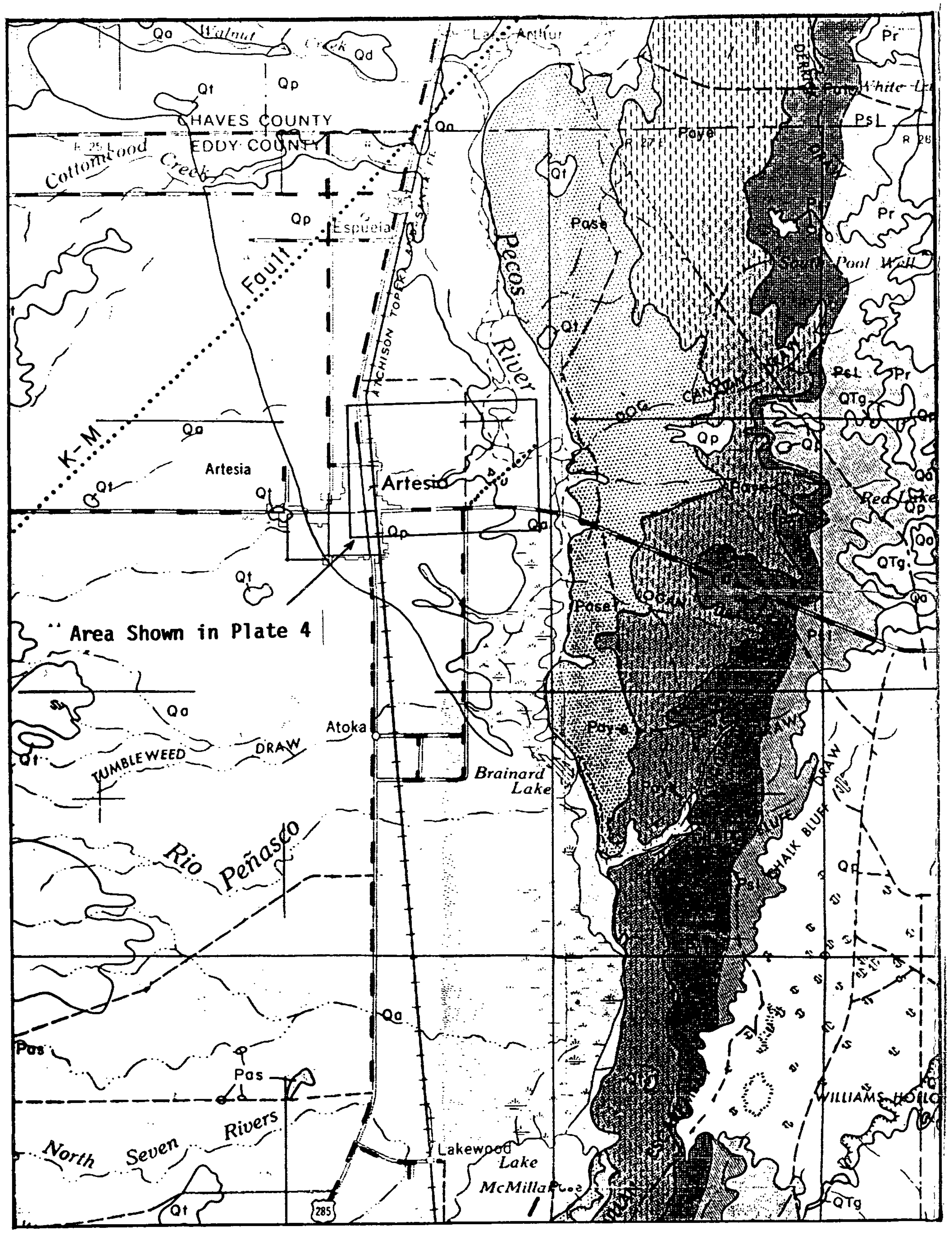


Plate 1

Location Map of Navajo Refinery Area Showing Refinery, Ditch and Ponds



SEDIMENTARY ROCKS

Qa **Qs** **Qe** **Ql** **Qd** **Qtr** **Qt** **Qp** **Qc**

Surficial Deposits

Qa, alluvium of stream and valley bottoms; Qs, caliche soil; Qe, blow sand and dunes; Ql, landslides; Qd, disturbed gravel, etc. affected by collapse; Qtr, travertine spring deposits; Qt, terrace gravel; Qp, pediment gravel; Qc, caliche

QTg

Gatuna Formation

Red, tan, and buff sand, gravel, and mudstone

TERTIARY QUATERNARY

TKc

Cub Mountain Formation

Purplish mudstone and buff, conglomeratic sandstone

Kmv

Mesaverde Group

Olive-drab to black shale, grayish sandstone, and coal

Km

Mancos Shale

Black shale, local sandstone, and limestone

Kd

Dakota Sandstone

Gray to white sandstone, local shale, and conglomerate

CRETACEOUS

Ꞁc

Chinle Formation

Reddish-brown mudstone

Ꞁs

Santa Rosa Formation

Brown, buff, and red sandstone; local conglomerate

TRIASSIC

Pd

Dewey Lake Formation

Tan-brown, clean sandstone

Pr **Pru** **Prl**

Rustler Formation

Dolomite, gypsum, and reddish sandstone; Pru, upper member; Prl, lower member

Psl

Salado Formation

Gypsum, dolomite, mudstone, and orange-red, collapsed, recrystallized, residual breccia

Pc **Pcu** **Pcl**

Castile Formation

Gypsum, anhydrite and limestone; Pcu, upper member; Pcl, lower member

EXPLANATION

Artesia Group

Pat

Tansill Formation

Dolomite intertonguing northward into gypsum

Pay **Paye**

Yates Formation

Pay, limestone, sandstone, and dolomite southward
Paye, gypsum, dolomite, and siltstone northward

Pas **Pase**

Seven Rivers Formation

Pas, limestone and dolomite southward
Pase, gypsum, mudstone and then dolomite northward

Paq **Pag** **Paqg**

Queen and Grayburg Formations

Paq, Queen Formation; dolomite and sandstone southward; gypsum and mudstone northward
Pag, Grayburg Formation; sandstone and dolomite southward; gypsum, red sandstone, and local dolomite northward
Paqg, Queen and Grayburg Formations undivided in north and locally elsewhere

Pac

Capitan Limestone

Pbc

Bell Canyon Formation

Basin-facies limestone and sandstone

Pgs

Goat Seep Formation

Massive dolomite

Psf **Psb** **Psr** **Psbr** **Psg**

San Andres Formation

Psf, Fourmile Draw Member; Psb, Bonney Canyon Member; Psr, Rio Bonito Member; Psg, Glorieta Sandstone

Py

Yeso Formation

Tan, yellow and rusty sandstone, red mudstone, dolomite, and gypsum

PERMIAN

Precambrian rocks, undivided

Granite, syenite, and gneiss

PRECAMBRIAN

IGNEOUS ROCKS

Tsb

Sierra Blanca Volcanic Group

Andesitic to rhyolitic breccia, tuff, and flows

Dikes, sills, stocks, and laccoliths

Ti, not identified; Tis, syenite or latite; Tig, granite or aplite; Tir, rhyolite; Tim, monzonite; Tid, diorite or diabase

TERTIARY

PLATE 4 Geologic Map of Artesia Area

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JAN 12 1987
OIL CONSERVATION DIVISION
SANTA FE

NAVAJO REFINING CO., INC.

PLATE 2

NAVAJO PONDS
SITUATE WITHIN
SECTIONS 1 & 12, T 17 S, R 26 E, N.M.P.M.,
EDDY COUNTY, NEW MEXICO

JOHN WEST ENGINEERING CO.
CONSULTANTS
HOBBS NEW MEXICO

Surveyed By J. Lowe	Drawn By G. Mitchell	Last Rev. Date	Drawing Number
[illegible]	Date 7/18/86	File No.	
[illegible] 7/17/86	Checked By	Sheet 1 of 1	

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JAN 1 2 1987
OIL CONSERVATION DIVISION
SANTA FE

FOR REFERENCE ONLY

NOTES	REFERENCE DRAWINGS	NO.	REVISIONS	BY	CHK.	DATE	APPR.	APPR.	NO.	REVISIONS	BY	CHK.	DATE	APPR.	APPR.

DRAWING TITLE

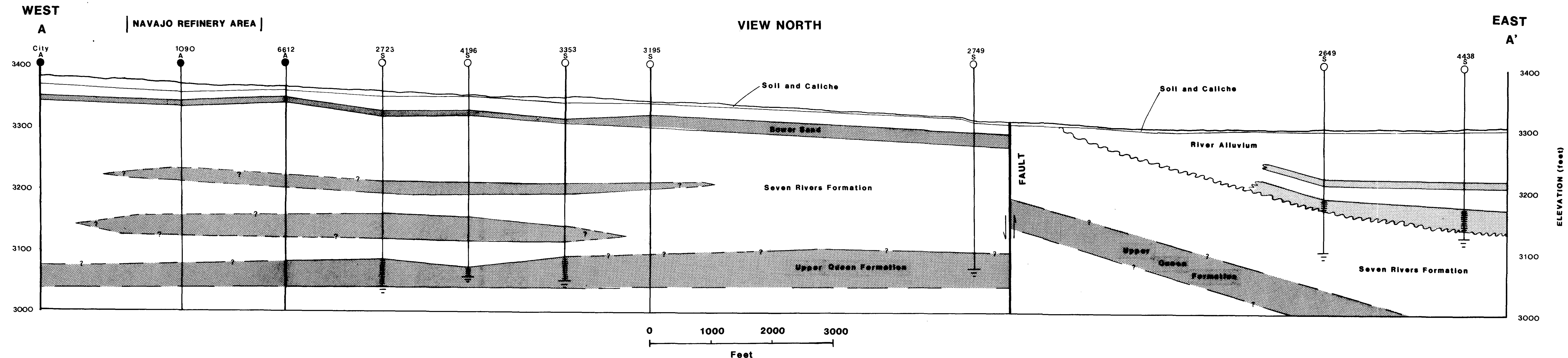
NAVAJO PONDS

WELL LOCATIONS

PLATE 3

Navajo REFINING COMPANY
ENGINEERING DEPARTMENT
ARTESIA, NEW MEXICO

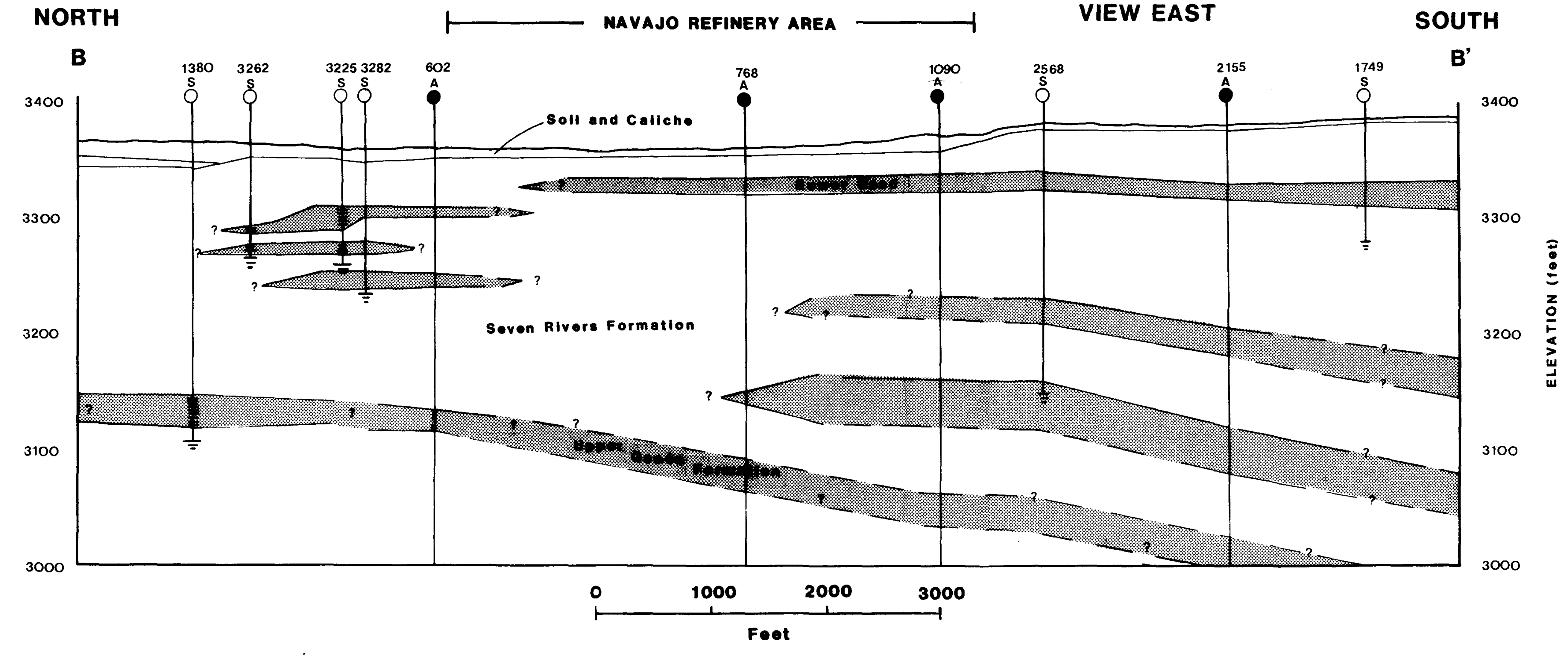
DRAWN BY	CHK'D BY	SCALE	
GLS		1" = 200'	
DATE	DATE	DRAWING NO.	REV.
5-30-85		102 - 09 - D	0



▨ PERMEABLE BEDROCK

☐ IMPERMEABLE BEDROCK

VERTICAL EXAGGERATION -10X



VERTICAL EXAGGERATION - 10X

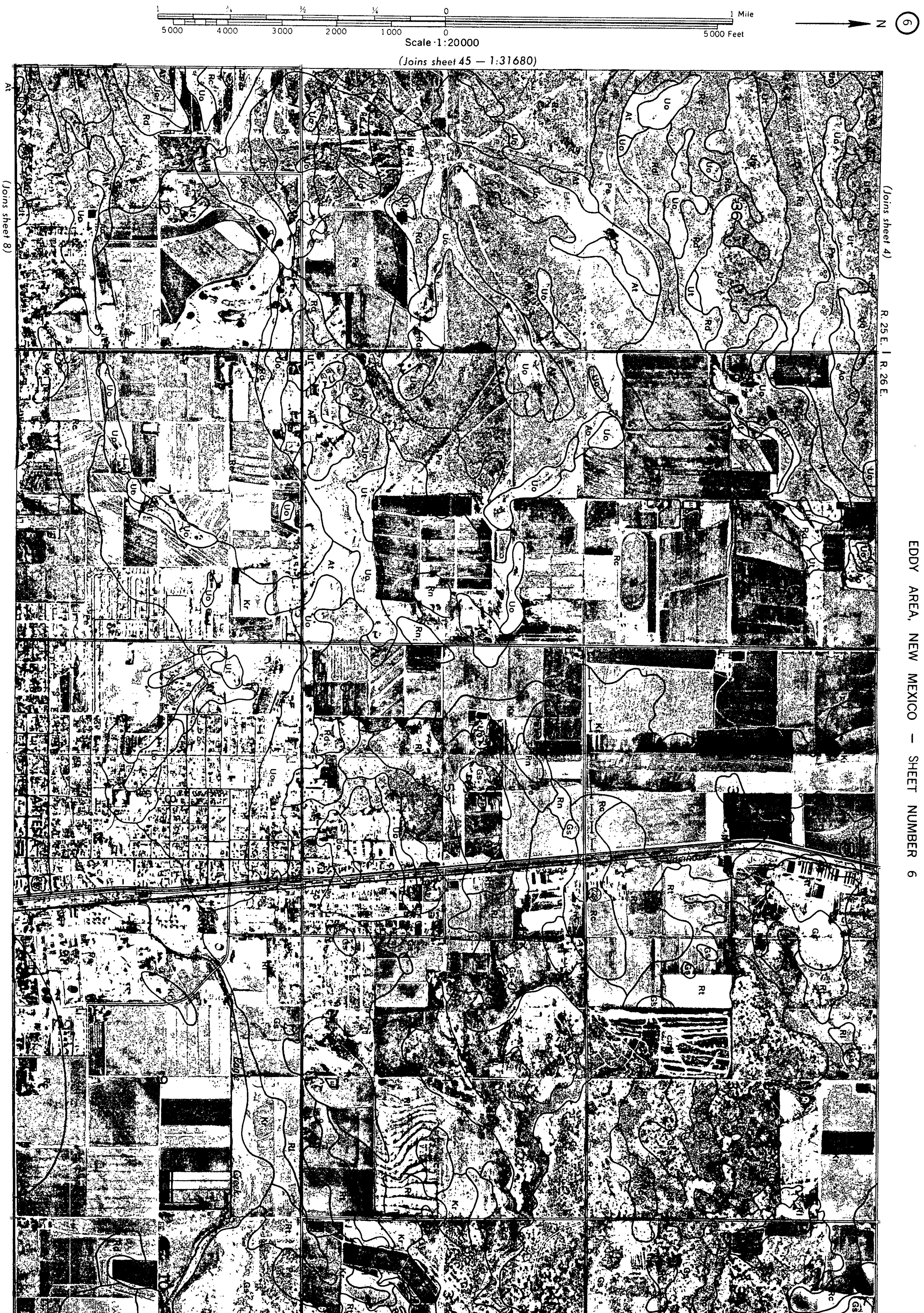
WELLS PROJECTED ONTO NORTH-SOUTH CROSS SECTION

Geoscience Consultants, Ltd.

PLATE 9

CROSS SECTIONS
NAVAJO REFINING COMPANY AND
ARTESIA , NEW MEXICO AREA

CLIENT: NAVAJO REFINING CO.
DATE: 10/11/84
DRAWN BY: Anita Larson
CHECKED BY: Randy Hicks
REVISED:
SCALE: 1:22,000(H) 1:1200(V)



EDDY AREA, NEW MEXICO — SHEET NUMBER 6

PLATE 7
MAP SHOWING SOIL TYPES, ARTESIA AREA

EDDY AREA, NEW MEXICO NO. 6

Land division corners are approximately positioned on this map.

This map is one of a set compiled in 1968 as part of a soil survey by the Soil Conservation Service, United States Department of Agriculture and the New Mexico Agricultural Experiment Station.

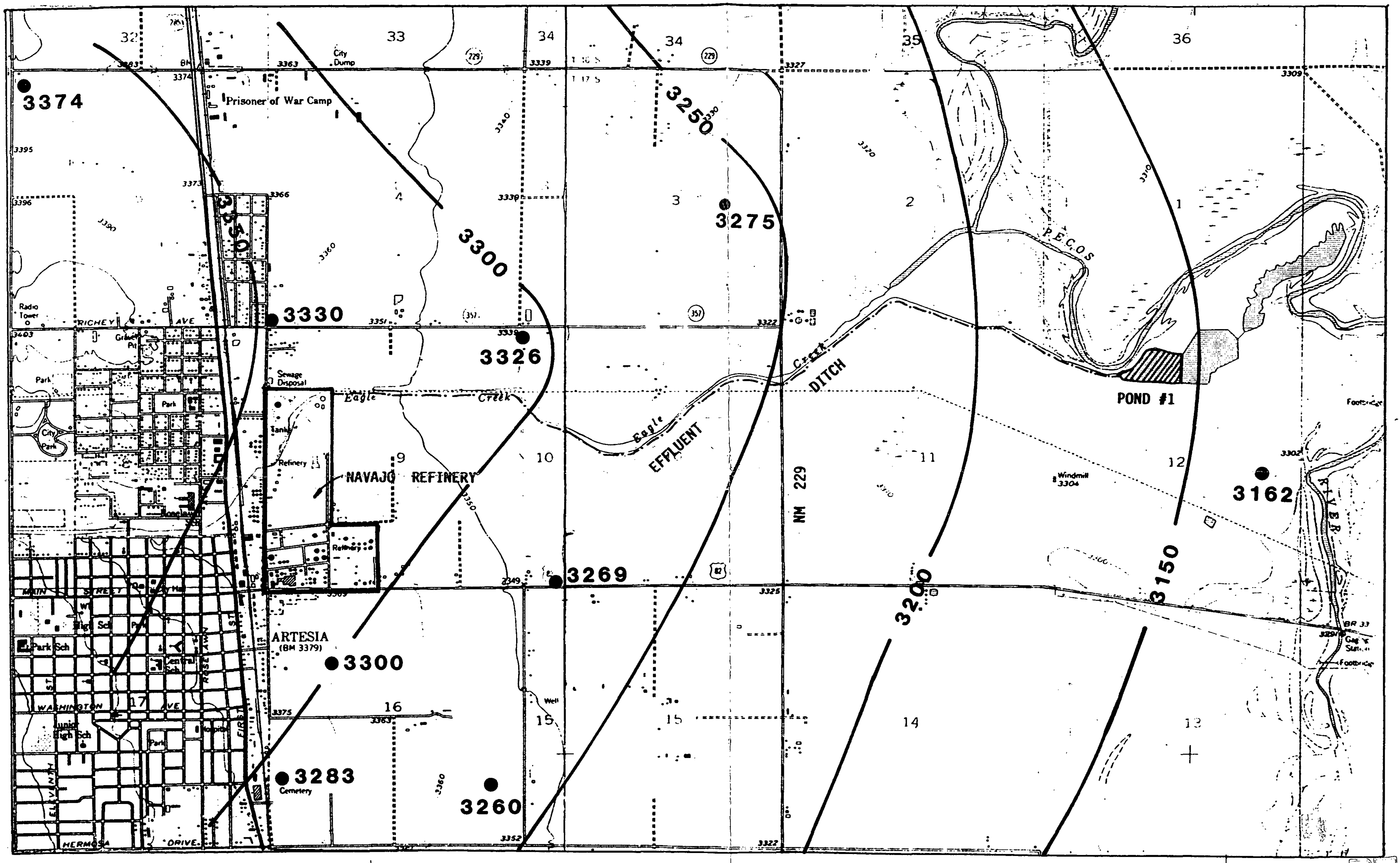
This map is one of a set compiled in 1968 as part of a soil survey by the Soil Conservation Service, United States Department of Agriculture, and the New Mexico Agric
Land division corners are approximately positioned on this map.

EDDY AREA, NEW MEXICO NO. 7

RECEIVED
JAN 1 2 1987
OIL CONSERVATION DIVISION
SANTA FE

PLATE 8
MAP SHOWING SOIL TYPES, ARTESIA AREA

⑦



CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

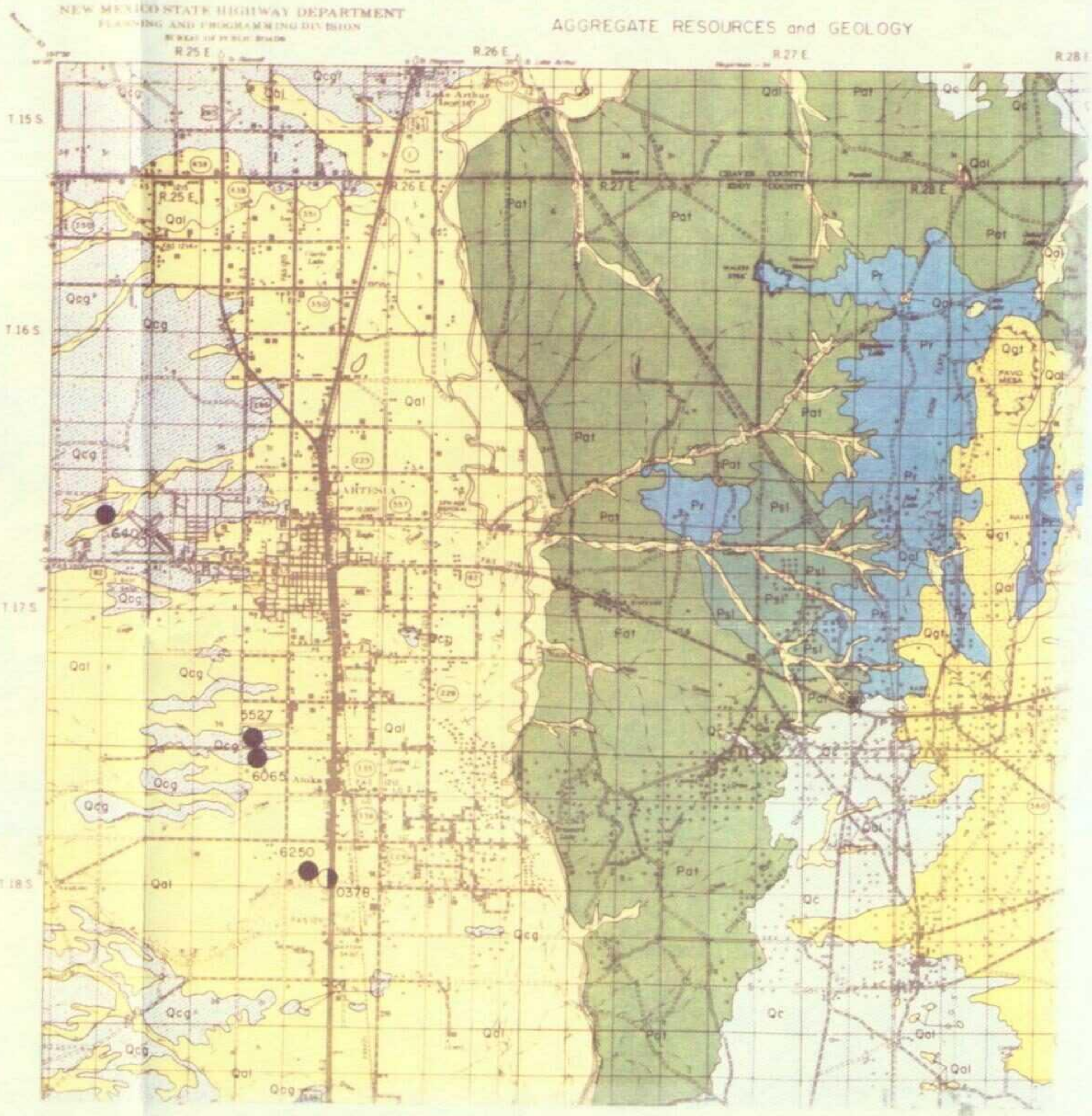
POTENTIOMETRIC SURFACE
QUEEN AQUIFER

PLATE 10

EXPLANATION

QUATERNARY	Qal	Alluvium Silt, sand, gravel and clay. Stippled area indicates granular or gravelly deposits.
	Qe	Eolian deposits Wind-blown sand
	Qc	Caliche deposits Medium to hard, nodular, caliche, locally having a well-cemented caprock
	Qab	Alluvium and bolson deposits Sand, silt and clay deposited in lowlands; rarely having local incrustations of soft nodular caliche
	Qcg	Caliche and gravel Caliche-capped limestone gravel, sand, silt and clay underlain locally by deposits of lime-cemented conglomerate
	Qgt	Gatuña Formation Well indurated sand, gravel, silt and clay derived from the Ogallala formation
	Pr	Rustler Formation Anhydrite, gypsum, interbedded red and green sandy clay, and some beds of dolomite
PERMIAN	Psl	Salado Formation Residual material derived from the solution of halite, anhydrite, polyhalite and other potassium salts and red sandy shale
	Pt	Tansill Formation Light olive-gray to very pale orange, fine-grained, laminated dolomite, and rare, thin beds of very pale orange, fine-grained quartz sandstone or siltstone
	Pya	Yates Formation Very pale orange to yellowish-gray, fine-grained, laminated dolomite, alternating with grayish-orange to pale yellowish-orange, calcareous quartz siltstone or very fine-grained sandstone
	Psr	Seven Rivers Formation Gray to white dolomitic limestone, white and red gypsum, orange-red siltstone and shale
	Pq	Queen Formation Red to white gypsum, interbedded sandstone, siltstone and dolomite. Surface exposures are primarily evaporite.
	Pat	Artesia group undivided Primarily red to white gypsum with some interbeds of dolomite, sandstone and siltstone. This essentially represents a lateral facies change where the Seven Rivers, Queen, Yates and Tansil formations become indistinguishable as separate units.

●	Developed pit or quarry
◐	Prospect pit or quarry
*	Selected exploration sites



Surficial Geology of Artesia Area

PLATE 5

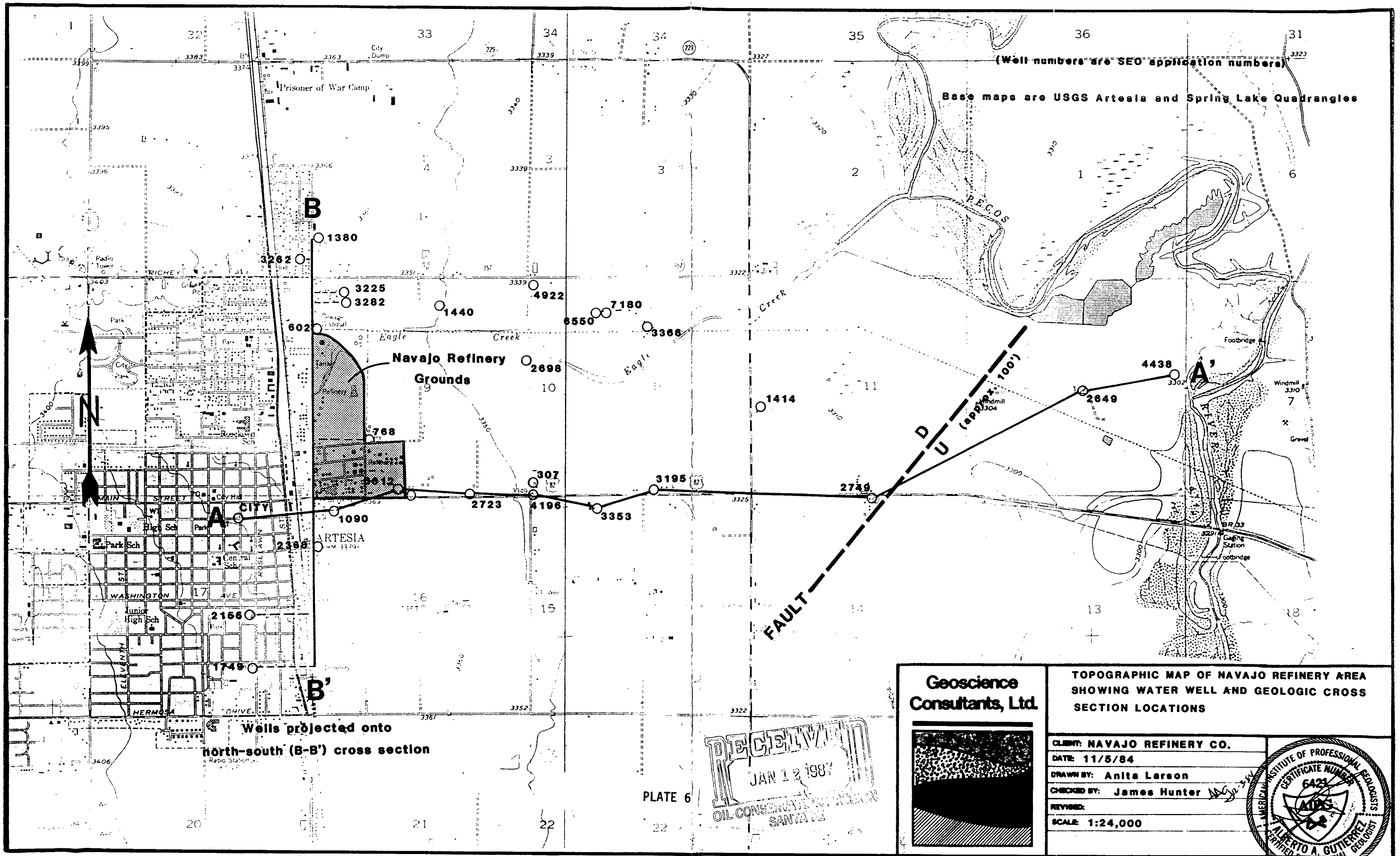


PLATE 6

Geoscience Consultants, Ltd.

TOPOGRAPHIC MAP OF NAVAJO REFINERY AREA SHOWING WATER WELL AND GEOLOGIC CROSS SECTION LOCATIONS

CLIENT: NAVAJO REFINERY CO.
DATE: 11/5/84
DRAWN BY: Anita Larson
CHECKED BY: James Hunter
REVISED:
SCALE: 1:24,000

6421
ALBERTO A. GUTIERREZ

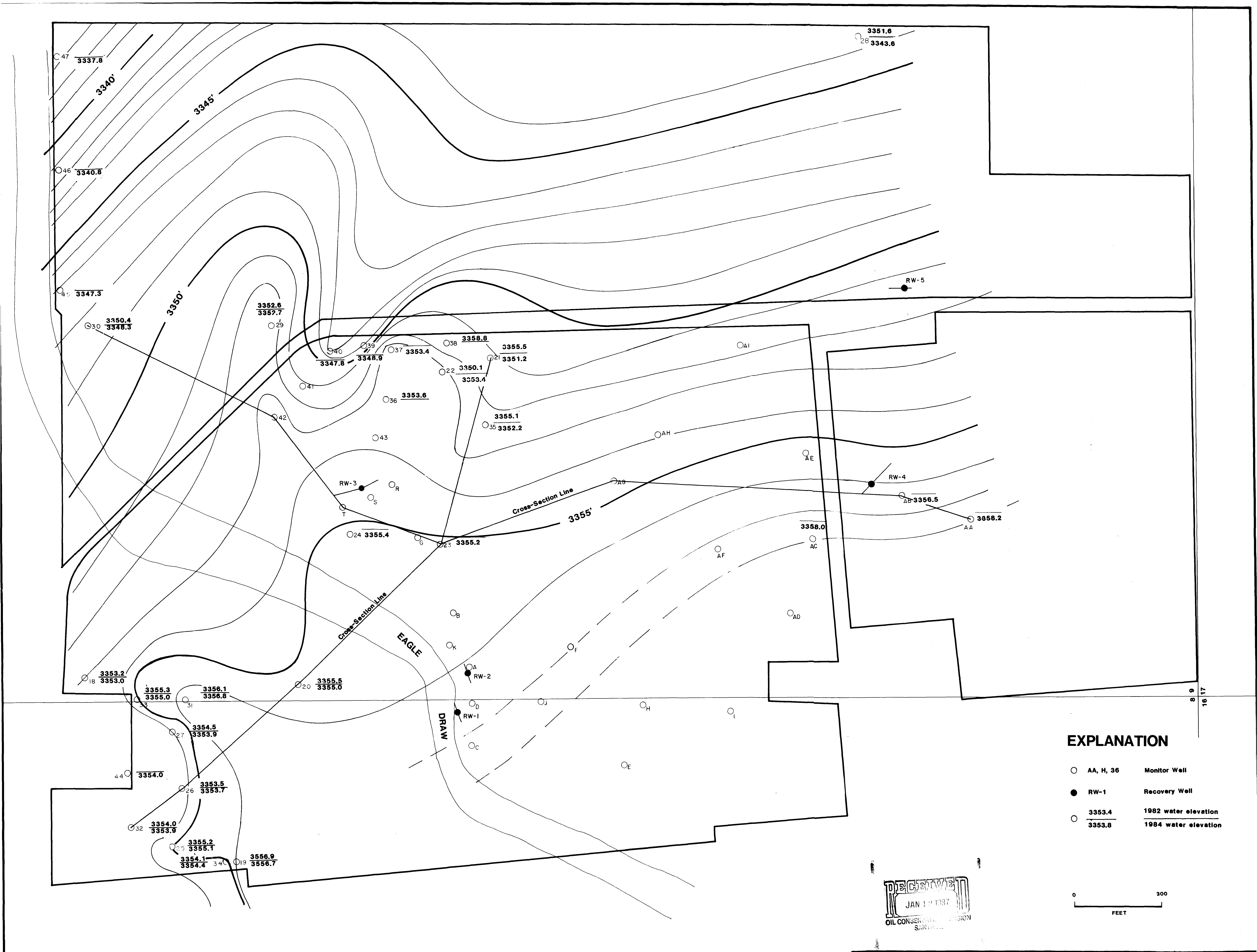


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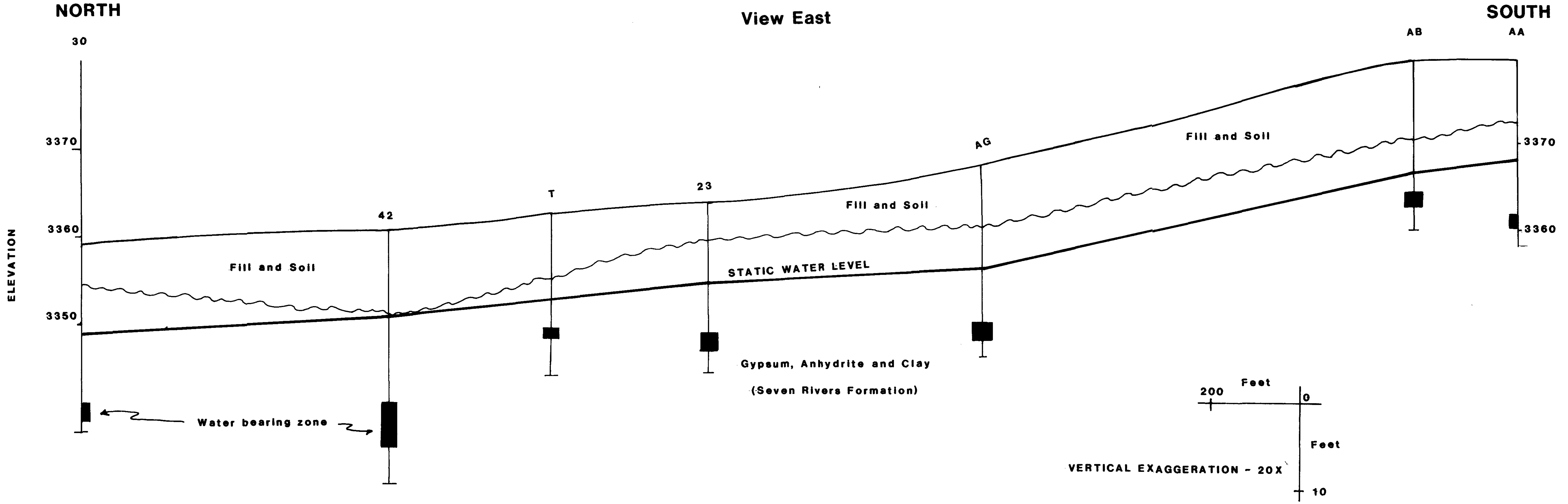
PLATE 11

POTENTIOMETRIC SURFACE

SHALLOW PERCHED AQUIFER

NAVAJO REFINING COMPANY ARTESIA , NEW MEXICO

CLIENT:	NAVAJO REFINING COMPANY
DATE:	November 9, 1984
DRAWN BY:	James Hunter
CHECKED BY:	
REVISED:	
SCALE:	1 [illegible] equals 150 feet



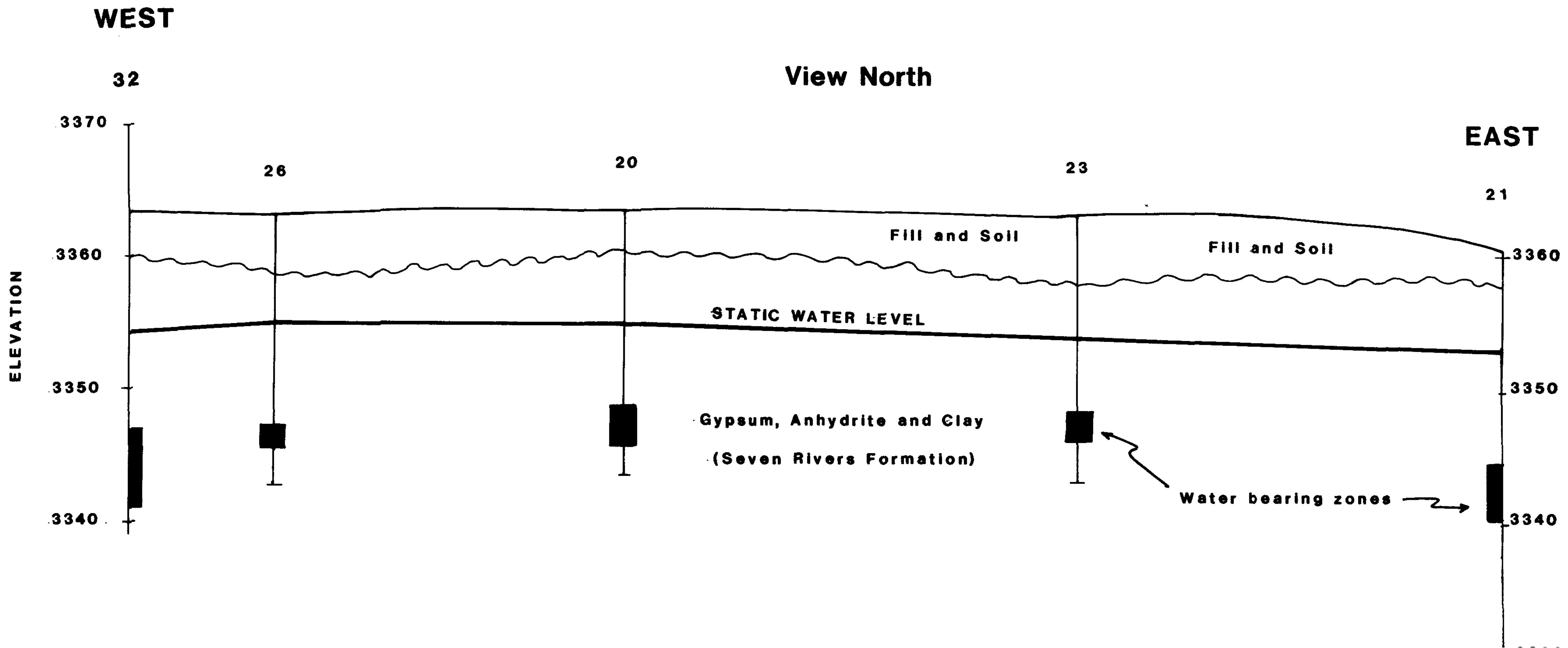


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PLATE 12

HYDROGEOLOGIC CROSS SECTION OF REFINERY SITE AREA

CLIENT: NAVAJO REFINING CO.
DATE: 11/5/84
DRAWN BY: Anita Larsen
CHECKED BY: James Hunter
REVISED:
SCALE:

PLATE 13

POTENTIOMETRIC SURFACE

VALLEY FILL AQUIFER
EVAPORATION POND AREA

CLIENT:	NAVAJO REFINING COMPANY
DATE:	November 9, 1984
DRAWN BY:	James Hunter
CHECKED BY:	
REVISED:	JCH12-28-84
SCALE:	1 inch equals 200 feet

Base Map by: R.E. Lamb Engineering

GCL