GW - 28

MONITORING REPORTS

DATE:

1987

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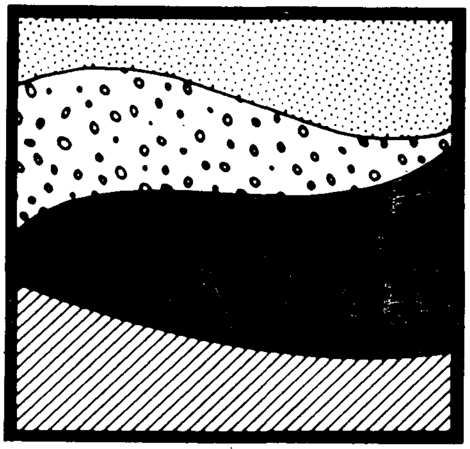
GCL



VOLUME I

FINAL REPORT
GROUND WATER INVESTIGATIONS OF POND #1 AND CONVEYANCE DITCH, NAVAJO REFINING COMPANY, ARTESIA, NEW MEXICO

May 12, 1987

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OIL CONSERVATION DIVISION
SANTA FE

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TABLE OF
CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

SECTION 1.0

1.0 EXECUTIVE SUMMARY

The Navajo Refining Company (Navajo) operates a petroleum refining facility in Artesia, New Mexico that processes approximately 40,000 barrels of crude oil per day. Refinery wastes include 400,000 gallons per day of wastewater that is discharged to unlined evaporation ponds via an unlined conveyance ditch. Sludge samples from the ditch and Pond #1, collected by the New Mexico Environmental Improvement Division (NMEID), indicated the presence of hazardous constituents. Following discussions with NMEID, Navajo and Geoscience Consultants Ltd. (GCL) prepared a plan to determine potential impacts to ground water underlying the ditch and pond.

Investigations have shown that the minor releases to ground water have occurred from the pond, but no contamination from the ditch has been detected. Existing ground water contamination consists of part-per-billion levels of dissolved toluene, ethylbenzene and xylenes in the shallow, saline valley-fill aquifer south (downgradient) of the pond. No samples contained concentrations of these constituents at levels in excess of state and Federal drinking water standards.? Human exposure is very unlikely, due to the saline (average total dissolved solids content 26,000 mg/l) nature of the affected aquifer.

No

The affected aquifer is not interconnected with local or regional sources of drinking water in any way that could allow contaminant migration to those water resources. The valley-fill aquifer ultimately discharges to the Pecos River, the waters of which are used only for agricultural purposes. Limited sampling has shown no detectable levels of the ground water contaminants in the river.

Have potable water

SECTION 2.0

2.0 LOCATION, PURPOSE AND BACKGROUND

2.1 LOCATION

Navajo Refining Company operates a 40,000 barrel-per-day petroleum refinery in Artesia, New Mexico (Plates 1, 2 and Figure 2-1). The refinery's plant facilities are located in the western ½ of Section 9, Township 17 S., Range 26 E. Refinery wastewater flows through a conveyance ditch crossing Sections 9, 10, 11, 2 and 12 of T. 175., R. 26 E., and is discharged to evaporation ponds in Sections 1 and 12 of T. 175., R. 26 E. and the southwest ¼ of Section 1, T. 17 S., R. 27 E. (Plate 2).

The refinery site lies at an elevation of approximately 3370 feet MSL, and the evaporation ponds are at an approximate elevation of 3310 feet MSL.

2.2 PURPOSE

In 1986, a site visit and sampling conducted by the New Mexico Environmental Improvement Division (NMEID) indicated that hazardous waste constituents were present in sludges found in the conveyance ditch and Evaporation Pond #1. A Consent Order was prepared, requiring Navajo Refining Company to identify those hazardous waste constituents which might be present in the ditch and Pond #1, and to determine the potential impacts of these wastes on ground water in the area of the waste units.

The NMEID Consent Order required Navajo to address 12 major items (Appendix A). The sections of this report in which these items are addressed are identified at the end of the description of each item.

1) A proposed schedule for implementation of the items below, and for regular reporting of results to NMEID: SECTION 2.4

2) The manner in which wastes/constituents are stored, treated or disposed of, including whether all or part of the wastes were or are containerized and the depth of burial of any such wastes: SECTION 3.0

3) The location and amounts of all chemical and other wastes identified by EPA as hazardous constituents in 40 CFR 261, that have been stored, treated or disposed of or may be located on the site (Pond #1 and the conveyance ditch): SECTION 4.0

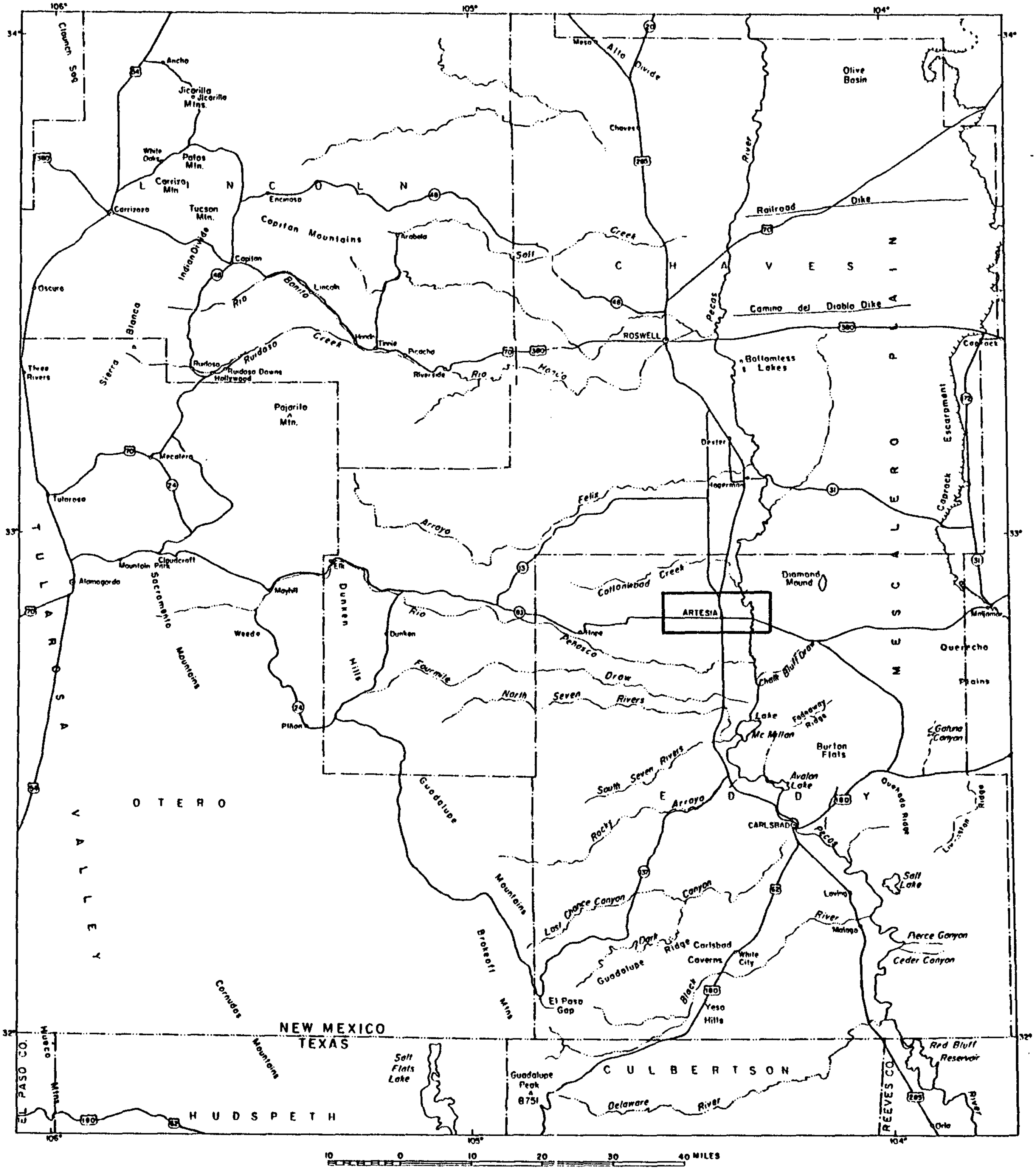


Figure 2-1 General Location Map

4) A description of the facility in which the waste constituents were or are being stored, treated or disposed of; together with available engineering plans, specifications or drawings of these facilities. If such plans or specifications are unavailable, Navajo should submit their best available descriptions regarding the existence and characteristics of such items as liners, leachate collection systems or other waste containment systems: SECTIONS 3.0 AND 4.0

5) A determination of soils including depths, types, characteristics, areal distributions, horizontal and vertical permeabilities and other chemical and physical characteristics: SECTION 5.0

6) Definition of the geologic and geohydrologic characteristics of unconsolidated and bedrock units, including lithology and structure, and the properties of any bedrock aquifers likely to be impacted by migration of waste constituents from the site: SECTION 5.0

7) Determination of flow paths and areas of recharge and discharge in water-bearing units likely to be affected by potential discharges from the waste units: SECTION 6.0

8) Investigation of the interactions between the Pecos River and local ground water: SECTION 6.0

9) Establishment of a permanent network of monitoring wells adjacent to the ditch and Pond #1: SECTION 6.0

10) Sampling and analysis of ground water for waste constituents identified in Pond #1 and the ditch: SECTION 7.0

11) Plans for definition of any contaminant plumes in ground water: SECTION 7.0

12) Plans for corrective action: SECTION 8.0

In response to the Consent Order, Navajo and GCL prepared a proposal to investigate the potential impacts to ground water from the ditch and Pond #1. The proposal was verbally approved by NMEID on December 1, 1986, and written confirmation was provided on February 9, 1987. This report summarizes the results of this investigation.

2.3 BACKGROUND

Navajo Refining Company processes approximately 40,000 barrels of crude oil per day, obtained from oil fields in New Mexico and Western Texas.

Primary products include gasoline, diesel fuel, aviation fuel and paving asphalt. Process water is obtained from wells completed in the San Andres aquifer (see Section 5.3). The refinery discharges approximately 400,000 gallons of wastewater per day to the evaporation ponds. This wastewater has a total dissolved solids (TDS) content of 2000-4000 mg/l and also contains trace amounts of petroleum hydrocarbons.

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 the investigations in this field study (Figure 3-1). The ditch (Plates 1 and 2) is approximately 15,000 feet in length, 3 to 4 feet wide, 1 to 2 feed 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, Harkey and Karro series (see Section 5.2). The ditch lies approximately parallel to the path of a natural drainage (Eagle Creek). The ditch is <u>not</u> in Eagle Creek, but rather parallels the natural drainage on a bench whose elevation is approximately 3 to 5 feet above the stream's bed (Plate 1). No plans or specifications were prepared when the ditch was built, and none are currently available.

Pg. 27 [illegible]
[illegible] +
[illegible]
[illegible]
+ [illegible]

The conveyance ditch begins at the discharge from the oil-water separator on the northeast side of the refinery, and is typically 3-4 feet wide and several feet deep. The ditch is bermed along its course to prevent overflow or influx of surface water (storm-water 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 than an oily sludge accumulates in the bottom of the conveyance ditch. NMEID analyses (see Section 4.0) indicate that this sludge contains certain hazardous constituents. This sludge may also act as a "natural" liner and limit infiltration of organic and inorganic constituents by reducing the permeability of the ditch sides and bottom.

No ditch wastes are or have ever been containerized. The "depth of burial" of these wastes is essentially the depth of the ditch, which varies from 3 to 5 feet below grade. When sludge accumulations fill the

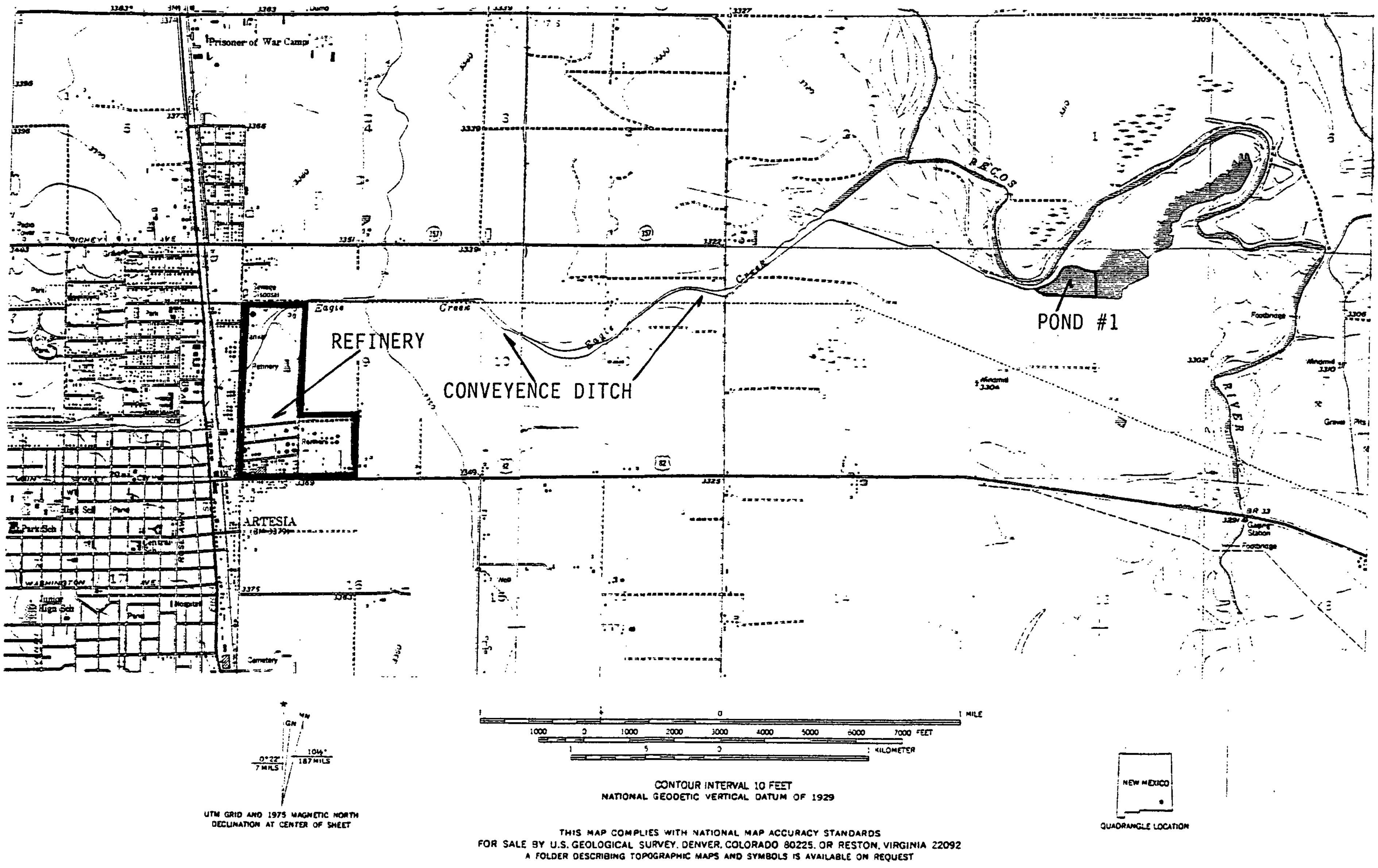


Figure 3-1 Map of Refinery Site and Artesia, New Mexico Area
(Note: Ponds Shown in 1975 Configuration, Spring Lake Quadrangle Map)

ditch, the sludge is removed by backhoe and added to the ditch's berm.

Navajo is presently in the process of installing an underground pipeline to replace the existing ditch. This pipeline is constructed of high-density polyethylene with thermally-welded joints.

3.2 EVAPORATION POND #1

Wastewater from the conveyance ditch flows directly into Pond #1 (Plate 3). Pond #1 has a surface area of 16.1 acres, and is contained by earthen dikes with its bottom at approximately the local grade. Wastewater is typically 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 5.2). 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.

Sludges that have accumulated in Pond #1 also contain some hazardous constituents (see Section 4.0). The sludge is present as a layer 1 to 2 feet in thickness. None of the pond sludges have been containerized, and their "depth of burial" is essentially the thickness of the sludge, 1 to 2 feet.

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 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. Some wastewater may, by seepage, reach the Pecos River. This is discussed in Sections 6.0 and 7.0.

4.0 WASTE CONSTITUENT IDENTIFICATION

This section outlines the sampling and analysis 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 the scheduled ground water monitoring programs (see Section 6.0). This section also includes rough calculations of waste volumes.

4.1 EVAPORATION POND #1

4.1.1 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 (Figure 4-1) and a random-numbers table was used to select 4 individual sampling sites in each area. The pond areas were selected on the basis of three natural divisions: 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 a 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 where they were held 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. Samples sites were reached by use of a small boat, except in the western "delta" area. There, the water was too shallow to maneuver the boat and all four samples were collected from randomly-selected sites inside the water line along the pond's boundary (see Figure 4-1).

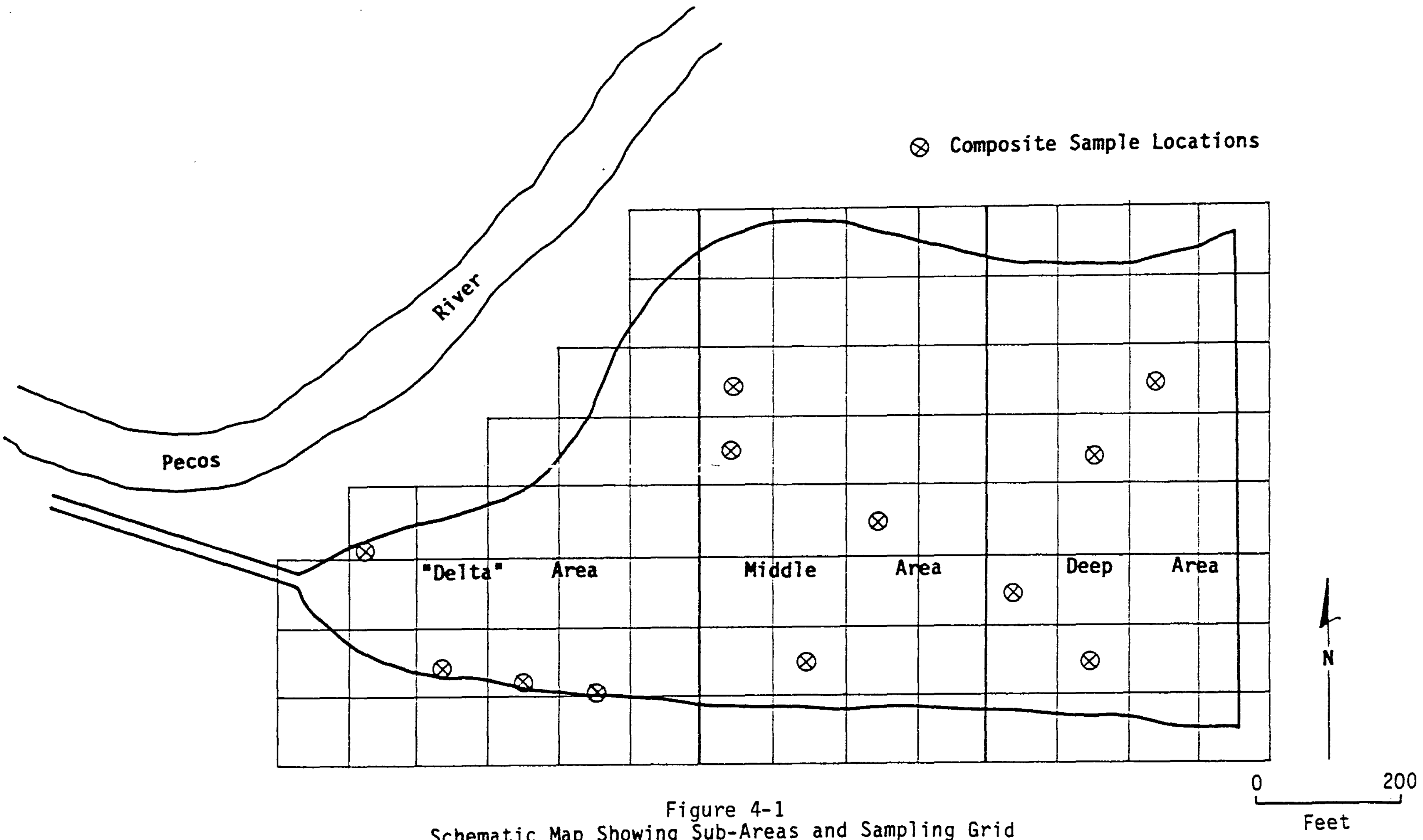


Figure 4-1
Schematic Map Showing Sub-Areas and Sampling Grid
In Area of Evaporation Pond #1

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 request form (Figure 4-2). As each sample was composited, it was properly containerized and preserved. Each sample container was then sealed with a chain-of-custody tape (Figure 4-3) and all identifying information was logged on a chain-of-custody form (Figure 4-4). The chain-of-custody form accompanied all samples to the analytical laboratory. All sample documentation and analytical results from the sludge sampling are included as Appendix B.

4.1.2 Analytical Protocols

All composited sludge samples collected from Pond #1 were preserved and containerized according to the procedures in Table 4-1, and shipped to Rocky Mountain Analytical Laboratories for analysis. Each sludge sample was accompanied by a field log/sample analysis request form (Figure 4-2) and was analyzed for those organic and inorganic hazardous constituents listed in the "Modified Skinner List" (Table 4-2) 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. Parameters were analyzed according to the methods listed in Table 4-3; 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 . Organic constituents included 12 volatile compounds, 25 base/neutral extractable organics and 6 acid-extractable organics (Table 4-2). Volatile compounds were analyzed using EPA Method 8240, purge and trap GC/MS. 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. Results are summarized in Tables 4-4 and 4-5.

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

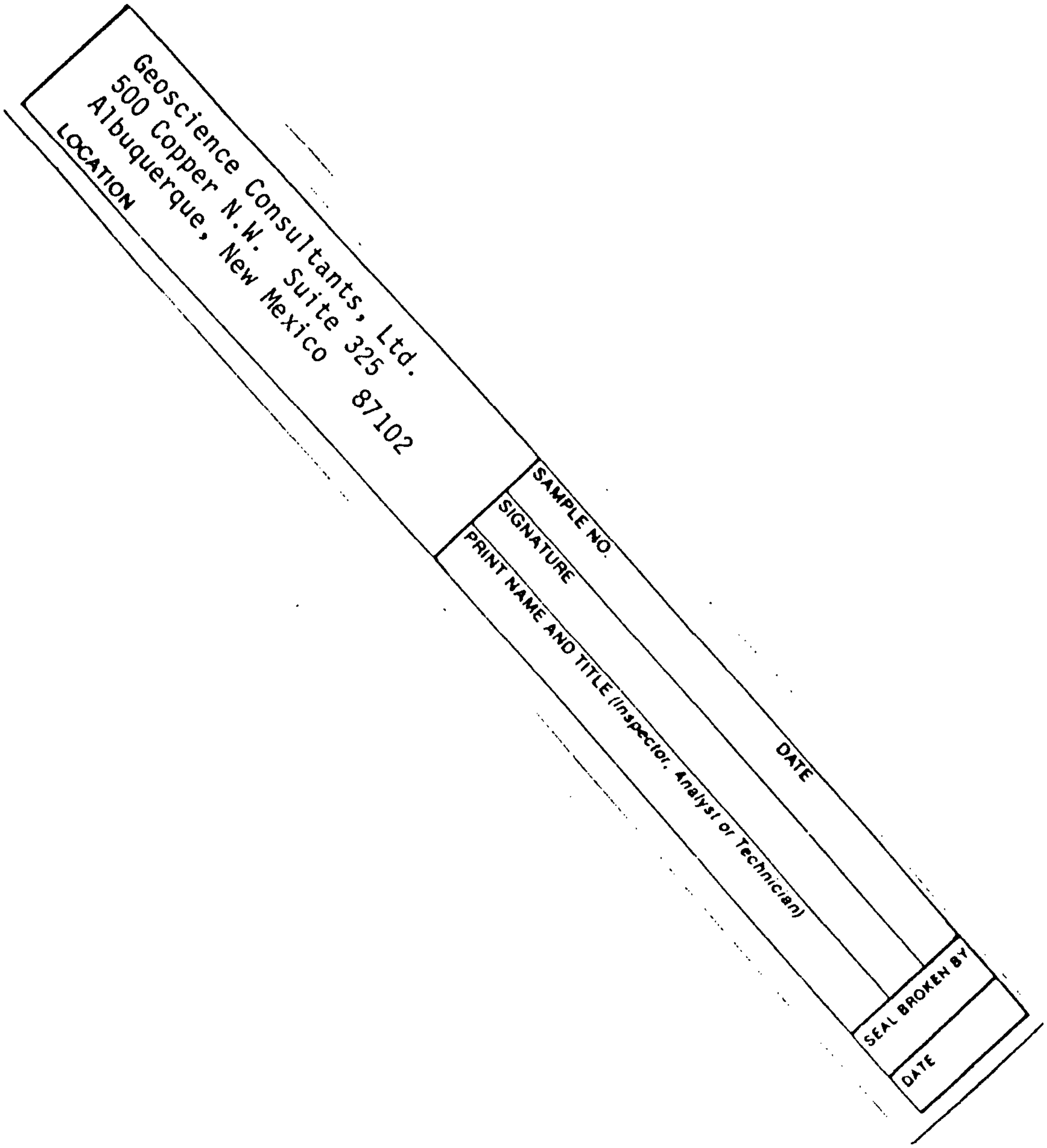
APPENDIX VIII CONSTITUENTS
FOR PETROLEUM REFINERIES
☐ Volatiles

_____ 40 mil septum vials cool to 4°C

APPENDIX VIII CONSTITUENTS
FOR PETROLEUM REFINERIES
☐Volatiles

Remarks on Analyses: ____________________

Figure 4-2
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 4-3

CHAIN OF CUSTODY TAPE

Geoscience Consultants, Ltd.

Figure 4-4

CHAIN OF CUSTODY

CHAIN OF CUSTODY FORM

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 1

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	

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

Table 4-2

"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 4-3

Analytical Methods

Parameter	Units	Nominal Detection Limit(a)	Methodology	Reference(1)	Preservation Bottle No.	Maximum Holding Time(b
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 day
Acids	ug/l	10	Extraction/GC/MS	625	12	7 days/40 day
Organochlorine Pesticides/PCB's	ug/l	0.01	Extraction/GC/ECD	608	13	7 days/40 day
		10	Extraction/GC/MS	625	12	7 days/40 day
Phenoxy Herbicides	ug/l	0.01	Extraction/GC/ECD	(2)	14	7 days/40 day
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 day
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 day
Benzidines	ug/l	0.1	Extraction/HPLC	605	19	7 days/40 day
Phthalate Esters	ug/l	10	Extraction/GC/FID	606	12	7 days/40 day
Nitrosamines	ug/l	1	Extraction/GC/NPD	607	20	7 days/40 day
Nitroaromatics/isophorone	ug/l	1	Extraction/GC/FID & GC/ECD	609	12	7 days/40 day
Polynuclear Aromatics	ug/l	0.5	Extraction/HPLC	610	20	7 days/40 day
Haloethers	ug/l	1	Extraction/GC/Hall	611	17	7 days/40 day
Chlorinated Hydrocarbons	ug/l	0.02	Extraction/GC/ECD	612	12	7 days/40 day
Organophosphorus Pesticides	ug/l	0.1	Extraction/GC/NPD	622(5)	12	7 days/40 day
Triazine Pesticides	ug/l	0.1	Extraction/GC/NPD	(6)	12	7 days/40 day

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 4-3 (Continued)

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

Table 4-3 (Concluded)

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.

Table 4-4

Pond #1 Sludge Detected 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 4-5
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)

4.2 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. With NMEID concurrence, ditch sludges were not sampled at this time.

4.3 ANALYTICAL RESULTS

All 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 (Tables 4-4 and 4-5). 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 6.0).

4.4 WASTE QUANTITIES

Rough calculations of waste quantities are presented in Table 4-6. These indicate that the ditch contains approximately 3400 metric tons of solid wastes, and Pond #1 contains approximately 80,000 tons.

Table 4-6 Calculation of Waste Quantities

Ditch:

Length x Width x Depth = Volume
15,000 ft x 4 ft x 1 ft = 60,000 ft^3
60,000 ft^3 x (2.382 x 10^{-2} m^3/ft^3) = 1699.2 m^3

[illegible]
([illegible])

Volume x Density (Estimated) = Mass
1700 m3 x 2.0 $tonnes/m^3$ = 3400 tonnes

Pond #1:

16.1 Acres x 43,560 ft^2/Acre = 701,316 ft^2
701,316 ft^2 x 2 ft = 1,402,632 ft^3
1,402,632 ft^3 x (2.382 x 10^{-2} m^3/ft^3) = 39,722 m^3
40,000 m^3 x 2.0 $tonnes/m^3$ = 80,000 tonnes

[illegible]
[illegible]

SECTION 4.0

SECTION 5.0

5.0 REGIONAL GEOLOGY, SOILS AND HYDROGEOLOGY

5.1 GEOLOGY AND GEOMORPHOLOGY

The town of Artesia and the Navajo Refinery are underlain by thin (20 feet or less) layers of soils, alluvium, artificial fill and weathered bedrock that conceal subcrops of the Artesia Group (Permian). As seen in the explanation of Plate 4 and Table 5-1, the Artesia Group consists of carbonates, evaporites, and shales deposited in a backreef environment. Beneath the Artesia Group lies the San Andres Formation, the major ground water aquifer in the area.

Weathering of the underlying bedrock and local fluvial and colluvial (surface flow) processes have concealed much of the region's geology under a mantle of surficial deposits (Plate 5). These deposits range in origin from thin soils formed from in-place weathering to relatively thick alluvial fill in the Pecos valley.

The Artesia area lies in the Pecos slope region of the eastern plains of New Mexico. Topography is relatively flat, sloping southeastward at a few feet per mile. With the exception of the Pecos River, all other drainages are typically dry for much of the year, and the average annual precipitation is only 12.8 inches per year. Ground water from the San Andres aquifer, however, supports a major agricultural industry.

The site is located on the northwestern shelf of the geologic province known as the Permian Basin. This basin contains up to 12,000 feet of Permian and older Paleozoic rocks, predominantly composed of carbonates, evaporites and fine-grained clastics. Subsurface fluids flow primarily through diagenetic pores, fractures or solution cavities in the carbonate beds, confined by stratigraphically adjacent evaporites and shales.

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 appears to be

			Formations & Members			Thick	Description
Holocene and Pleistocene			Assorted surficial deposits			0-300	Valley alluvium, terrace and pediment gravel, caliche soils, aeolian sand, travertine
Pleistocene-Pliocene			Gatuna Formation			0-200	Sandstone, sand gravel, siltstone, limestone, red, brown, tan, gray, yellowish
Oligocene			Sierra Blanca Volcanics			700-4,000	Andesite breccia and tuff; some flows
Paleocene			Cub Mountain Formation			500-2,000	Sandstone, mudstone, conglomerate, arkose; white, buff, lavender, purple, maroon
Cretaceous			Mesaverde Formation			500-1,500	Sandstone, shale, coal, conglomerate; buff, gray, black
			Mancos Shale			400-700	Shale, siltstone, with local thin sandstone and limestone; black, grayish-black
			Dakota Sandstone			100-150	Sandstone, conglomerate, black shale; gray to tan
Upper Triassic			Chinle Shale			0-300	Mudstone with some claystone and thin sandstone; reddish brown
			Santa Rosa Sandstone			0-300	Sandstone, conglomerate, mudstone; brown, buff, lavender
PERMIAN	Ochoan Series		Dewey Lake Formation			200-250	Sandstone, siltstone; orange-brown; commonly laminated
			Rustler Formation:				
			Upper Member			150-200	Dolomite, gypsum, mudstone, white, red-brown, green, gray, deep orange; Magenta dolomite at base
			Lower Member			100-250	Dolomite, gypsum, mudstone, sandstone; white, red-brown, gray, green; salt in subsurface; Culebra dolomite at base.
			Salado Formation			0-2,500	Gypsum, mudstone, thin local dolomite; white, red, brown, green, deep orange; breccia residue at surface, thick salt, potash in subsurface
			Castile Formation				
			Upper Member* (surface)			1,000±	Gypsum (anhydrite), salt; white, gray
			Lower Member (surface)			1,000±	Laminated gypsum (anhydrite) and limestone, laminated limestone, laminated gypsum; gray, black, white
	Guadalupian Series	Artesia Group	Tansill Formation	Capitan Ls.†	Bell Canyon Fm.*	200-300	Dolomite and siltstone (south); dolomite, gypsum, and anhydrite (north); Ocotillo siltstone tongue near exposed top
			Yates Formation			250-350	Siltstone, sandstone, dolomite, limestone and gypsum (south); gypsum, siltstone and thin dolomite (north)
			Seven Rivers Formation			450-600	Dolomite, siltstone (south); gypsum and siltstone (north)
			Queen Formation	Goat Seep Do.†	Cherry Canyon Fm.*	200-400	Dolomite and sandstone (south); gypsum, red mudstone, dolomite (north); Shattuck member near top
			Grayburg Formation			250-450	Dolomite and sandstone (south); gypsum, mudstone, dolomite (north)
			San Andres Formation:				
			Fourmile Draw Member			0-700	Dolomite, gypsum, reddish mudstone; sandstone locally at top; thin-bedded
			Bonney Canyon Member			0-300	Dolomite, local limestone; gray, light-gray, local black; thin-bedded
	Leonardian Series		Rio Bonito Member			250-350	Dolomite, limestone, sandstone (Glorieta); gray, brownish gray; thick-bedded
			Yeso Formation			0-1,400	Sandstone, siltstone, dolomite, gypsum; tan, red-yellow, gray, white
Precambrian			Syenite, gneiss, and diabase				

* Delware basin facies only
† Reef facies only

Table 5-1

Stratigraphy of the Artesia-Permian Basin Area nearly vertical and 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 bedrock aquifers, there are several reasons why the fault is unlikely to 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 the gypsum and anhydrite that are abundant in these units. Strong, upward vertical hydraulic gradients observed in the Queen and San Andres formations also act to protect these aquifers from 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 underlain by shallow (5-20 feet in depth) soils and fill that cover 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 where it merges with the alluvium of the Pecos River valley. The alluvial fill may be up to 250 feet thick in the axial valley (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 unconfined ground water contained in that unit) does not extend under the refinery site.

Logs of refinery-site monitoring and product-recovery wells show 0 to 10 feet of soils or fill overlying the Seven Rivers Formation. In the Seven Rivers there are several small, discontinuous permeable zones containing perched or semi-confined ground water. These saturated units are apparently paleochannel facies composed of dolomitic gravels. These zones typically exhibit several feet of artesian head (Plate 11).

What about
[illegible] Sand?

5.2 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 major substrate. Soil properties vary as a result of differing parent materials, grain size, land slope and available moisture. Plates 7 and 8 show the distribution of soil types in the Artesia area. Table 5-2 shows physical and engineering properties of soils in this area.

The refinery site proper is located in an area of Pima, Reagan and 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 (Figure 2-1 and Plates 1 and 2) parallels Eagle Creek, and is constructed in soils of the Pima, Arno and Arno-Harkey 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).

Reagan, Arno, Harkey, Karro

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 (0.05-0.20 inches/hour) and high water holding capacity (0.18-0.20 inches/inch).

Data for horizontal permeability are not available. Stratified soils and fluvial sedimentary rocks generally exhibit a vertical/horizontal permeability ratio of 1/2 to 1/10 (see Freeze and Cherry, 1979, p. 148).

Table 5-2
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 14-60	Silty clay loam Silty clay	CL CH	A-6 A-7
Atoka: Ao, At	20 to 36.	0-8 8-33 33	Loam Loam and light clay loam Hard, fractured caliche.	ML CL	A-4 A-6
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 17-50	Loamy fine sand and fine sand Sandy clay loam	SM SC	A-2 A-6
Bippus	More than 60.	0-48 48	Silty clay loam and clay loam Weakly cemented caliche.	CL	A-6
Cacique: CA	12 to 36.	0-17 17-24 24	Loamy sand and sandy loam Sandy clay loam Indurated, fractured caliche.	SM SC	A-2 A-6
Cottonwood: CR (For Reeves part of CR, see Reeves series.)	Soft to hard gypsum below a depth of 9 inches.	0-9 9	Loam Gypsum.	ML-CL	A-4
Dev: DP (For Pima part of DP, see Pima series.)	More than 60.	0-15 15-60	Gravelly loam Very gravelly loam	GM GP	A-1 or A-2 A-1
Ector: EC, EE, ER (For Reagan part of ER, see Reagan series.)	1 to 18.	0-6 6	Stony loam Limestone bedrock.	SM-ML	A-4
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 19	Gypsiferous earth Gypsum.	ML	A-4
* 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 24-60	Loam Clay loam	ML-CL CL	A-4 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 9	Loam Caliche.	ML	A-4
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 5-2
(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 5-2
(Continued)

Soil series and map symbols	Reaction	Electrical conductivity (Ec × 10³) Mmho/cm. at 25° C.	Corrosivity (Untreated steel pipe)	Shrink-swell potential
	pH			
Active dune land: AD	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 5-2
(Continued)

Soil series and map symbols	Depth to bedrock, hard caliche, or gypsum	Depth from surface	Classification		
			USDA texture	Unified	AASHO
	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-2
* 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	Gravelly loam	SM	A-2
		10	Fractured, indurated caliche.		
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-6
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	Heavy loam and light clay loam.	CL	A-4 or A-6
		32	Gypsum.		
Rr	Soft or hard gypsum at a depth of 20 to 36 inches.	0-31	Heavy loam and light clay loam.	CL	A-4
		31	Gypsum.		
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	Loam	ML-CL	A-4
		11-52	Clay loam	CL	A-6
		52	Gypsiferous earths.		
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	Gravelly fine sandy loam	SM	A-4
		19	Indurated, fractured caliche.		
Stegall	18 to 40.	0-22	Clay loam and heavy clay loam.	CL	A-6
		22	Indurated, fractured caliche.		
Tonuco: TC, TF, TN, TO (For Berino part of TO, see Berino series.)	6 to 20.	0-15	Loamy fine sand	SM	A-1
		15	Indurated, fractured caliche.		
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	Gravelly loam	SM	A-2
		9	Indurated, fractured caliche.		
Wink: WK	More than 60.	0-60	Loamy fine sand and fine sandy loam.	SM	A-1 or A-2

Table 5-2
(Continued)

Soil series and map symbols	Reaction	Electrical conductivity ($Ec \times 10^3$) Mmho./cm. at 25° C.	Corrosivity (Untreated steel pipe)	Shrink-swell potential
	pH			
Pajarito: PA, PD (The Dune land part of PD is too variable for reliable evaluations.)	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 5-2
(Continued)

Soil series and map symbols	Percentage passing sieve— No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 200 (0.074 mm.)	Permeability	Available water capacity
				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	100	100	60-75	0. 8-2. 5	0. 16-0. 18
(For Ector part of RU, see Ector series.)	100	100	70-80	0. 2-0. 8	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

5.3 REGIONAL HYDROGEOLOGY

Artesia is located in the Roswell-Artesia artesian water basin (Welder, 1983). The principal ground water reservoirs are:

- The deep, artesian San Andres aquifer,
- A local artesian aquifer in porous facies of the Queen Formation, and
- An unconfined water-table aquifer in the alluvium of the Pecos River valley.

Bowers Sand, [illegible]

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 wells completed in the valley alluvium adjacent to the Pecos River, all wells in the Artesia area exhibit some degree of artesian head.

Deep (800-1200 feet) artesian wells completed in the San Andres Formation produce the great majority of ground water used in this area and have static water levels 50-80 feet below ground level. When this aquifer was first developed in the early 1900's, wells flowed at up to 8000 gallons per minute. The San Andres aquifer is confined above by shales and evaporites of the lower Queen Formation, and below by the siltstones and evaporites of the Yeso Formation. The potentiometric surface of the San Andres aquifer slopes southeasterly at 5 to 25 feet per mile (0.001 to 0.005) from recharge areas in the Sacramento Mountains to the west (Figure 5-1). The San Andres aquifer discharges primarily to irrigation, commercial and domestic wells located along the Pecos Valley.

The San Andres aquifer produces most of the ground water locally used 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 of Artesia (Welder, 1983).

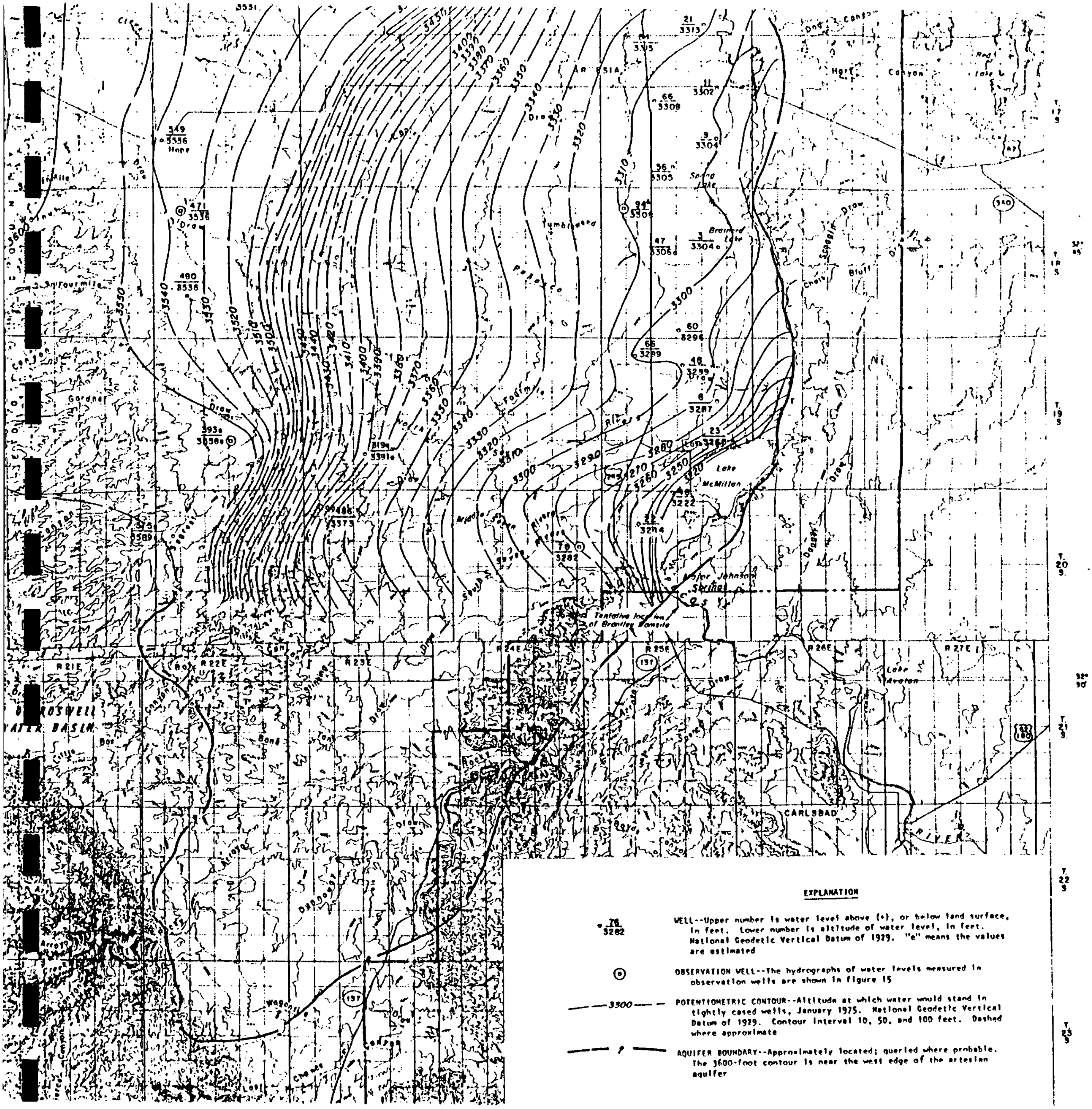


Figure 5-1
Potentiometric surface of San Andres Aquifer (Welder, 1983)

Shallow, semi-confined aquifer wells (150-250 feet in depth) produce minor amounts of water for domestic wells from the upper sands of the Queen Formation. These sands are confined by aquitards of anhydrite, gypsum and shale in the Queen Formation and the overlying Seven Rivers Formation (Plate 9). Water levels in these shallow wells range from 50-100 feet below ground level. The potentiometric surface of the Queen aquifer (Plate 10) slopes easterly at approximately 50 feet per mile (0.009).

The Queen aquifer is recharged by precipitation on Queen outcrops located in the slopes and foothills to the west of Artesia. Discharge is primarily through wells in the Pecos Valley area, and possibly through upward leakage to overlying units. The irregular distribution of porous and permeable facies in the Queen Formation limits the use of this aquifer, and it is not considered a reliable ground water resource in this area. Water quality is also variable, ranging from several hundred to several thousand ppm of dissolved solids.

The valley-fill aquifer is hosted by the alluvial deposits of the Pecos River. In this unit, ground water typically lies within 20 feet or less of the land's surface, and hydraulic gradients are subparallel to the topography in areas away from the Pecos River or Navajo's evaporation ponds (see Section 6.0, Figures 6-10, 6-11 and 6-12).

Ground water dynamics in the valley-fill aquifer are strongly dominated by river stage and apparent mounding adjacent to the ponds. The aquifer recharges via bank seepage during high river stages, and by direct infiltration of precipitation. Discharge occurs as return seepage to the Pecos during lower river flow, and by evapotranspiration. Quality of ground water is poor, with TDS values over 10,000 mg/l being typical. The interactions of the valley aquifer and the Pecos River are discussed in more detail in Section 6.6.

High TDS from only shallow depths.

No observation or explanation [illegible]

SECTION 6.0

6.0 GROUND WATER INVESTIGATIONS

A permanent ground-water monitoring network has been installed to investigate potential impacts to ground water from the effluent ditch and evaporation Pond #1, and a network of steel drive points has been used to explore the extent of possible contamination near the ponds. Seven well locations (Plates 2 and 13) near the ponds were selected for permanent wells 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 locations were discussed with NMEID technical personnel and an agreement on the number and design of wells was obtained prior to initiating site work.

Steel drive points were installed at approximately 20 locations on a 1000 foot center grid in the area south (downgradient) of the ponds. Data from these points was used to define a possible plume of hydrocarbon contamination in this area.

6.1 PERMANENT GROUND WATER MONITORING SYSTEM

Navajo Refining Company has installed nine new RCRA-style monitoring wells. Plates 1, 2 and 13 show the locations and surveyed elevations 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 permanent wells were constructed of 2.0 inch diameter 304 stainless steel casing and screens (Figure 6-1). This material has excellent strength, is corrosion resistant, and is essentially inert with respect to the expected waste constituents.

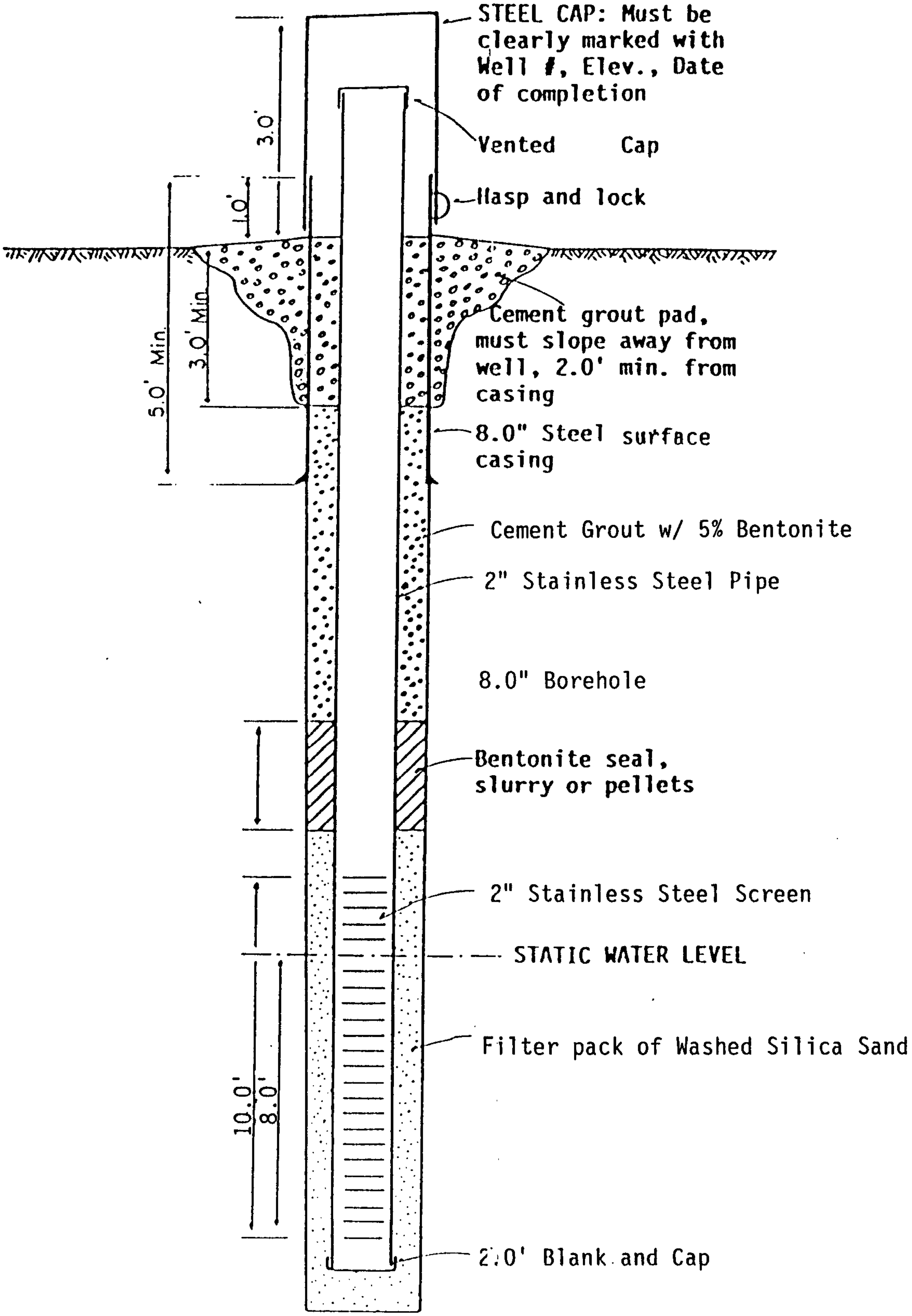


Figure 6-1
TYPICAL MONITOR WELL DESIGN

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 downward sloping concrete pads to protect the well heads (Figure 6-1).

Monitor wells were installed by use of an air-rotary rig, using filtered air. All tools and well materials were thoroughly steam-cleaned prior to use and installation. Temporary casing was used to install a filter pack of clean, silica sand. Following installation, all wells were developed by pumping (with a steam-cleaned, stainless steel air-displacement pump) and surging until produced waters were free of excessive silt and specific conductance and pH were stable. Approximately 120 to 180 gallons (75 - 100 casing volumes) were pumped from all wells during development.

Well heads are secured with vented, 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.

6.2 STEEL DRIVE POINTS

Following receipt of the analytical results from the first sampling of the monitor wells, it was apparent that some contamination of ground water existed in the area of Pond #1. Rather than expend resources on continuing monthly sampling, Navajo proposed to NMEID that a preliminary effort be made to define the nature and extent of the apparent contamination. To this end, a network of steel drive points (Figure 6-2) was installed in the area downgradient of Pond #1.

A total of 19 of these points (Figure 6-3) were installed on approximately 1000-foot centers over an area of approximately 1 square mile. All points were made of galvanized steel. The points and attached steel pipe were thoroughly steam cleaned prior to installation with a steam-cleaned power auger.

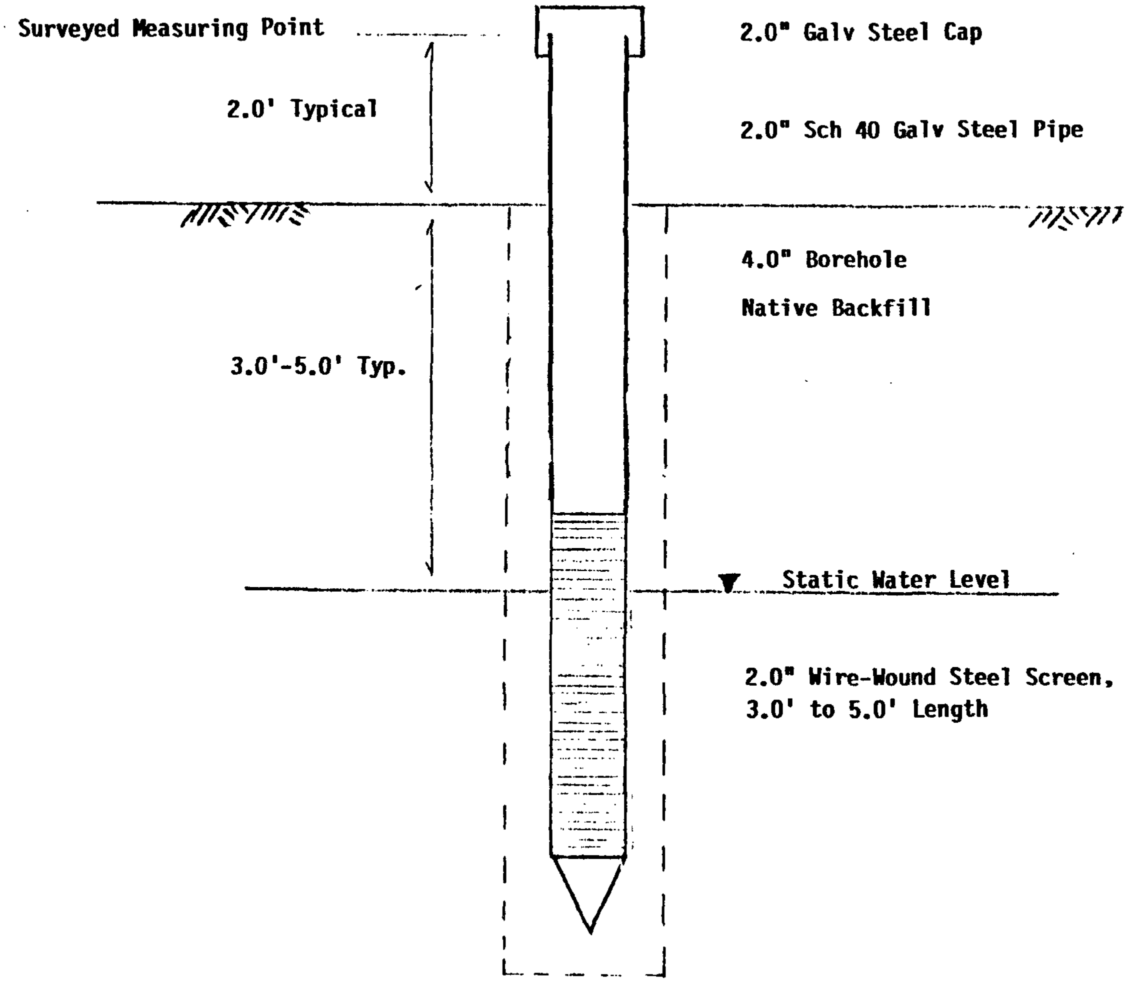
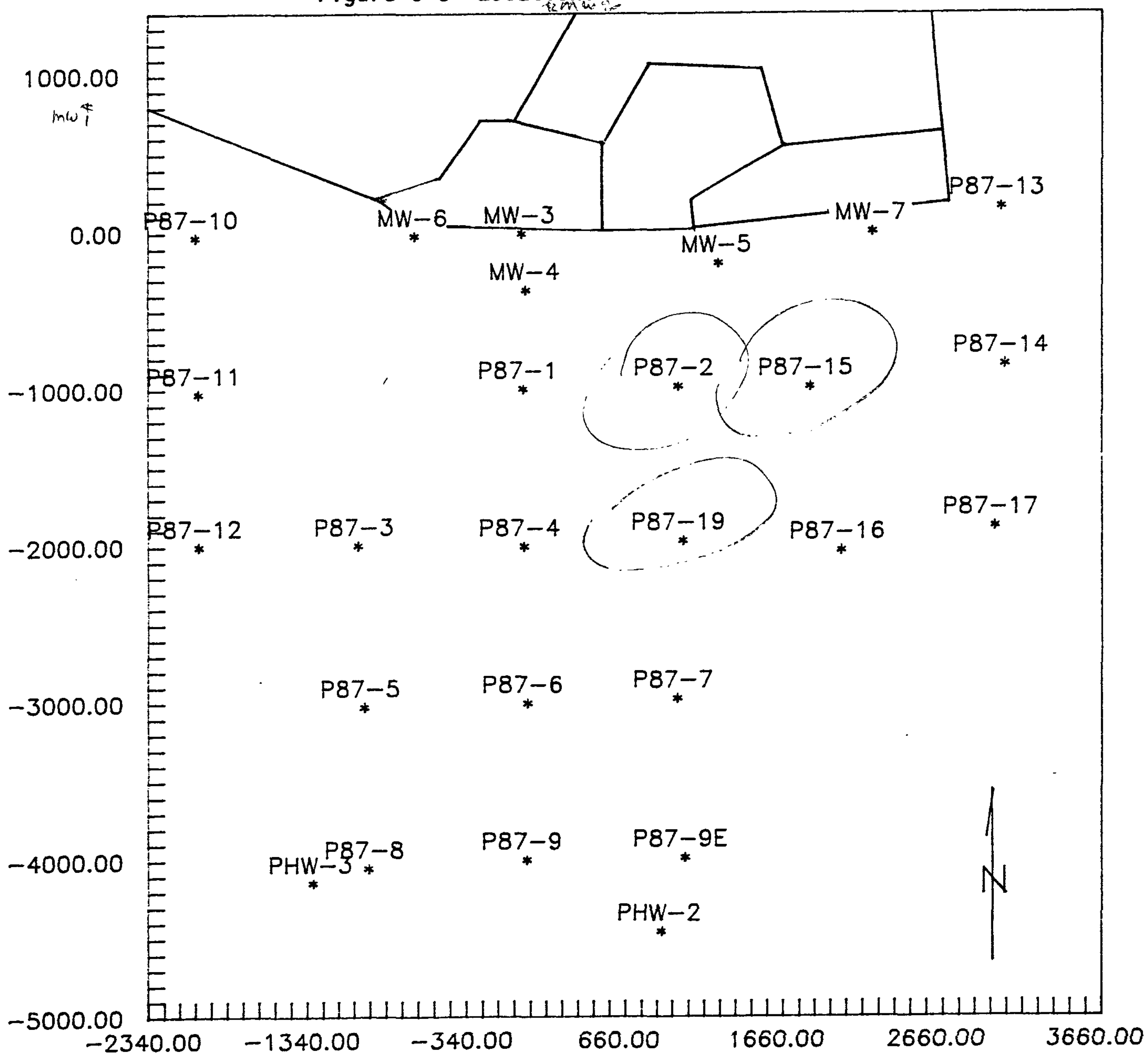


Figure 6-2

Typical Steel Drive Point Design

Figure 6-3 Locations of Steel Drive Points



Development was accomplished by bailing or pumping with a suction pump. Following development, the points' locations and elevations were determined by a registered surveyor (Plate 13). Recent field work indicates that some of these points may have settled; surveyed elevations may no longer be accurate.

All points were sampled according to the procedures described in Section 6.3. Samples were analyzed for volatile organic constituents, EC, pH and total dissolved solids (TDS). Data was also collected on water-level elevations, and logs were prepared of lithologies encountered during the points' installation. Samples of ground water were also collected from 2 well points adjacent to Highway 82. The history of these 2 points is unknown, but it is believed that they were installed by the state Highway Department.

6.3 GROUND WATER SAMPLING AND ANALYSIS

6.3.1 Sampling Equipment

The equipment that Navajo Refining Company used in the field investigation for monitoring and collecting representative ground water samples is detailed in Table 6-1. Similar techniques were used to sample and analyze the steel well-points.

6.3.2 Sampling Techniques

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.
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.

Table 6-1

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

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. If floating or sinking phases are anticipated, the probe or a tape will be coated with an indicator paste. If floating or sinking phases are detected, this is noted in the log and the permanent notebook.

The purging pump (if used) is 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. 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:

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

The exact amount to be purged will, of 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.

The discharge rate will be reduced to less than 100 ml/minute and 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 collected first and 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 4-1. As each sample is collected, it will be logged, sealed and entered on a chain-of-custody form.

6.3.3 Analytical Protocols

Ground water samples collected from the RCRA wells on June 4, 1986 for inorganic and organic constituents were shipped to Rocky Mountain Analytical Laboratory for analysis. Assaigai and Radian Laboratories provided the analyses of samples from the steel points.

Analytical parameters for the initial RCRA-well ground water samples included volatile organic constituents (Table 6-2), semi-volatile compounds (Table 6-3) and heavy metals (Table 6-4). Samples were collected from three downgradient 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.

Table 6-2 Volatile Organic Compounds Analyzed in MW-Series Wells

Acetone
Chloromethane
Bromomethane
Vinyl Chloride
Chloroethane
Methylene Chloride
1,1-Dichloroethene
1,1-Dichloroethane
trans-1,2-Dichloroethene
Chloroform
1,2-Dichloroethane
1,1,1-Trichloroethane
Carbon Tetrachloride
Dichlorobromomethane
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-Tetrachloroethene
Tetrachloroethene
Toluene
Chlorobenzene
Ethylbenzene
1,3-Dichlorobenzene
1,2-Dichlorobenzene
1,4-Dichlorobenzene

[illegible]
[illegible] in

Table 6-3 Semivolatile Organic Compounds Analyzed in MW-Series Wells

1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Hexachloroethane
Bis(2-chloroethyl) ether
Bis(2-chloroisopropyl) ether
N-Nitroso-di-n-propyl amine
Nitrobenzene
Hexachlorobutadiene
1,2,4-Trichlorobenzene
Isophrone
Naphthalene
Bis(2-chloroethoxy) methane
Hexachlorocyclopentadiene
2-Chloronapthalene
Acenapthylene
Acenapthene
Dimethyl phthalate
2,6-Dinitrotoluene
2,4-Dinitrotoluene
Fluorene
4-Chlorophenyl phenyl ether
Diethylphthalate
N-Nitrosodiphenylamine
Hexachlorobenzene
4-Bromophenyl phenyl ether
Phenanthrene
Anthracene
Dibutylphthalate
Fluoranthene
Pyrene
Benzidine
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(g,h,i) pyrene

Table 6-3 (Continued)

N-Nitrorodimethyl 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 6-4 Inorganic Constituents Analyzed in MW-Series Wells

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

6.3.4 Quality Assurance/Quality Control

To assure reliable, precise and accurate analyses, field blanks and equipment blanks were used to check on cross contamination in the field. Field blanks are water samples carried in the field and handled in the same manner as the actual samples. Equipment blanks are samples of the final distilled-water rinse used to decontaminate sampling equipment. These blanks were handled, containerized, labeled and shipped in exactly the same manner as all other samples. These QA/QC samples were thus submitted to the laboratories in a "blind" manner; the laboratories did <u>not</u> know which samples are blanks or duplicates. Analytical laboratories may also provide internal QA/QC documentation regarding surrogate and spike recovery percentages. Results of QA/QC reviews are given in Table 6-5.

6.4 ANALYTICAL RESULTS

Results of the analyses of the permanent RCRA wells are given in Table 6-6, and results from the steel points are given in Table 6-7. These tables include the parameters tested, the methods used, nominal detection limits, QA/QC footnotes where applicable, and the current New Mexico and/or USEPA ground water standards for each parameter.

No evidence of ground water contamination was detected in the wells (MW-8 and MW-9) adjacent to the conveyance ditch. Monitor wells downgradient from the evaporation ponds have detected low-level plumes of volatile organic constituents (toluene, ethylbenzene and xylenes) in the shallow aquifer (Figures 6-4, 6-5 and 6-6). No samples contained any organic parameter in excess of human health standards. Human exposure to these substances is very unlikely, due to the high salinity (average total dissolved solids 26,000 mg/kg) of that aquifer (Figure 6-7).

Table 6-5 QA/QC Review

PARAMETER	METHOD (SW-846)	DET. LIMIT (ug/l)	61882-06 (Equip. Blank)	61882-07 (Field Blank)
Benzene	602	0.5	ND	ND
Chlorobenzene	602	1.0	ND	ND
Ethylbenzene	602	1.0	ND	ND
1,2-Dichlorobenzene	602	2.0	ND	ND
1,3-Dichlorobenzene	602	2.0	ND	ND
1,4-Dichlorobenzene	602	2.0	ND	ND

Date of Sampling
why no benzene
xylene?

TABLE 6-6
MONITOR WELL ANALYTICAL RESULTS (ug/l)

PARAMETERS	METHOD	DL	1	2	3	4
			61552 -10	-08	[illegible]	-11
Volatile Organics	8240		-	-	-	-
Acetone	8240	10.0	ND	NT	ND	NT
Ethylbenzene		5.0	ND	NT	ND	NT
Base/Neutral Organics	8250	-	-	-	-	-
All Parameters	8250	-	ND	NT	ND	NT
Purgable Organics	602	-	-	-	-	-
Ethylbenzene	602	1.0	NT	ND	NT	39
Toluene	602	1.0	NT	6.4	NT	140
Acid Extractable Organics		-	-	-	-	-
2,4,Dimethylphenol		5.0	ND	ND	ND	ND
Priority Pollutant Metals	-	-	-	-	-	-
Antimony	7041	0.002	0.004	NT	0.003	NT
Arsenic	7060	0.002	ND	NT	0.084	NT
Barium	7081	0.01	0.030	NT	0.22	NT
Beryllium	7091	0.002	ND	NT	ND	NT
Cadmium	7131	0.008	ND	NT	ND	NT
Chromium	7191	0.01	ND	NT	0.02	NT
Cobalt		0.06	ND	NT	0.007	NT
Copper	7211	0.03	ND	NT	ND	NT
Lead	4421	0.04	ND	NT	ND	NT
Mercury	7470	0.0001	ND	NT	ND	NT
Nickle	7521	0.02	0.10	NT	0.02	NT
Selenium	7740	0.04	ND	NT	ND	NT
Silver	7761	0.006	ND	NT	ND	NT
Thallium	7841	0.04	ND	NT	ND	NT
Vanadium	7911	0.004	ND	NT	0.014	NT
Zinc	7951	0.02	ND	NT	ND	NT

TABLE 6-6 Continued

PARAMETERS	5	6	7	8	9	13	DWS
Volatile Organics	-	-	-	-	-	-	-
Acetone	NT	74	NT	ND	ND	ND	NS
Ethylbenzene	NT	12	NT	ND	ND	5.0	750
Base/Neutral Organics	-	-	- NT	-	-	-	-
All Parameters	NT	ND		ND	ND	ND	-
Purgable Organics	-	-	- ND	-	-	-	-
Ethylbenzene	ND	NT	7.2	NT	NT	NT	750
Toluene	58	NT		NT	NT	NT	750
Acid Extractable Organics	-	-	- ND	-	-	-	-
2,4,Dimethylphenol	ND	ND		ND	ND	19	NS
Priority Pollutant Metals	-	-	- NT	-	-	-	
Antimony	NT	0.007	NT	0.006	ND	0.006	
Arsenic	NT	0.092	NT	0.012	0.020	0.064	0.1
Barium	NT	0.040	NT	0.049	0.020	0.22	1.0
Beryllium	NT	NT	NT	ND	ND	ND	
Cadmium	NT	NT	NT	ND	ND	ND	0.01
Chromium	NT	0.019	NT	ND	ND	0.007	0.05
Cobalt	NT	NT	NT	0.018	0.012	ND	
Copper	NT	NT	NT	ND	ND	ND	
Lead	NT	NT	NT	ND	ND	ND	0.05
Mercury	NT	NT	NT	ND	ND	ND	0.002
Nickle	NT	NT	NT	0.039	0.048	ND	
Selenium	NT	NT	NT	ND	ND	ND	
Silver	NT	NT	NT	ND	ND	ND	0.05
Thallium	NT	NT	NT	ND	ND	ND	
Vanadium	NT	0.005	NT	0.053	0.048	0.011	
Zinc	NT	NT		ND	ND	ND	

ND: Not detected
NT: Not tested
DL: Detection limit
DWS: Drinking Water Standard on WQCC

Table 6-7

SUMMARY OF ANALYTICAL RESULTS

LOCATION					ANALYTICAL RESULTS (ug/l)				
POINT	X(ft)	Y(ft)	SAMPLE NUMBER	ANALYSIS DATE	BENZENE	TOLUENE	EB	CBA	1,4-DCB
1	E0007	S0993	8703121635	3/18/87	ND	ND	ND	ND	ND
-13 2	E0991	S0977	8703121655	3/18/87	ND	2.0	ND	ND	ND
3	W1020	S1993	8703130815	3/19/87	ND	1.0*	ND	ND	ND
4	E0018	S1999	8703131020	3/20/87	ND	9.7	ND	ND	ND
5	W0980	S3024	8703130840	3/19/87	ND	ND	ND	ND	ND
6	E0039	S2999	8703131005	3/20/87	ND	0.6*	ND	ND	ND
7	E0989	S2970	8703130950	3/20/87	ND	3.8	0.5*	ND	ND
8	W0954	S4050	8703130900	3/19/87	ND	1.1	ND	ND	ND
9	E0036	S3997	8703130915	3/19/87	ND	7.3	ND	ND	ND
9-E	E1036	S3983	8703130930	3/19/87	ND	0.9*	ND	ND	ND
10	W2047	S0027	8703121720	3/19/87	ND	1.1	ND	ND	ND
11	W2027	S1026	8703130755	3/19/87	ND	2.5	ND	ND	ND
12	W2023	S2001	8703121400	3/18/87	ND	ND	ND	ND	ND
13	E3024	N0163	8703121425	3/18/87	ND	ND	ND	ND	ND
14	E3046	S0841	8703121445	3/18/87	ND	2.2	ND	ND	ND
15	E1823	S0980	8703121530	3/18/87	ND	ND	ND	ND	ND
16	E2022	S2028	8703121515	3/18/87	ND	ND	ND	ND	ND
17	E2984	S1874	8703121500	3/18/87	ND	ND	ND	ND	ND
18	NP	NP	-	-	-	-	-	-	-
19	E1019	S1963	8703121610	3/18/87	ND	1.8	ND	ND	ND
HP-2	E0885	S4856	8703131220	3/20/87	ND	ND	ND	ND	ND
HP-3	W1308	S4143	8703131200	3/20/87	ND	0.8*	ND	ND	ND
			Analytical Method (SW-846)		602	602	602	602	602
			Nominal Detection Limit (ug/l)		0.2	0.2	0.3	0.3	0.3

What is CBA?

Table 6-7 (Cont.)

SUMMARY OF ANALYTICAL RESULTS (Continued)

LOCATION					ANALYTICAL RESULTS (ug/l)					
POINT	X(ft)	Y(ft)	SAMPLE NUMBER	ANALYSIS DATE	1,3-DCB	1,2-DCB	P XYLENE	M XYLENE	O XYLENE	TOTAL VOC
1	E0007	S0993	8703121635	3/18/87	ND	ND	ND	ND	ND	ND
2	E0991	S0977	8703121655	3/18/87	ND	ND	3.1	450	ND	455.1
3	W1020	S1993	8703130815	3/19/87	ND	ND	ND	ND	0.4*	1.4
4	E0018	S1999	8703131020	3/20/87	ND	ND	ND	ND	ND	9.7
5	W0980	S3024	8703130840	3/19/87	ND	ND	ND	ND	ND	ND
6	E0039	S2999	8703131005	3/20/87	ND	ND	ND	ND	ND	0.6
7	E0989	S2970	8703130950	3/20/87	ND	ND	0.6*	1.4	1.3	7.6
8	W0954	S4050	8703130900	3/19/87	ND	ND	0.3*	0.9*	0.5*	2.8
9	E0036	S3997	8703130915	3/19/87	ND	ND	ND	ND	ND	7.3
9-E	E1036	S3983	8703130930	3/19/87	ND	ND	ND	ND	ND	0.9
10	W2047	S0027	8703121720	3/19/87	ND	ND	0.3*	1.3	1.6	4.3
11	W2027	S1026	8703130755	3/19/87	ND	ND	0.2*	0.4*	1.5	4.6
12	W2023	S2001	8703121400	3/18/87	ND	ND	ND	ND	ND	ND
13	E3024	N0163	8703121425	3/18/87	ND	ND	ND	1.6	ND	1.6
14	E3046	S0841	8703121445	3/18/87	ND	ND	0.3*	1.4	1.6	5.5
15	E1823	S0980	8703121530	3/18/87	ND	ND	1.5	210	ND	211.5
16	E2022	S2028	8703121515	3/18/87	ND	ND	ND	2.7	ND	2.7
17	E2984	S1874	8703121500	3/18/87	ND	ND	ND	ND	ND	ND
18	NP	NP	8703121530	3/18	-	-	1.5	210	-	-
19	E1019	S1963	8703121610	3/18/87	ND	ND	5.1	330	7.4	344.3
HP-2	E0885	S4856	8703131220	3/20/87	ND	ND	ND	0.2*	ND	0.2
HP-3	W1308	S4143	8703131200	3/20/87	ND	ND	ND	ND	ND	0.8
			Analytical Method (SW-846)		602	602	602	602	602	-
			Nominal Detection Limit (ug/l)		0.3	0.4	0.1	0.2	0.1	-

ND: Not Detected

DCB: Dichlorobenzene

VOC: Volatile Organic Compounds

NP: No Point at Location

*: Less than 5 Times Detection Limit, Quantification Uncertain by 50-100%

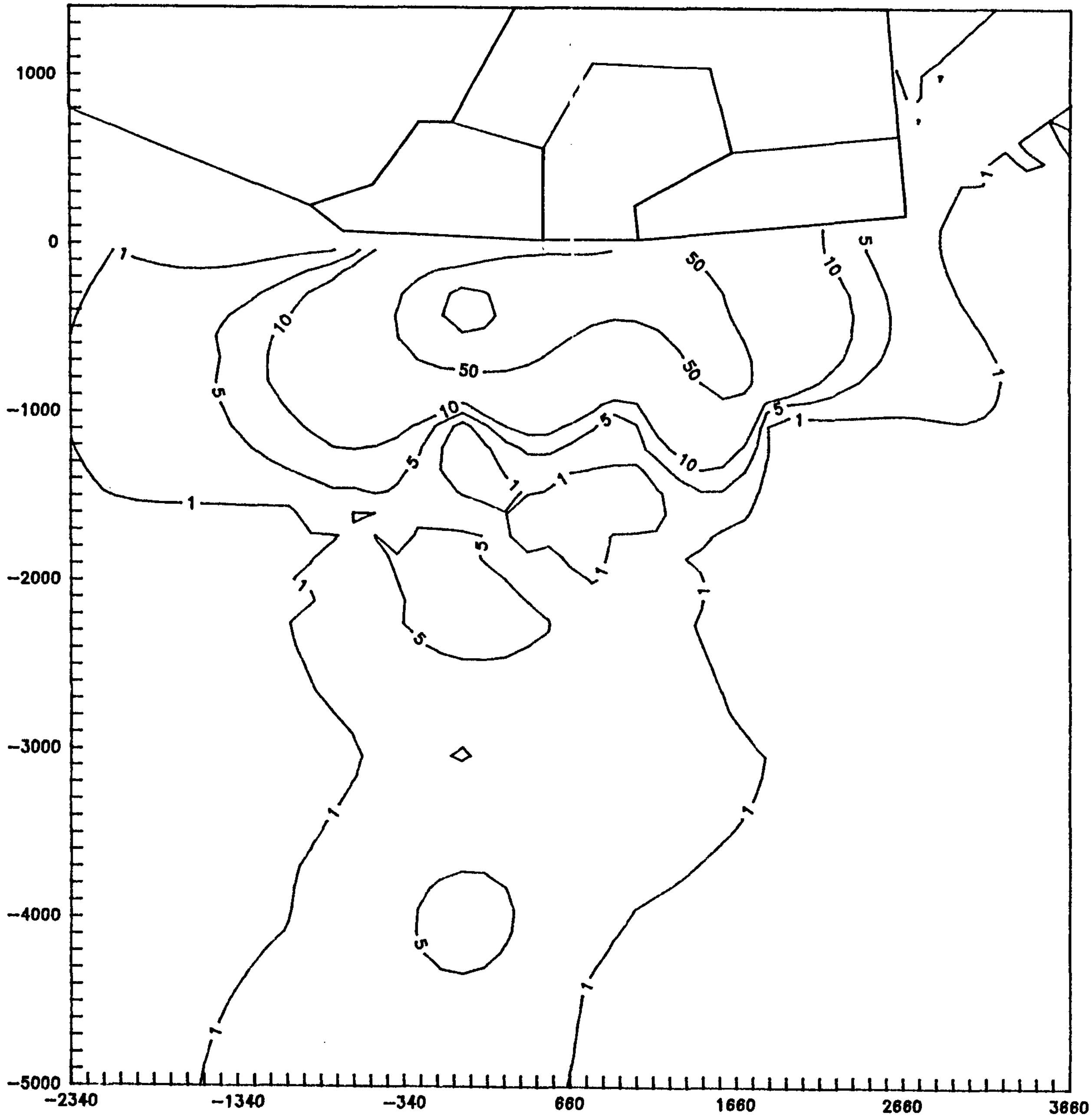


Figure 6-4a Contoured Toluene Concentrations in Valley-Fill Aquifer
Scales in Feet, Grid Origin is well MW-3
All Concentrations in ug/l

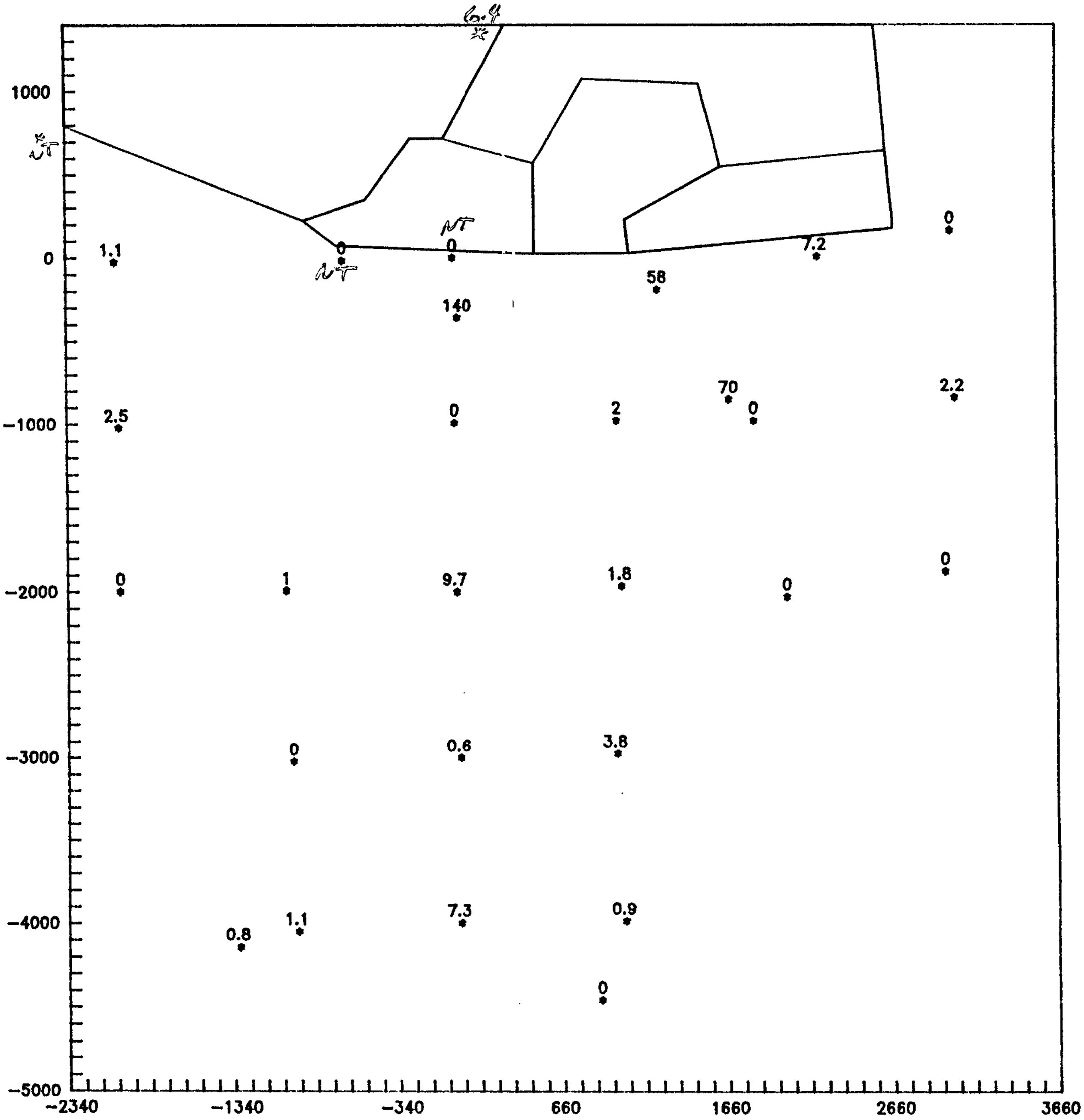


Figure 6-4b Mapped Toluene Concentrations
Scales in Feet, Grid Origin is well MW-3
All Concentrations in ug/l

[illegible]
0 [illegible]
[illegible]
EK:
mw 3
mw 6

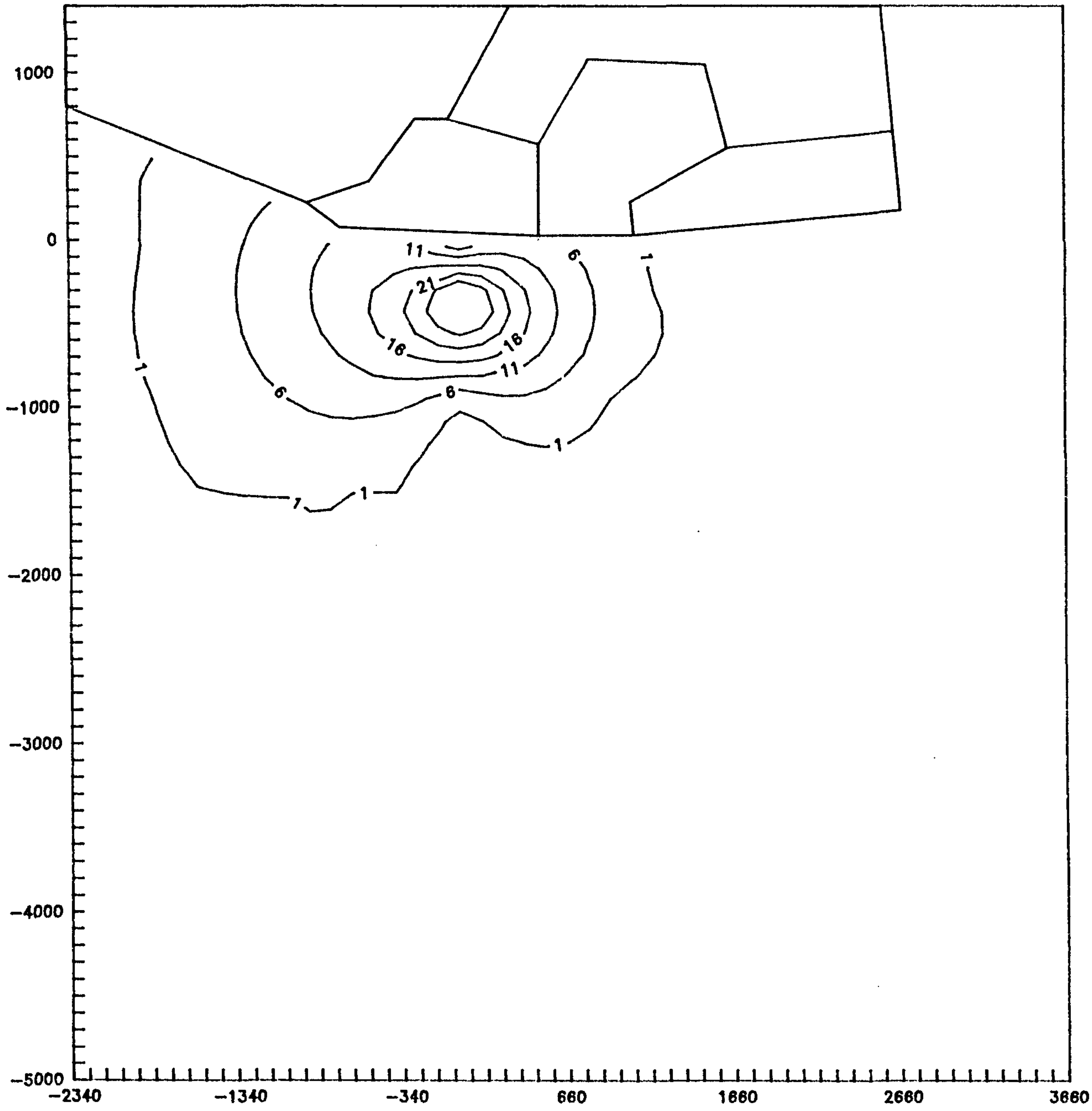


Figure 6-5a Contoured Ethylbenzene Concentrations in Valley-Fill Aquifer
Scales in Feet, Grid Origin is well MW-3
All Concentrations in ug/l

see comments
next pg

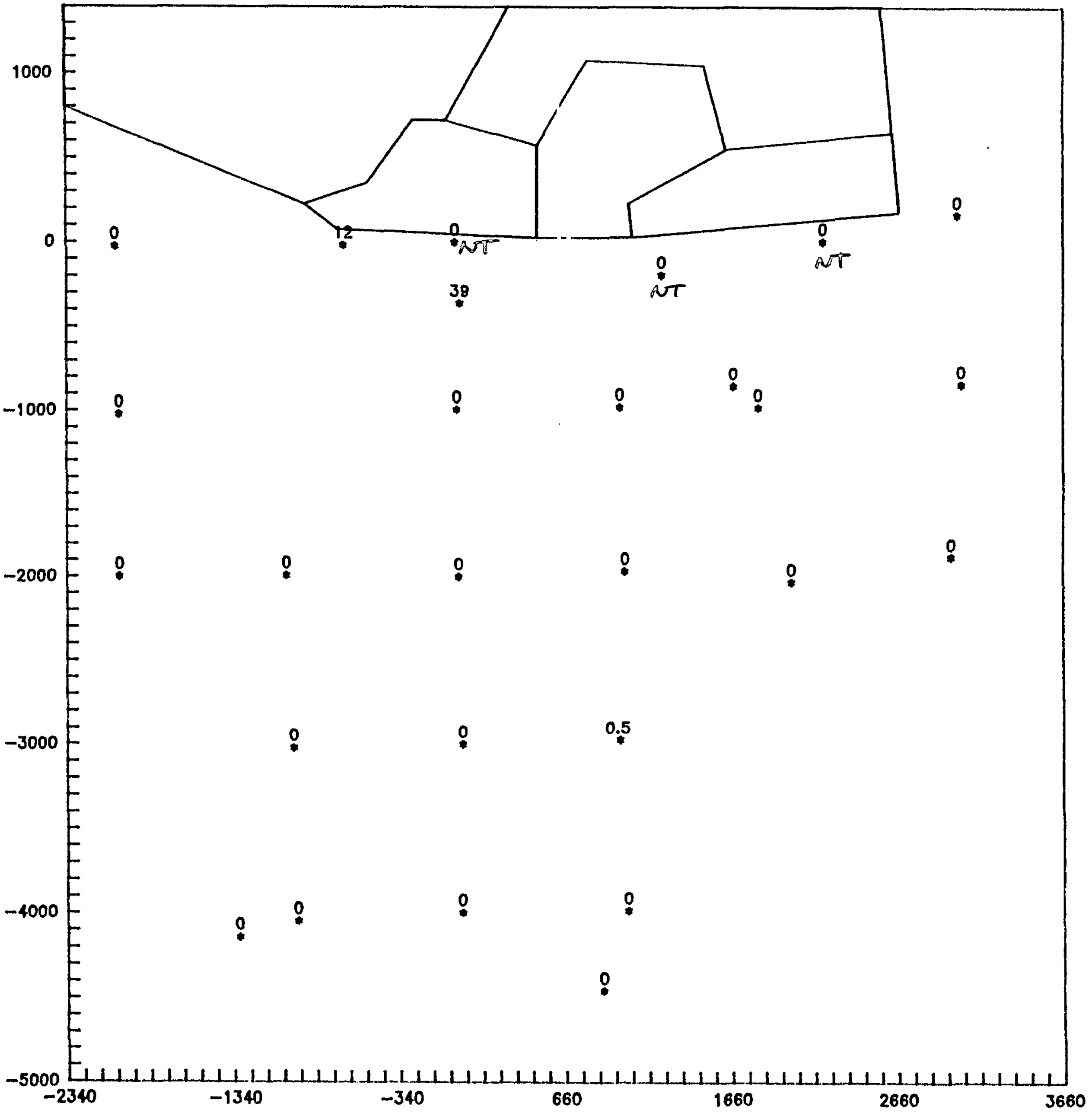


Figure 6-5b Mapped Ethylbenzene Concentrations
Scales in Feet, Grid Origin is well MW-3
All Concentrations in ug/l

Misleading
0 values given
where ethylbenzene
not [illegible]
Ex: MW-5
MW-7
MW-[illegible]

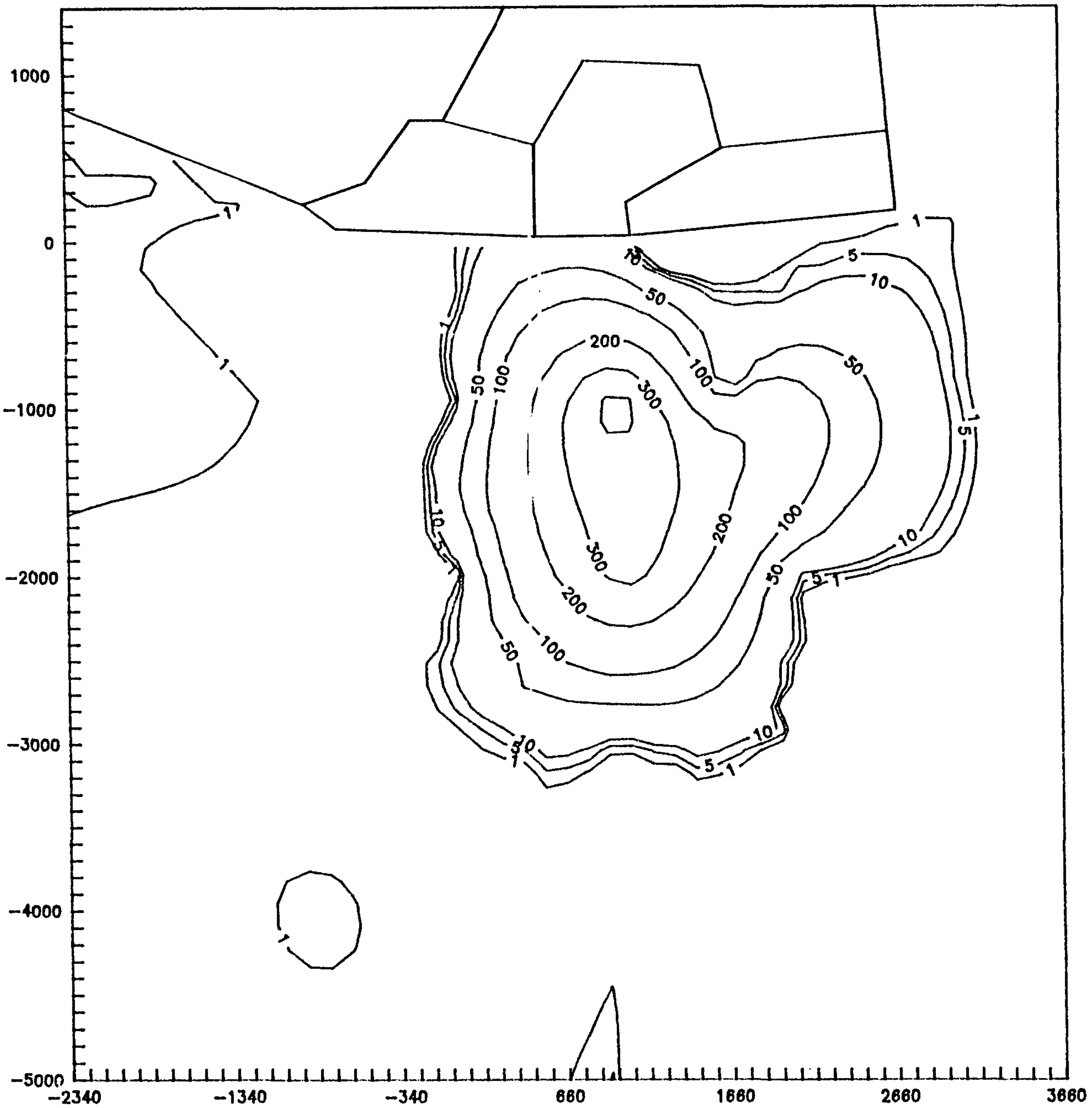


Figure 6-6a Contoured Xylene Concentrations in Valley-Fill Aquifer
Scales in Feet, Grid Origin is well MW-3
All Concentrations in ug/l

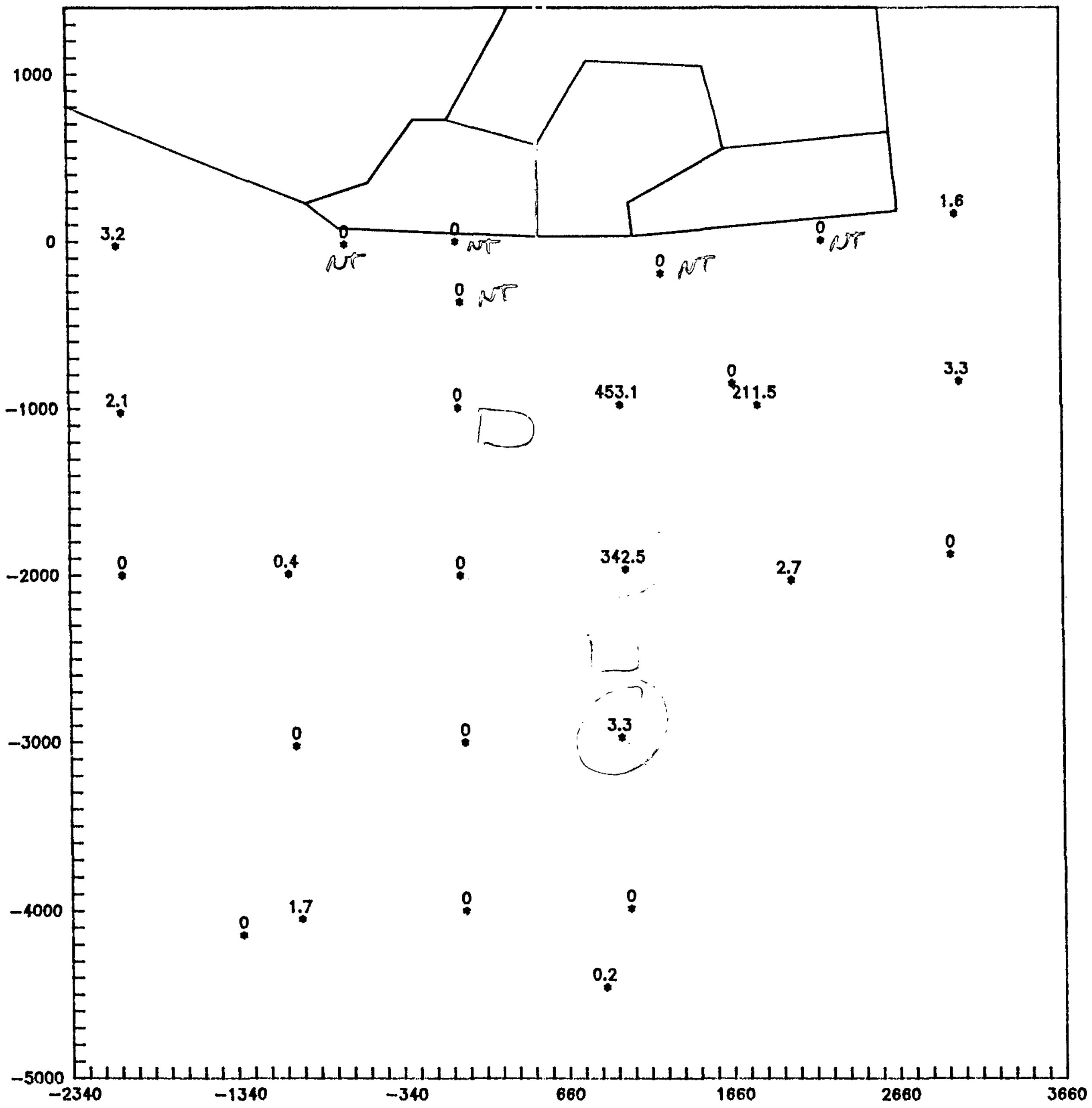


Figure 6-6b Mapped Xylene Concentrations
Scales in Feet, Grid Origin is well MW-3
All Concentrations in ug/l

0 values given
where Xylene
not tested?
No MW-series wells
tested for Xylene

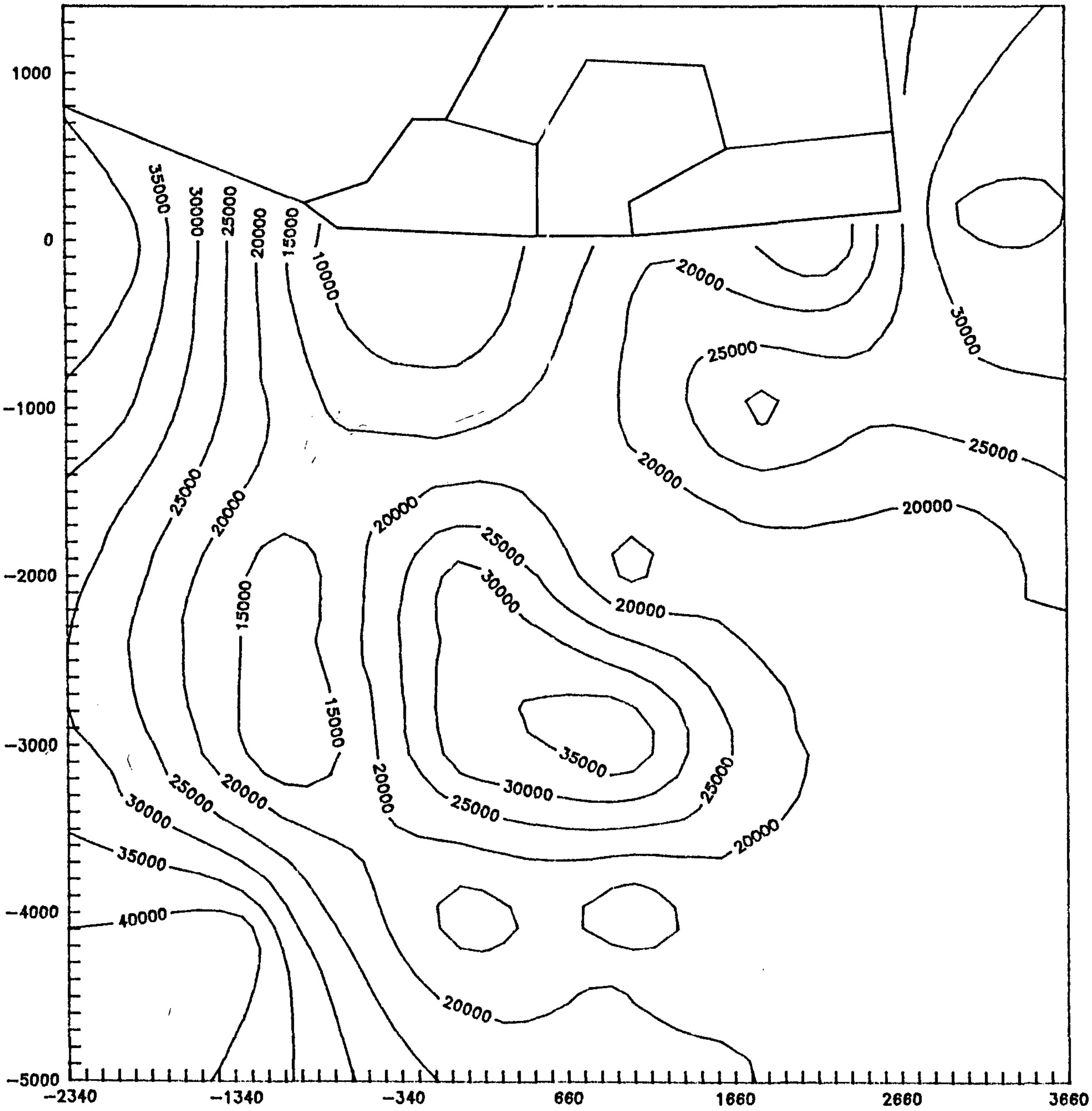


Figure 6-7a Total Dissolved Solids in Valley Fill Aquifer
Scales in Feet, Grid Origin is well MW-3
All Concentrations in mg/l

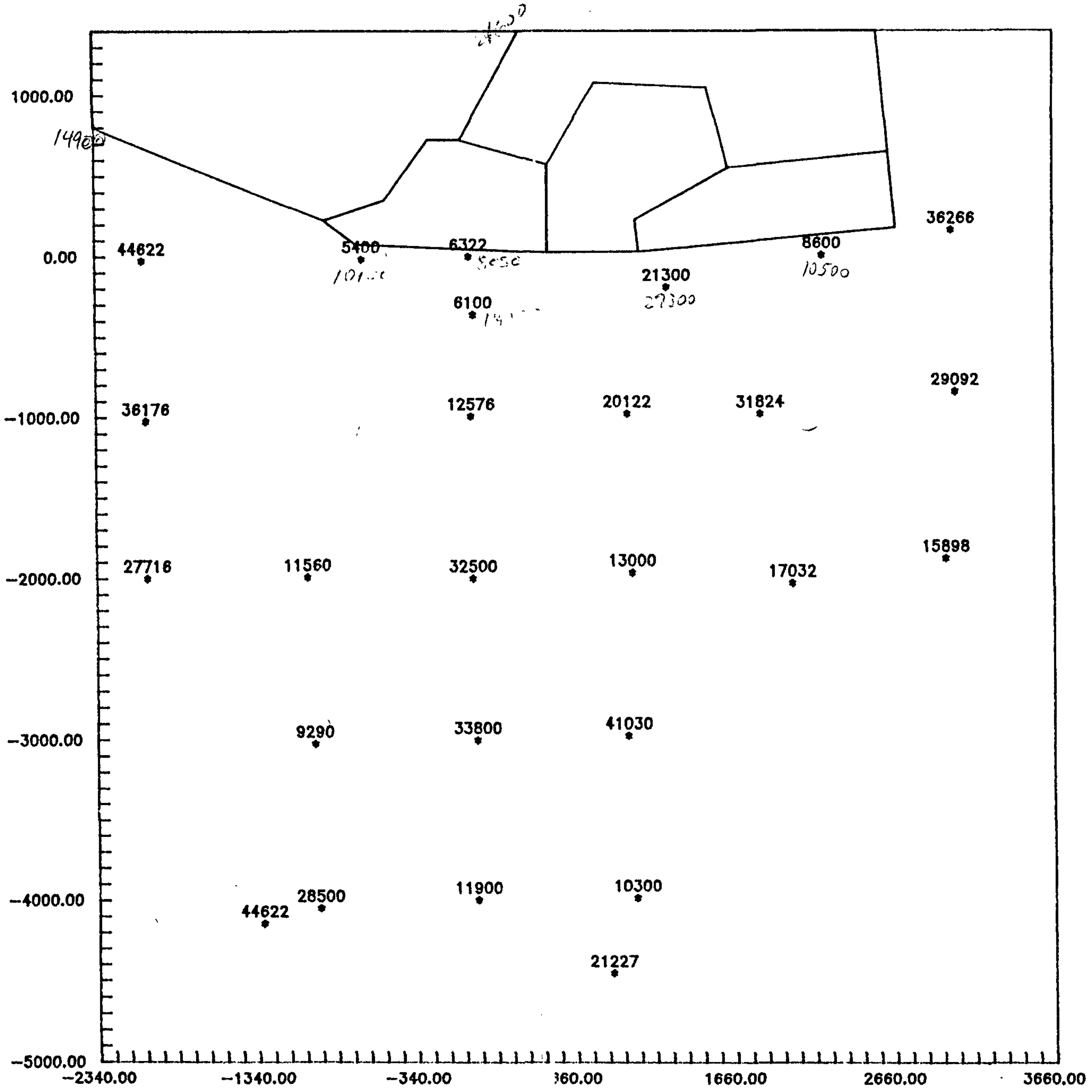


Figure 6-7b Mapped Total Dissolved Solids Concentrations
Scales in Feet, Grid Origin is well MW-3
All Concentrations in mg/l

[illegible] in TDS [illegible] Background data

6.5 PUMP TEST OF ALLUVIAL AQUIFER

On July 17 and 19, 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. The specific yield is 0.20. Based on a tested thickness of 25 feet, this corresponds to a hydraulic conductivity of approximately 250 gallons/day/ft^2, or 33 feet per day.

Data was recorded from the pumped well and from 2 piezometers and 1 existing observation well (Plates 2 and 13). Subsequent investigation indicated that the observation well (Navajo Well #13) may have an inefficient screen; data from this well was not used in the analysis.

Did not fit results? What was "subsequent investigation"?

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 hydraulic conductivity of 250 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.

6.6 INTERACTIONS BETWEEN PECOS RIVER AND VALLEY AQUIFER

Several methods were used to collect data on the interactions between the Pecos River and the valley-fill aquifer. These included a search for existing data, acquisition of USGS streamflow data from Pecos River gaging stations, instrumentation of several wells with recording water-level meters, and monthly surveys of water levels in wells near the ponds.

Water level data is summarized in Table 6-9, and water levels from the instrumented well (Navajo well #5, see Plate 1) and the gaging station at the Highway 82 bridge (see Figure 3-1) are shown in Figures 6-8 and 6-9. Well #5 is located approximately 75 feet south of the Pecos River, between the river and Pond #1. These data indicate that the Pecos is interconnected with the valley aquifer in the Artesia area. More regional studies (e.g., Welder, 1983) indicate that the river has a net yearly gain from the aquifer near Artesia. This trend is locally reversed when river levels rise more than approximately 6 feet above base level (Figures 6-10, 6-11 and 6-12).

In Figure 6-8 there are two data gaps, the first ending on December 31 and the second ending on January 31. These gaps are due to inoperative recording instruments in the first instance, and ice-locking of the gauge in the second case.

Areas of lost or unreliable data also exist in the Well #5 hydrograph; these periods are labeled on Figure 6-9. Problems with the well recorders included battery failure, rodent damage to chart paper, and the overturning of the recording devices by cattle.

Aquifer responses to changes in river stage are seen in several periods. The falling trend in river stage between September and October is matched by falling levels in Well #5, as are the sharp fluctuations in November and December. Well #5 is located approximately 75 feet from the river's channel, and many of the responses seem to occur within one day of the changes in river stage. The propagation of these changes throughout the entire pond area is likely, but the magnitude and nature of this interaction was beyond the scope of this investigation.

Table 6-9 Water Level Data From Valley Aquifer Wells

WELL	MPE	9/4/86	10/9/86	11/13/86	2/7/87	4/24/87
MW-1	3309.87	3301.12	3300.22	3300.66	ND	3301.91
MW-2	3310.22	3302.57	3301.67	3302.55	3303.22	3304.14
MW-3	3306.60	3299.30	3298.85	3299.47	3300.10	3300.57
MW-4	3306.90	3297.00	3296.50	3297.19	3297.86	3298.23
MW-5	3306.91	3300.28	3299.71	3300.24	3300.78	3301.32
MW-6	3307.92	3297.62	3297.02	3297.63	3298.21	3298.73
MW-7	3303.90	3298.40	3297.75	3298.40	3298.84	3299.75
MW-8	NS	(7.85)	(9.05)	(9.50)	ND	(8.79)
MW-9	NS	(8.40)	(9.80)	(10.25)	ND	(9.33)

MPE:	Measuring Point Elevation (ft)
NS:	Not Surveyed
ND:	Not Determined
(8.40):	Depth to water (ft) in unsurveyed wells

Figure 6-8

Pecos River Hydrograph

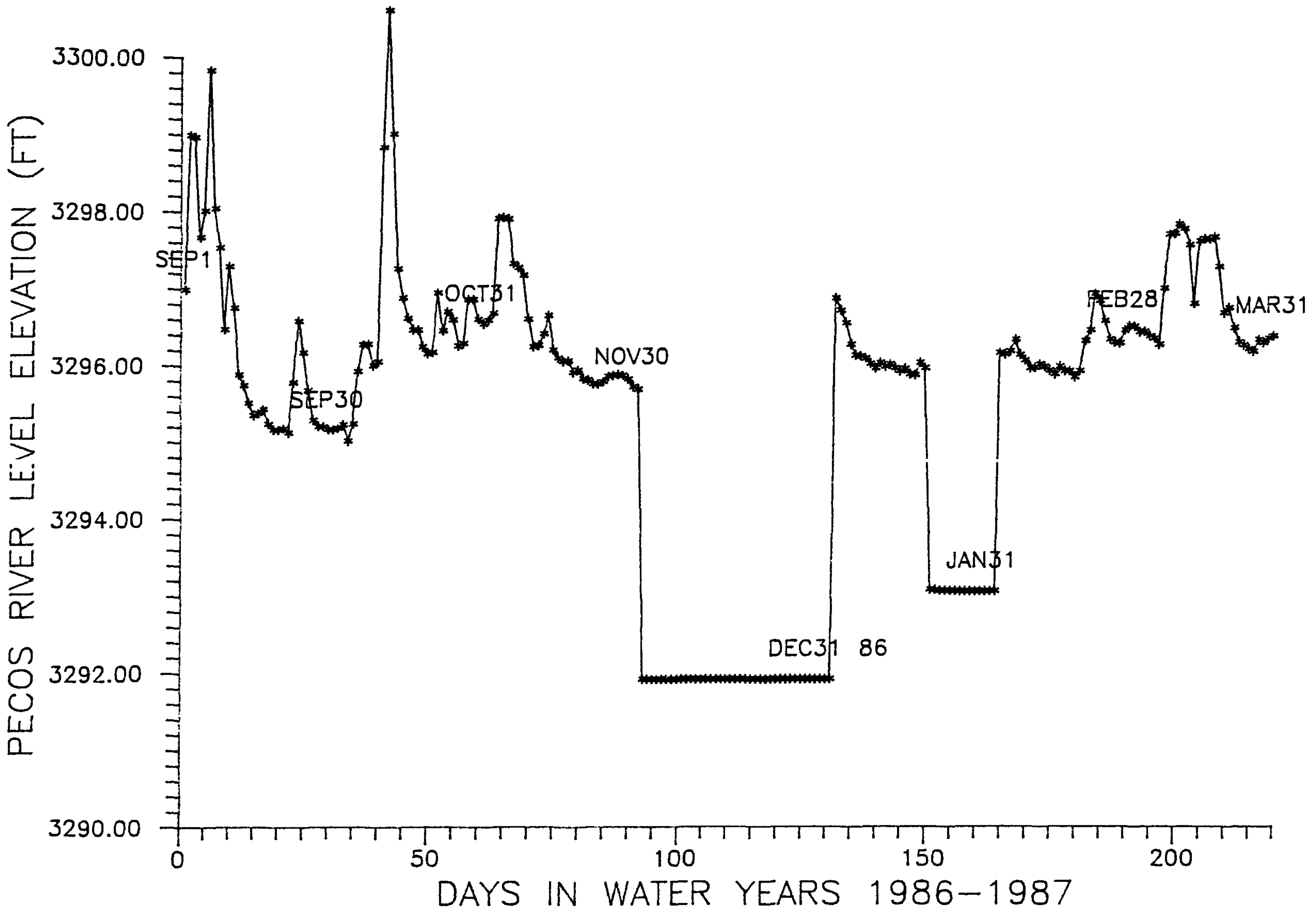
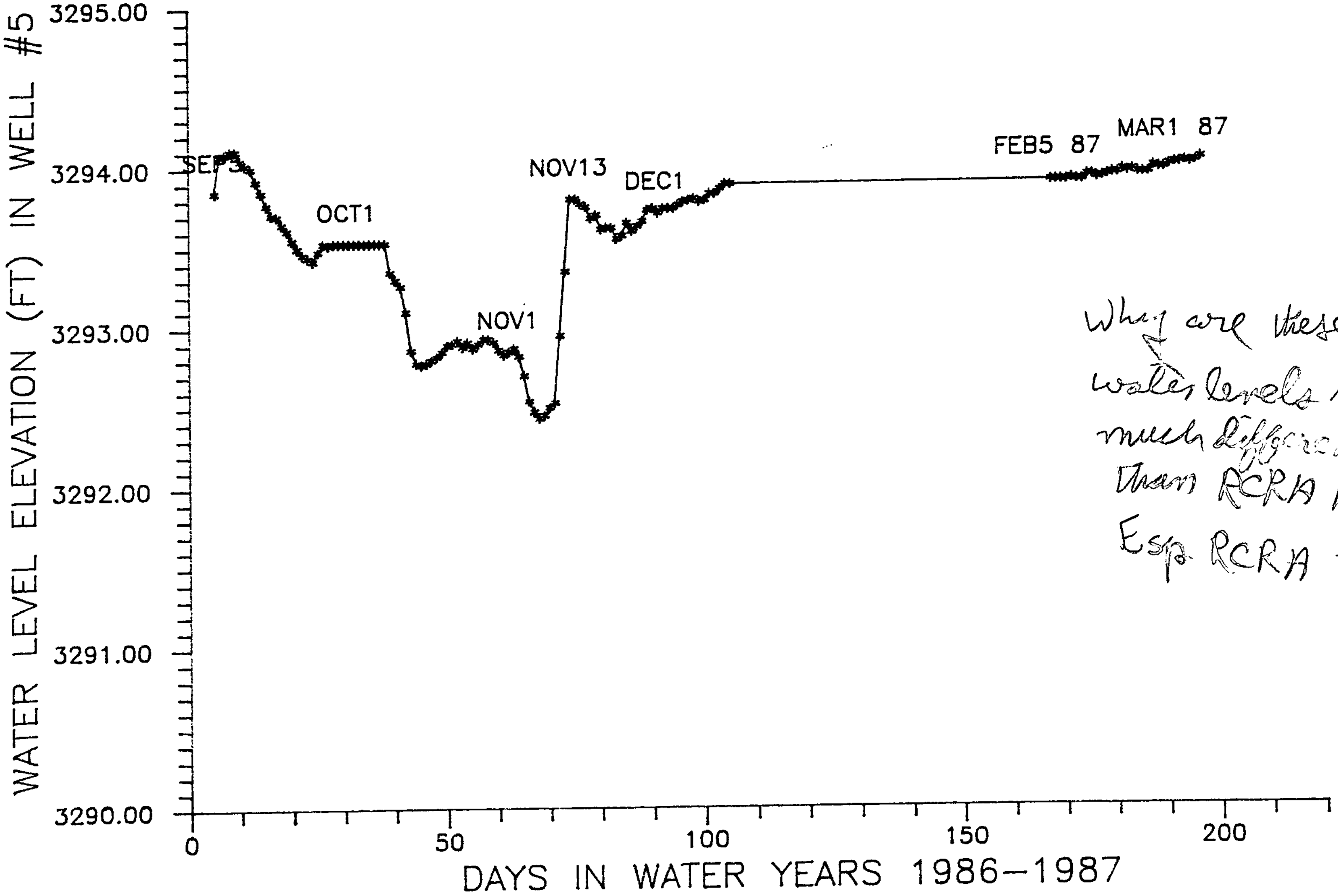


Figure 6-9

Hydrograph of Well #5



Why are these water levels so much different than RCRA levels? Esp RCRA #1, 2

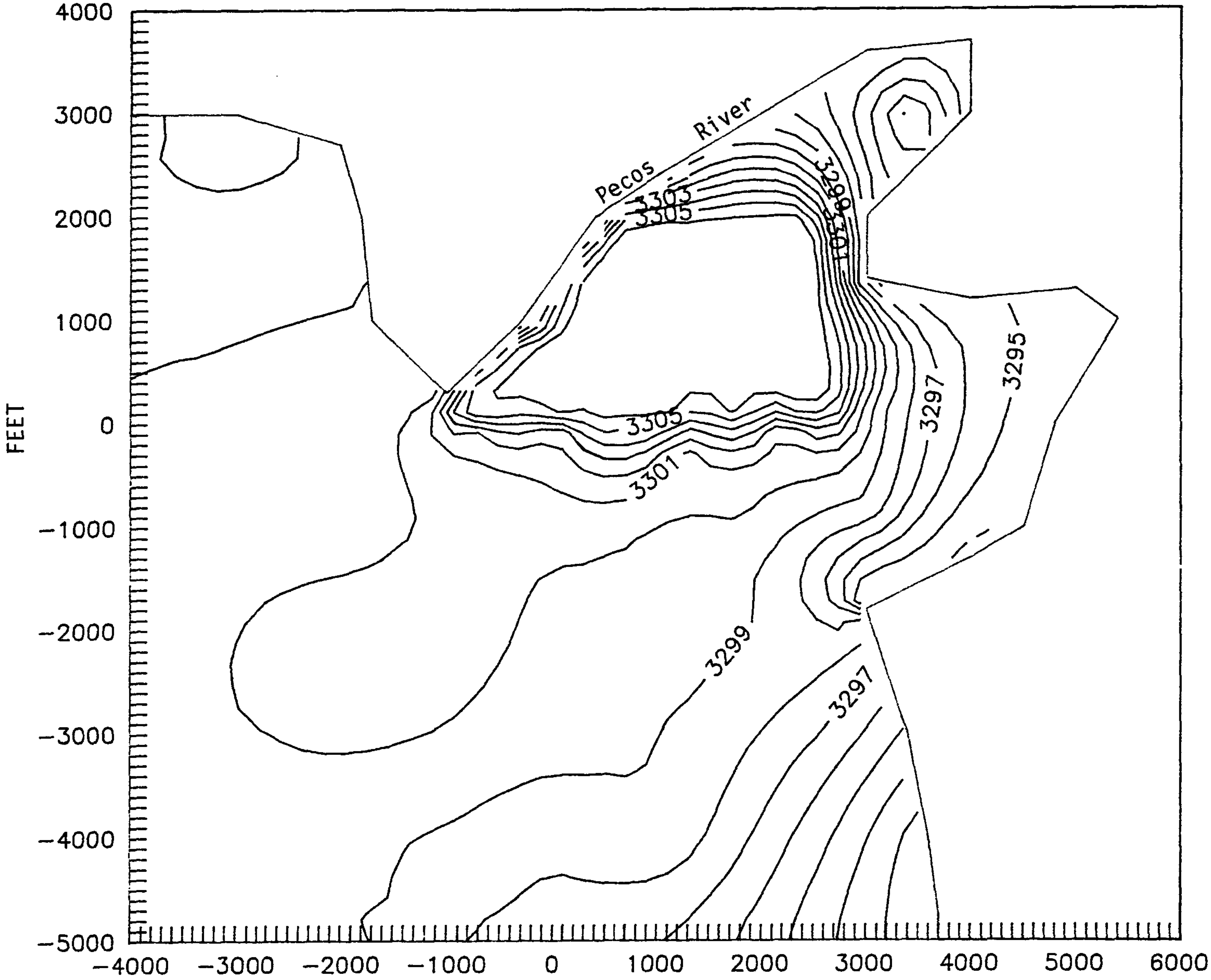


Figure 6-10: Base-Level Water Table Map, Pond Area

Date?

Where does WL from well #5 fit on here? WL 3292-94 ft

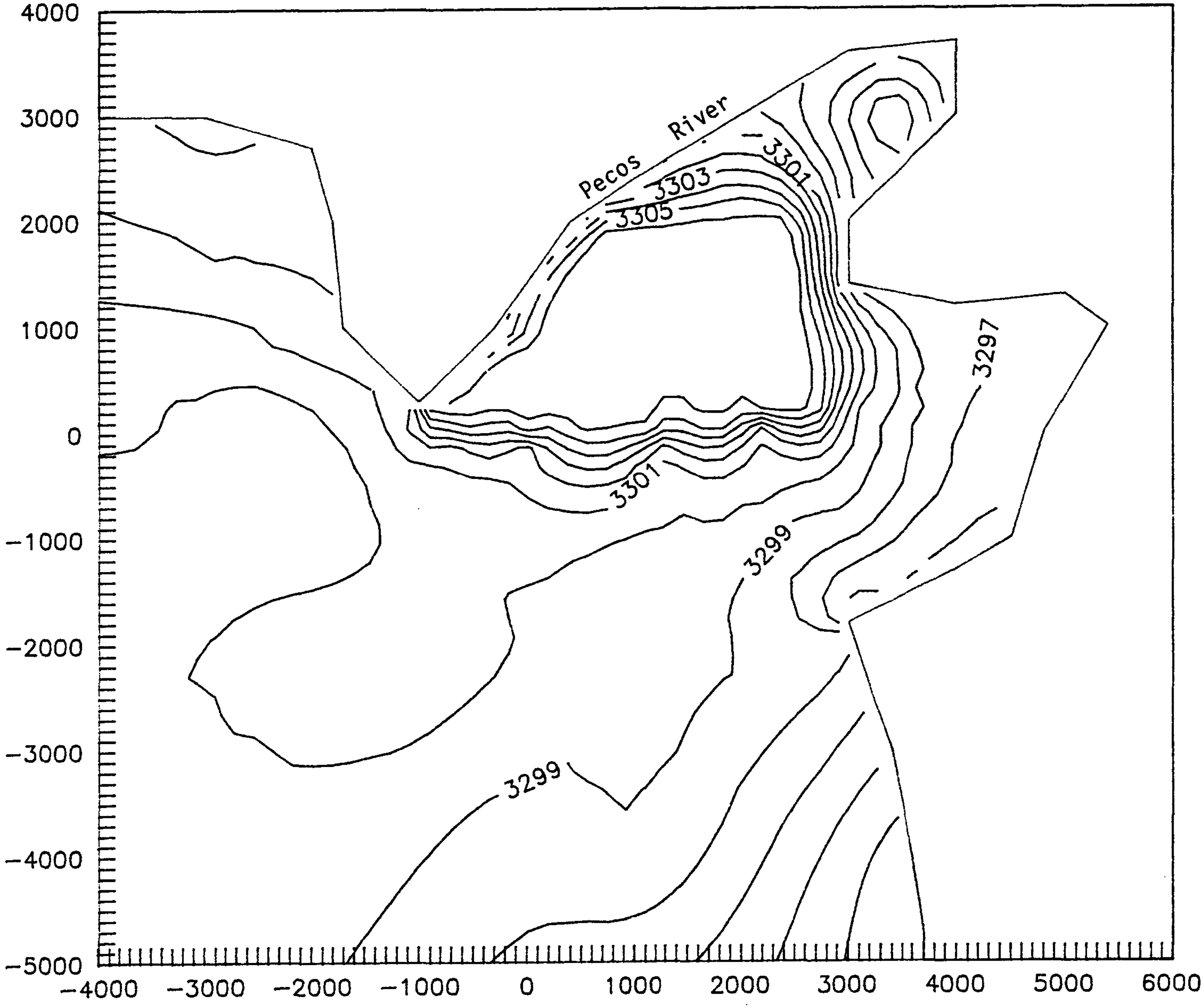
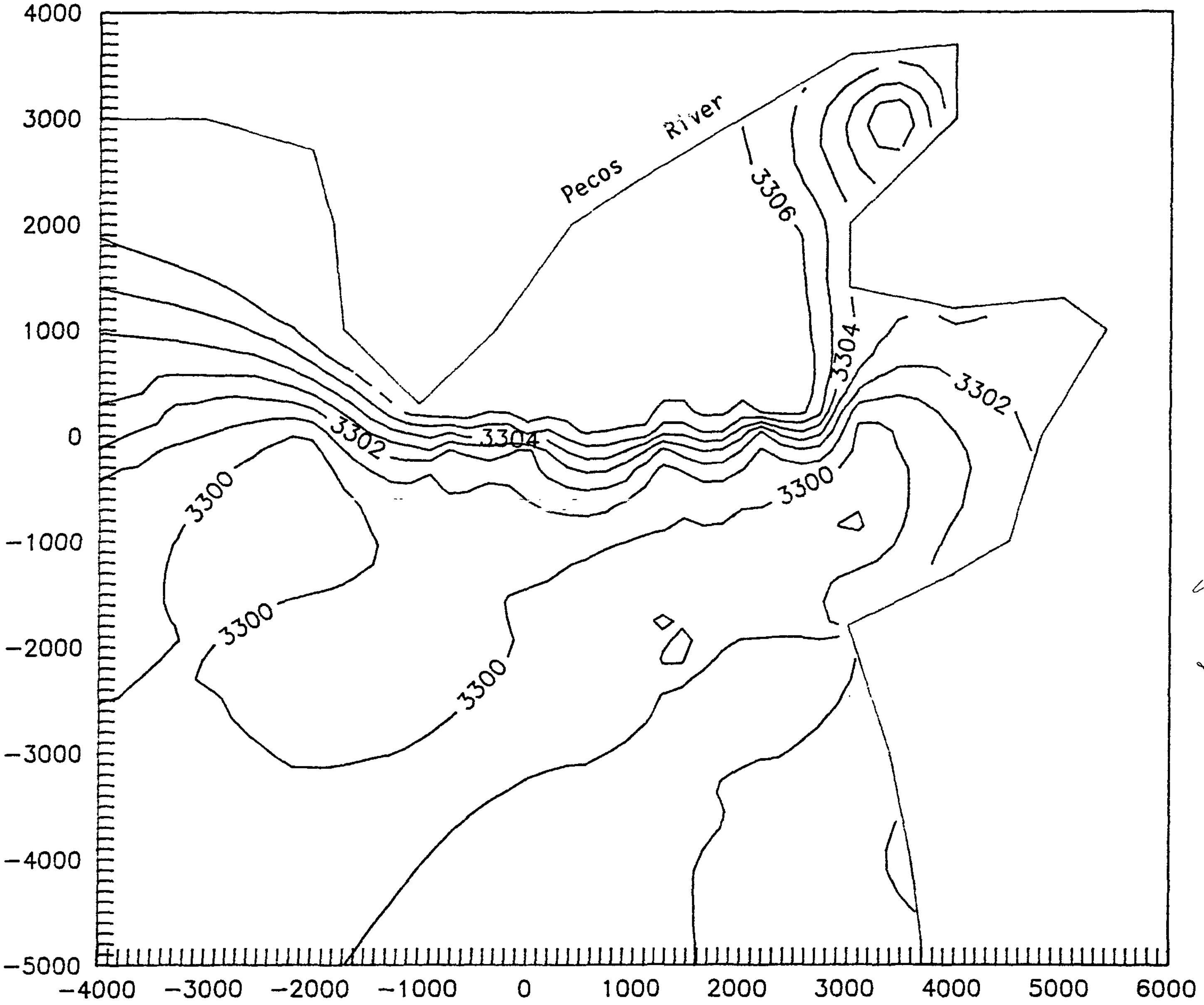


Figure 6-11: High Flow Water Table Map, Pond Area



What is the data for this?
Table 6-9, pg 65,
does not correlate with
these contours; can this
map be substantiated?

Figure 6-12: Flood Stage Water Table Map, Pond Area

SECTION 7.0

7.0 FACILITY IMPACTS TO GROUND WATER

7.1 AQUIFERS POTENTIALLY IMPACTED

[illegible]

As discussed in Section 5.0, the Artesia area is underlain by 3 major aquifers (San Andres, Queen and Valley Fill). Depth, intervening confining beds and upward hydraulic gradients act together to protect the deep artesian (San Andres and Queen) aquifers from contamination by the regulated units. Ground water in the alluvium underlying the ditch and the valley fill aquifer is vulnerable, due to its shallow depth, unconfined nature and permeable overburden. Although some contamination of the valley fill aquifer near the ponds has been discovered, there is no evidence that any of the other major regional aquifers has, or is likely to be, affected by Navajo's waste-disposal activities.

7.2 CONVEYANCE DITCH AREA

Based on the analytical results form monitor wells (MW-8 and MW-9) installed in this study, there is no apparent contamination of the portions of the valley fill aquifer adjacent to the ditch (see analyses of samples from MW-8 and MW-9, Table 6-6). Navajo is in the final stages of replacing this ditch with a pipeline (see Section 3.0). When the pipeline becomes operational in late 1987, the ditch will be removed from service and closed in accordance with the Closure Plan filed with NMEID.

7.3 EVAPORATION POND #1 AREA

7.3.1 Nature and Extent of Contamination

Sampling of downgradient monitor wells and steel drive points (see Table 6-7) have revealed the presence of low-level ground water contamination by volatile organic compounds, particularly xylenes, toluene and ethylbenzene. No samples analyzed contained contaminants in excess of existing human-health standards.

Benzene [illegible] ?

Exploratory sampling has shown that these constituents have formed plumes extending several thousand feet downgradient (south) of the evaporation pond. These plumes are illustrated in Figures 6-4, 6-5 and 6-6. All plumes appear to have migrated in the expected downgradient direction, spreading laterally due to dispersion, diffusion and seasonal changes in gradient.

Toluene levels (Figure 6-4b) range from below detection limits (BDL) to 140 ug/l (MW-5). The toluene plume is spatially large, but typically low-level except in the area immediately adjacent to Pond #1 (Figure 6-4a). This plume geometry appears to indicate a small, continuous source flux, with considerable dispersion (Freeze and Cherry, 1979, p. 394).

Ethylbenzene (Figure 6-5a) is much more localized, primarily in the area downgradient of Pond #1. The maximum level detected was 58 ug/l in MW-4 (Figure 6-5b). This constituent also appears to be the result of a small, relatively continuous source due to seepage from the pond.

The most concentrated plume is due to xlyenes, and covers a moderately large area south of the pond (Figure 6-6a). Maximum xylene concentrations of 453 ug/l were noted in steel point P87-2 (Figure 6-6b). This plume has a different geometry than the others, particularly with respect to the displacement of its concentration center to a point several thousand feet downgradient of the assumed source. Such a pattern generally results from a "slug" or single large release rather than long-term seepage from a large source (see Freeze and Cherry, p. 394). No record exists, however, of such a release.

7.3.2 Interactions of Pecos River and Valley Fill Aquifer

As discussed in Section 6.6, the valley fill aquifer is interconnected with and influenced by the Pecos River. Figures 6-9, 6-10 and 6-11 show the changes in this potentiometric surface during different river stages, and Figures 6-8 and 6-9 illustrate the hydrographic responses of the aquifer and the river.

The flow of the Pecos River is strongly controlled by dams, built for the purposes of flood control, sediment removal and irrigation storage. River discharge is regulated primarily by irrigation schedules and interstate agreements. During the spring, summer and fall, the river's discharge is dominated by releases from upstream dams. For several days a relatively uniform flow of several thousand cubic feet per second (CFS) is maintained. Then the release is terminated and the river slowly returns to base flow (Figure 7-1).

Base flow is typically a few tens's of CFS or less; the channel is commonly dry between releases in some areas. The base flow that occurs is maintained by irrigation returns, releases from bank storage in the alluvial aquifer, and local precipitation. Water quality in the Pecos is also dependent upon discharge levels. During releases the total dissolved solids (TDS) levels average 2000-4000 mg/l (USGS data, 1982-1983); this rises to over 10,000 mg/l during base flow (Figure 7-1). The increase in TDS is due to salt flushing by irrigation, releases of more saline water from the alluvial aquifer, and evapotranspiration in and adjacent to the channel.

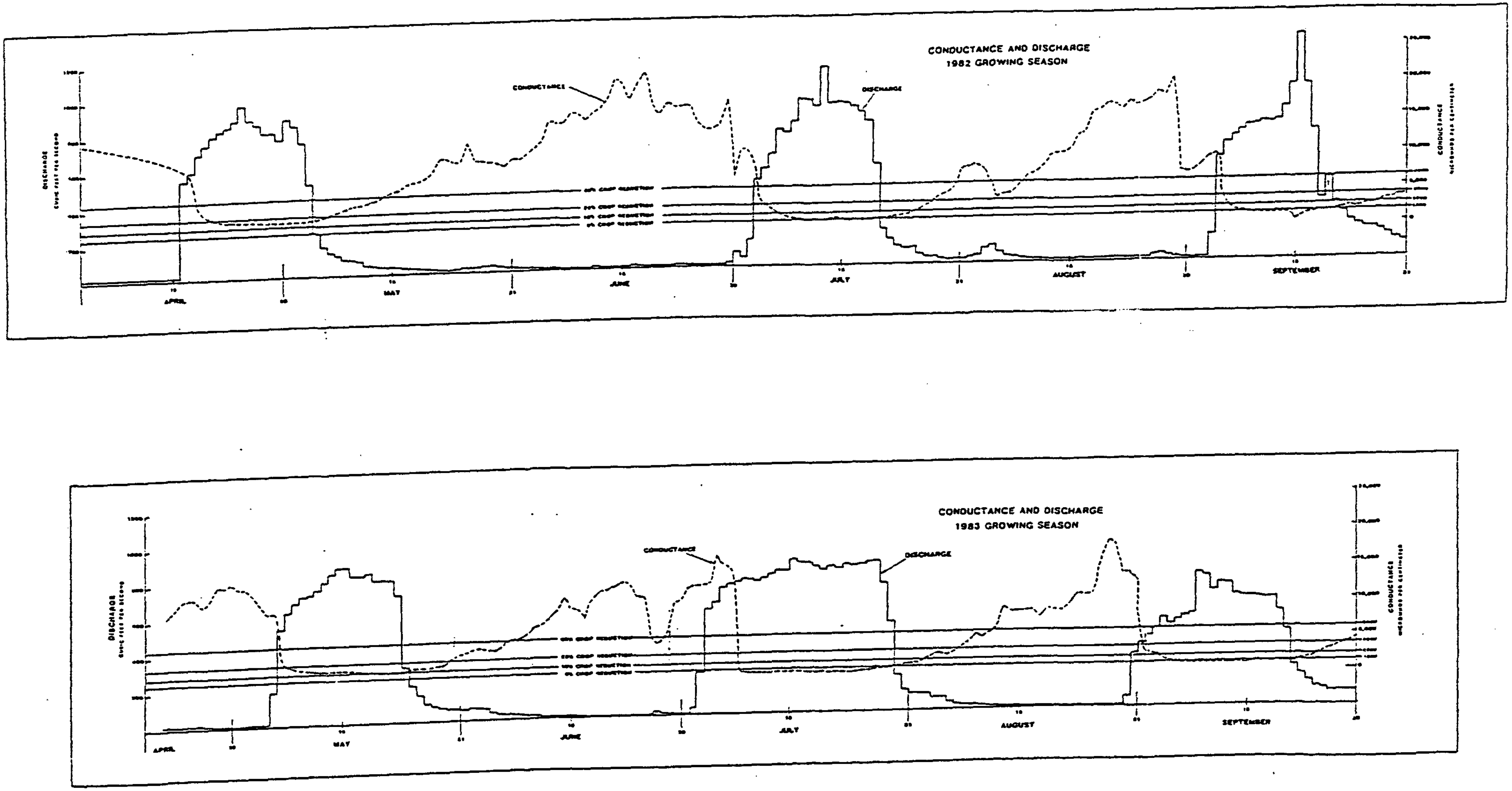
With the exception of unusually high flood events, it is clear that most of the year ground water flows from the alluvial aquifer into the Pecos River. For reasons discussed in Section 7.3.3, it appears that ground water in the valley fill near Navajo's evaporation ponds has a "residence time" of up to several years in the aquifer before reaching the river.

7.3.3 Migration and Fate of Contamination

Based on the extent and geometry of observed contamination, pump-test determination of aquifer properties and the hydraulic dynamics of the valley fill aquifer, it is possible to predict the general migration paths, rates and ultimate fate of the hazardous constituents in the ground water.

The velocity of ground water may vary with respect to local changes in gradient, porosity and hydraulic conductivity, but a general calculation

Figure 7-1 Pecos River Hydrographs and Specific Conductance



based on average parameters is very useful in predicting the overall behavior of the system. Ground water velocity (V) may be calculated on the basis of conductivity (K), gradient (h) and porosity (n) from the equation:

$$V = Kh/n$$

Using the average gradient of 0.001, a conductivity of 33 feet per day and a porosity of 0.20:

$$V = (33)(0.001)/0.2 = 0.15 \text{ feet per day}$$
$$(55 \text{ feet per year})$$

In the areas adjacent to the ponds, where mounding is evident, gradients as steep as 0.01 are observed; these areas may have ground water velocities as great as 1.5 feet per day (550 feet per year). In the area several thousand feet south of the ponds, gradients are as shallow as 0.0002 and velocities may be as low as 0.03 feet per day (11 feet per year).

The center of the xylene plume lies approximately 1500 feet downgradient of Pond #1. At 55 feet per year, this implies a transport time of 27 years. As little as 2.7 years would be required at the velocities calculated for areas immediately adjacent to the ponds. A more reasonable determination of plume velocity can be obtained by observing the different local gradients that a particle encounters as it moves downgradient. In the first 500 feet from the ponds, the velocity is approximately 550 feet per year; thus this distance is traversed in 0.91 years. The second 500 feet has a gradient of 0.002 and a velocity of 110 feet per year, this distance is passed in approximately 4.5 years. The final 500 feet has a gradient of 0.001 and a velocity of 55 feet per year, corresponding to a travel time of 9.1 years.

The total of the time segments (0.91 + 4.5 + 9.1) = 14.5 years. Because the time of release and the original concentration are unknown, the effects of dispersion, diffusion and degradation on the organic contamination cannot be calculated with any accuracy.

Because the valley fill aquifer ultimately discharges to the Pecos River, this discharge is apparently the ultimate fate of the contaminants. The low concentrations of organic contaminants observed in the aquifer, and the slow rates of seepage into the river indicate that it would be unlikely to find detectable concentrations of these compounds in the river. Samples collected from the Pecos River in 1985 showed no detectable levels of organic contamination (Table 7-1; Appendix B).

Human exposure to these contaminants is very unlikely under the present conditions. The area overlying the plume is presently a cattle pasture, with no domestic wells, and the ground water in the valley fill is of very poor quality (average TDS 26,000 mg/l), precluding any human consumption. Strong upward gradients in the principal drinking water reservoirs (San Andres and Queen aquifers) prevent any significant downward migration. Because of the high dissolved-solids content of the river, there are no downstream withdrawals of river water for human consumption.

Table 7-1 Analyses of Pecos River Samples

Parameter	Det. Limit	854111120 (Above Ponds)	854111135 (Below Ponds)
EC	0.1 um/cm	10,000	10,000
TDS	1 mg/l	8220	8782
Benzene	1 ug/l	ND	ND
GC Scan*	1 ug/l	ND	ND

* Scan for benzene, toluene, ethylbenzene, xylenes and other light aromatic hydrocarbons

SECTION 8.0

8.0 PROPOSED RESPONSES

Based on the low levels of contamination found, the highly saline nature of the valley-fill aquifer and the lack of paths for potential human exposure, Navajo does not propose any remedial action at this time.

8.1 PROPOSED CONCENTRATION LIMITS

Navajo proposes that the New Mexico Water Quality Control Commission ground water standards be used to determine the level of response appropriate to the observed contamination. Where standards exist (or are established in the future), any additional monitoring or remedial actions will be triggered by and directed towards these standards. Table 8-1 lists the constituents identified, their maximum observed levels, and the established standard.

8.2 PROPOSED SOURCE CONTROLS

Evaporation Pond #1 and the conveyance ditch are scheduled for closure. A wastewater treatment plant will be installed and the ditch is currently being replaced by a pipeline. Pond #1 is scheduled to be closed, buried and capped as soon as possible. At that time the major sources for additional contamination of ground water will be removed. Natural processes such as dilution and biological degradation should eventually reduce the residual contamination to undetectable levels.

Table 8-1 Proposed Concentration Limits for Detected Contaminants (ug/l)

Parameter	Standard	Maximum Detected
Toluene	750	140
Ethylbenzene	750	39
Xylenes	620	453

SECTION 9.0

9.0 REFERENCES CITED

Discharge Plan Application for Navajo Refining Company, Artesia, New Mexico Refinery, 1984: prepared by Geoscience Consultants, Ltd, 500 Copper NW, Albuquerque, NM. Submitted to New Mexico Oil Conservation Division, Santa Fe, New Mexico.

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Kelley, V.C., 1971, Geology of the Pecos Country, Southeastern New Mexico: New Mexico Bureau of Mines and Mineral Resources Memoir 24, Socorro, New Mexico, 77 p, 7 maps.

Proposed Investigations of Pond #1 and Conveyance Ditch To Determine Potential Effects to Ground Water Quality, Navajo Refinery, Artesia, New Mexico, 1986 (October 29 Revision): prepared by Geoscience Consultants, Ltd, 500 Copper NW, Albuquerque, NM. Submitted to New Mexico Environmental Improvement Division, Santa Fe, New Mexico.

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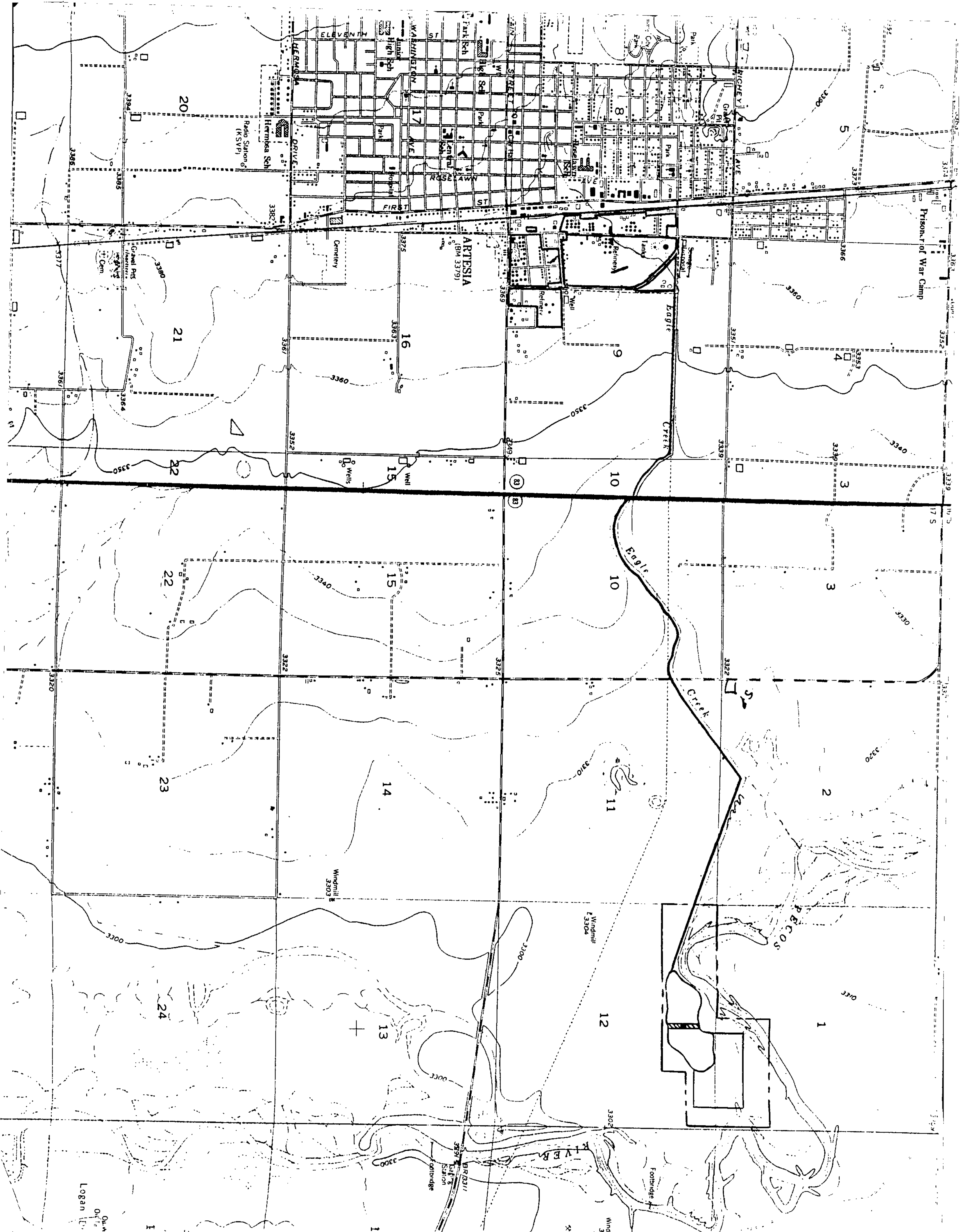
Welder, E.G., 1983, Geohydrologic Framework of the Roswell Ground Water Basin, Chaves and Eddy Counties, New Mexico: New Mexico State Engineer's Technical Report 42, Santa Fe, New Mexico, 28 p., 28 maps.


ELEVENTH ST
WASHINGTON AVE
HERMOSA DRIVE
MAIN STREET
ROSELAWN AVE
FIRST ST
RICHEY AVE
Junior High Sch
High Sch
Park
Hospital
Central Sch
City Hall
Roselawn Sch
Radio Station (KSVP)
Hermosa Sch
ARTESIA
(BM 3379)
Cemetery
Gravel Pits
Cem
Refinery
Tanks
Well
Wells
Prisoner of War Camp
Eagle Creek
PECOS RIVER
Windmill 3303
Windmill 3304
Footbridge
BM 3311
Logan
17 S
83
3300
3310
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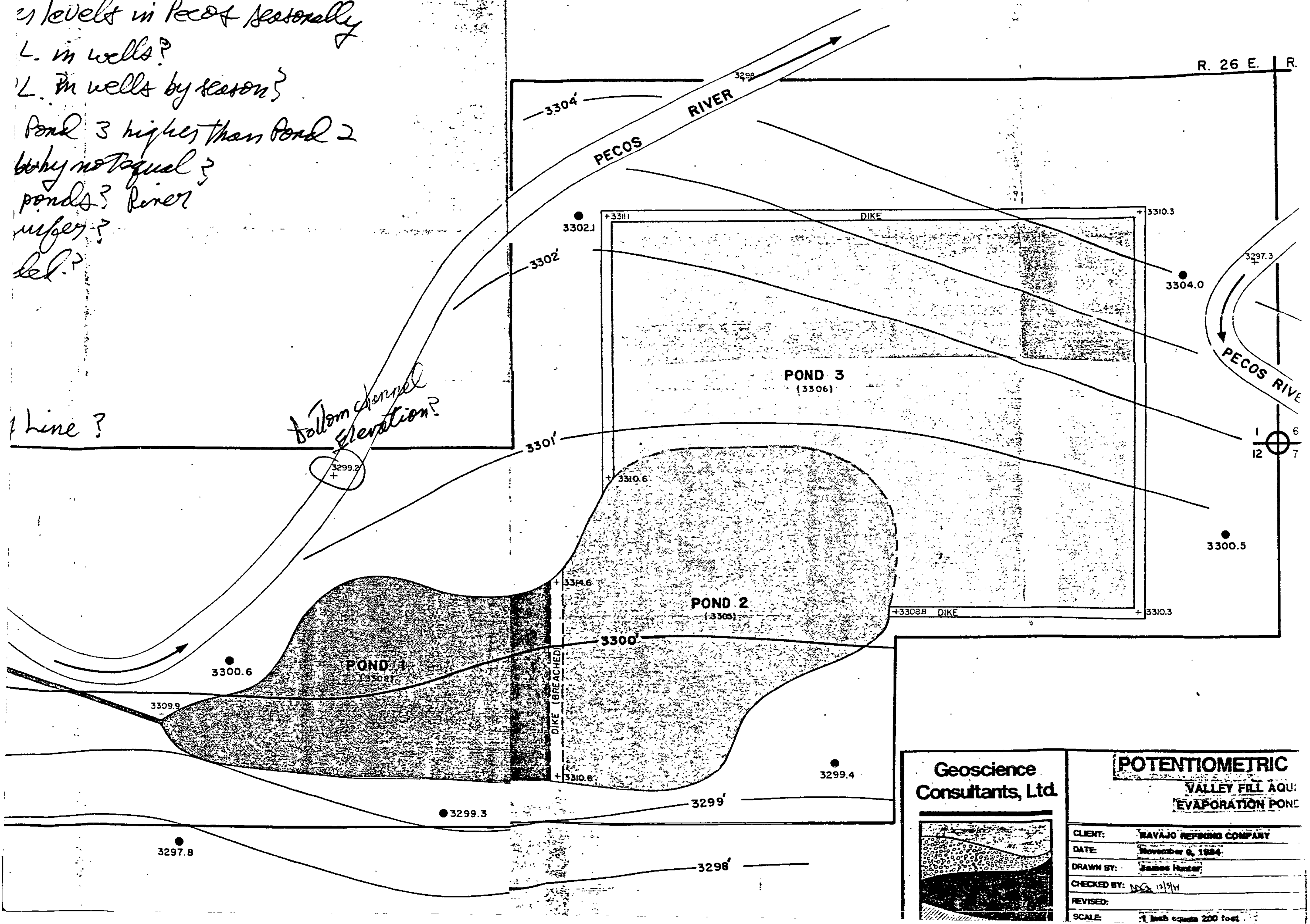
L. in Pecos?
es levels in Pecos seasonally
L. in wells?
L. in wells by season?
Pond 3 higher than Pond 2
why not equal?
ponds? River
uifer?
el.?

Line ?



Bottom channel Elevation?

Geoscience Consultants, Ltd.

POTENTIOMETRIC
VALLEY FILL AQU
EVAPORATION PON

CLIENT:	NAVAJO REFINING COMPANY
DATE:	November 6, 1984
DRAWN BY:	James Hunter
CHECKED BY:	DDG 12/9/11
REVISED:	
SCALE:	1 inch equals 200 feet

in Pecos?
levels in Pecos seasonally
in wells?
in wells by season?
nd 3 higher than Pond 2
y not equal?
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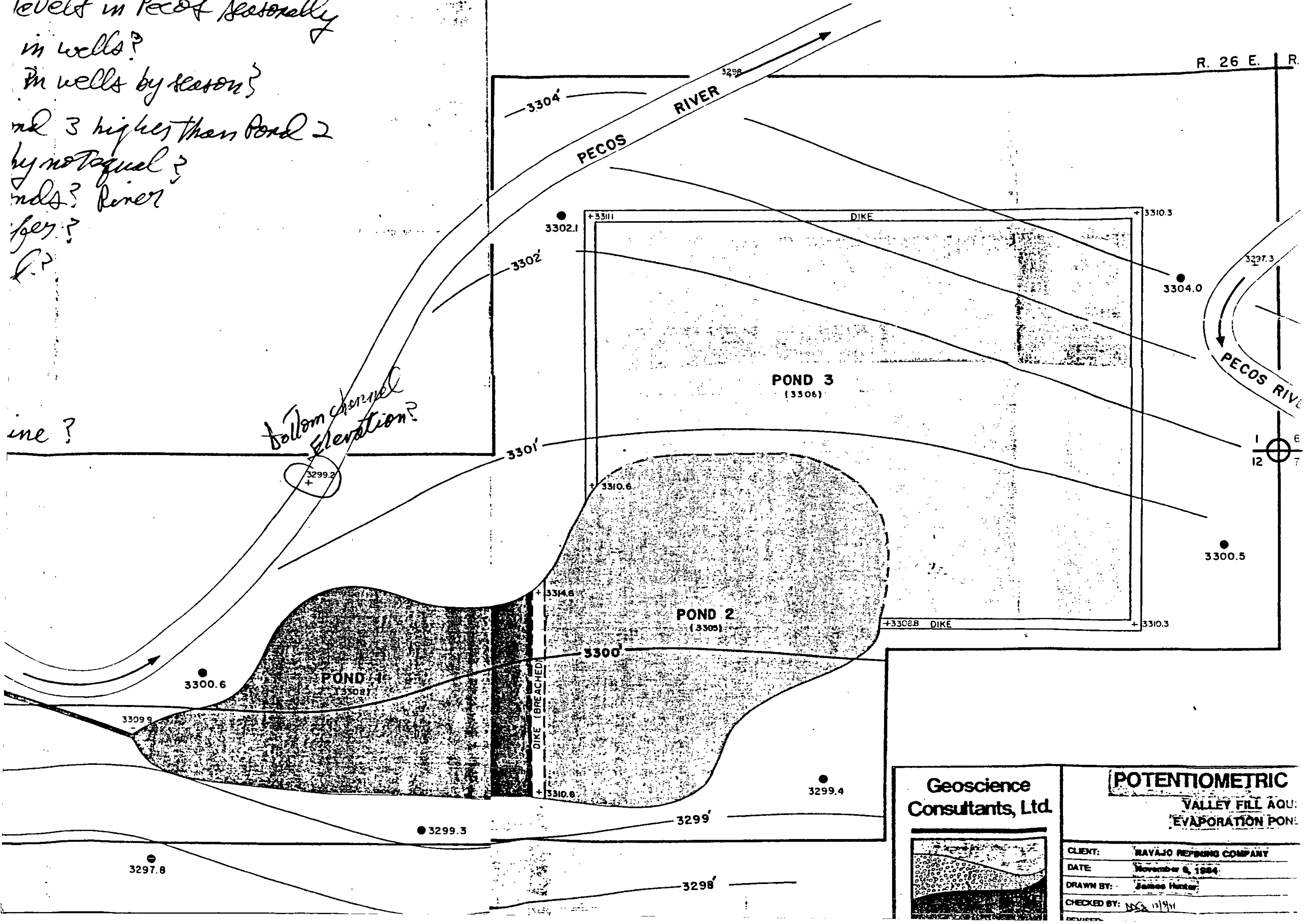

Bottom channel Elevation?

Geoscience Consultants, Ltd.

POTENTIOMETRIC
VALLEY FILL AQU
EVAPORATION PON

CLIENT: NAVAJO REFINING COMPANY
DATE: November 6, 1984
DRAWN BY: James Hunter
CHECKED BY: 12/9/91
REVISED:

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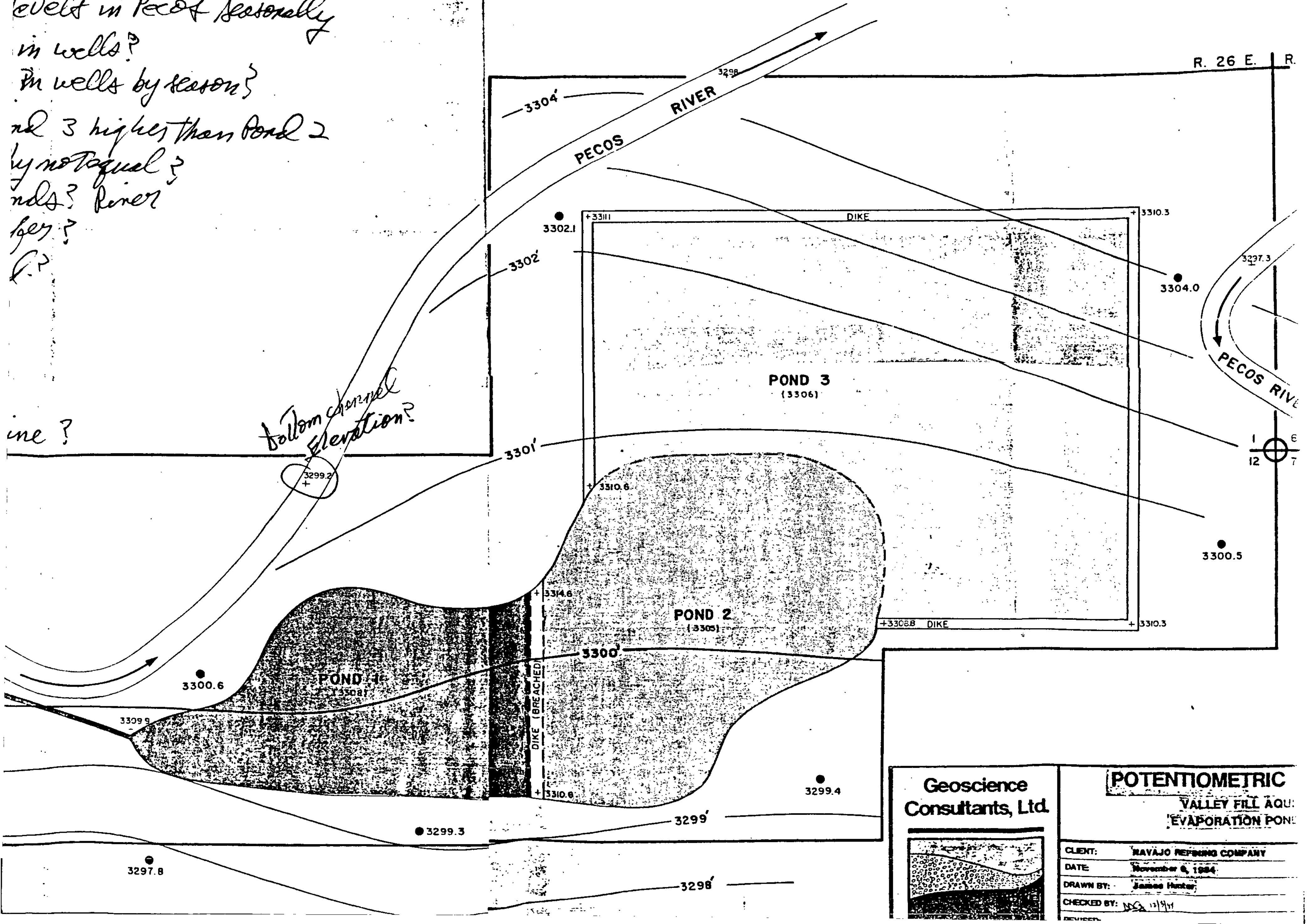

bottom channel Elevation?

Geoscience Consultants, Ltd.

POTENTIOMETRIC
VALLEY FILL AQU
EVAPORATION PON

CLIENT:	NAVAJO REFINING COMPANY
DATE:	November 6, 1984
DRAWN BY:	James Hunter
CHECKED BY:	12/9/84
REVISED:	

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levels in Pecos seasonally
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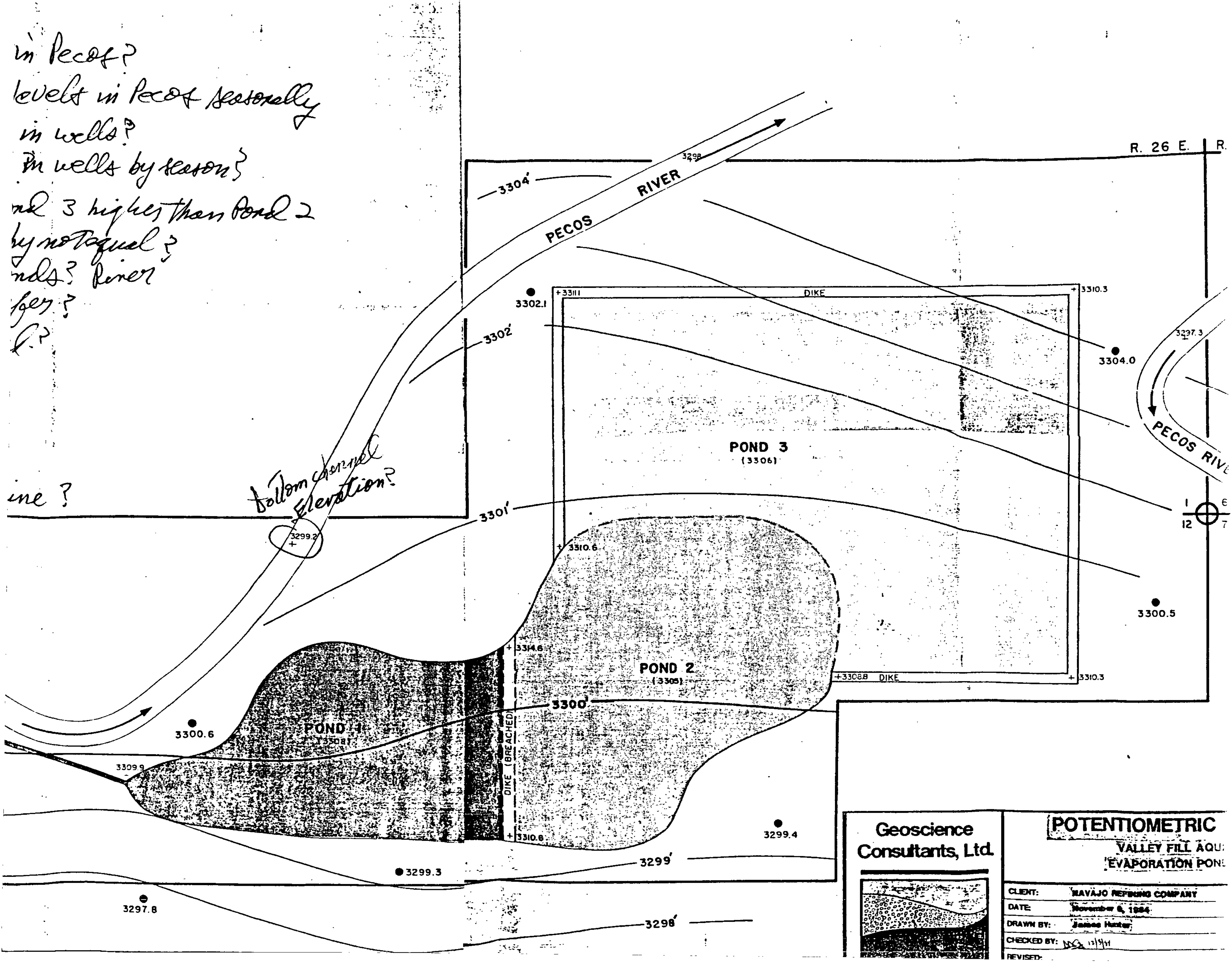
Elevation?



Geoscience Consultants, Ltd.

POTENTIOMETRIC
VALLEY FILL AQU
EVAPORATION PON

CLIENT:	NAVAJO REFINING COMPANY
DATE:	November 6, 1984
DRAWN BY:	James Hunter
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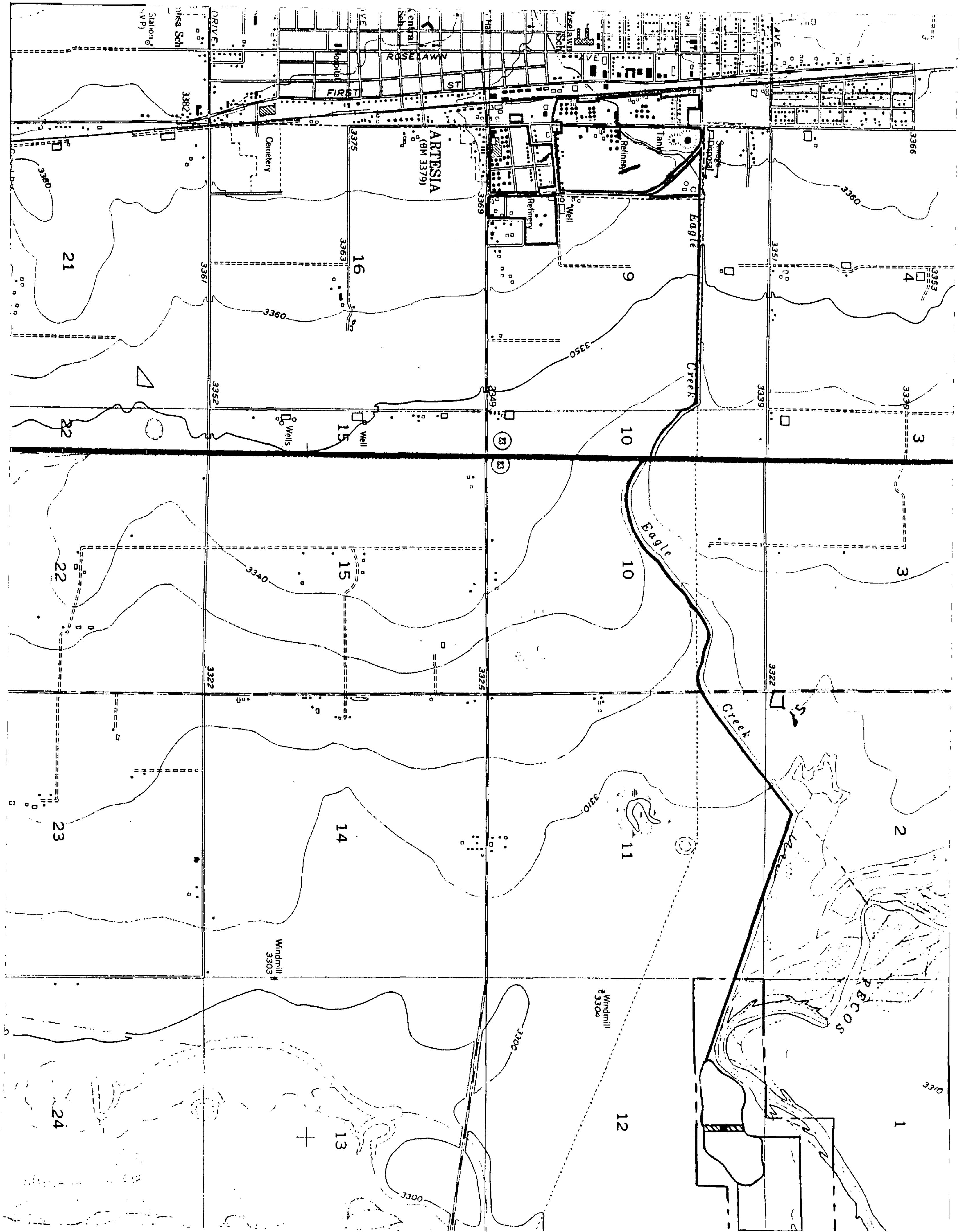
ARTESIA
(BM 3379)
ROSELAWN
FIRST
ST
AVE
DRIVE
Central Sch
Hospital
Cemetery
Refinery
Refinery
Tank
Sewage Disposal
Well
Wells
Well
Eagle Creek
Eagle Creek
Eagle
Creek
PECOS
Windmill 3303
Windmill 3304
83
83
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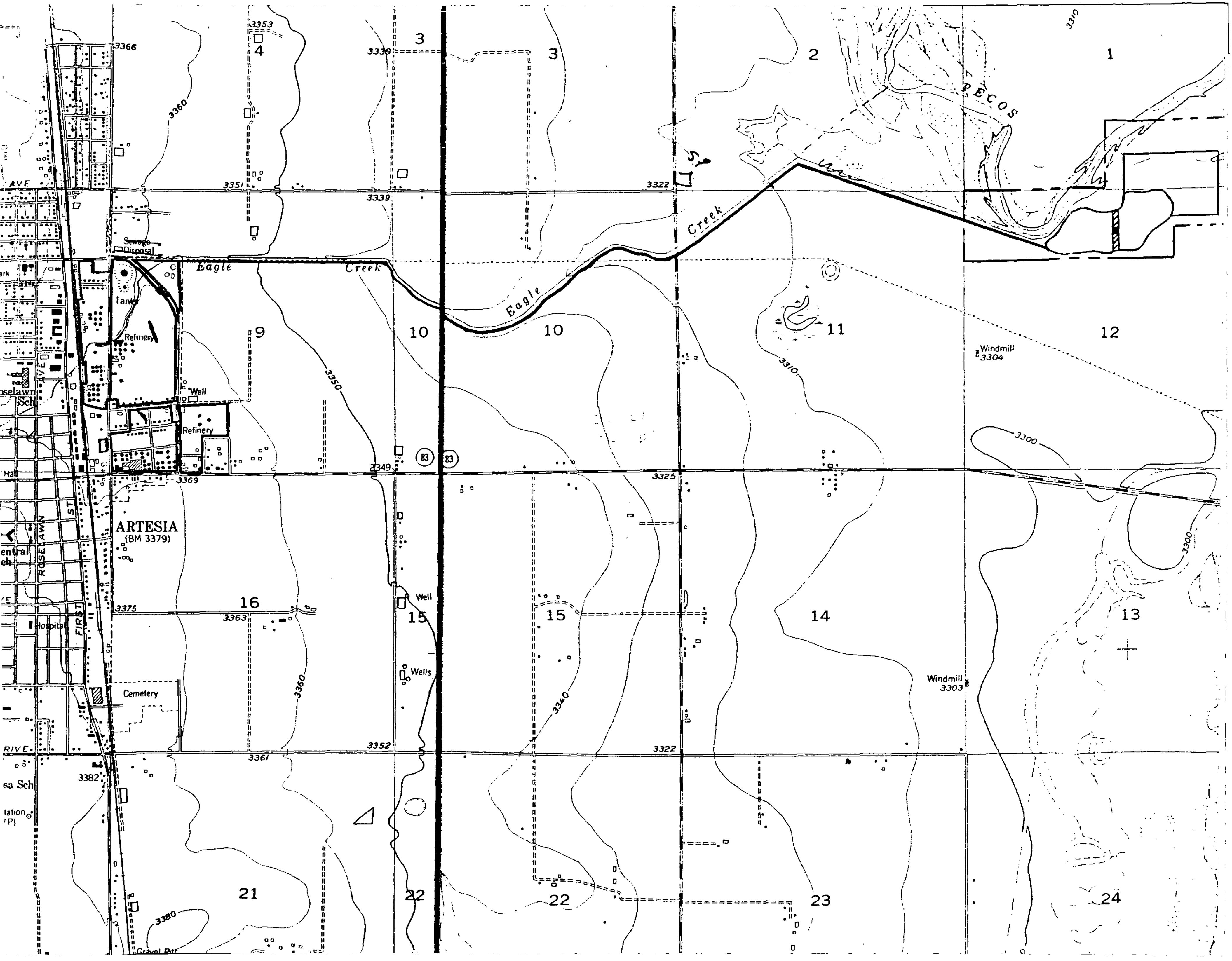
PECOS
Eagle Creek
Eagle Creek
Creek
Sewage Disposal
Tank
Refinery
Refinery
Well
Well
Wells
Windmill 3304
Windmill 3303
ARTESIA
(BM 3379)
Cemetery
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Hospital
Gravel Pit
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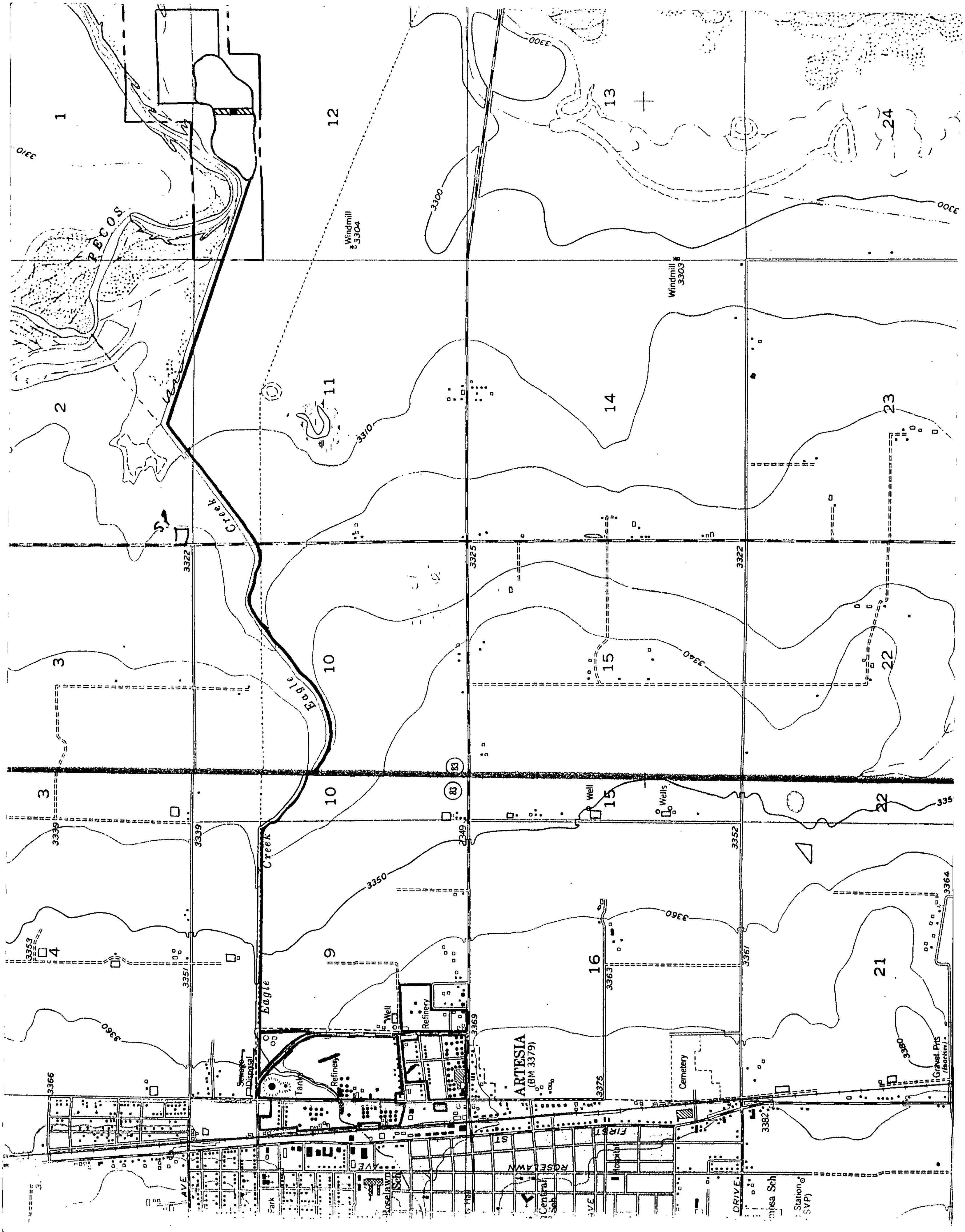
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Sewage Disposal
ARTESIA
(BM 3379)
Cemetery
Gravel Pits (Inactive)
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ROSELAWN
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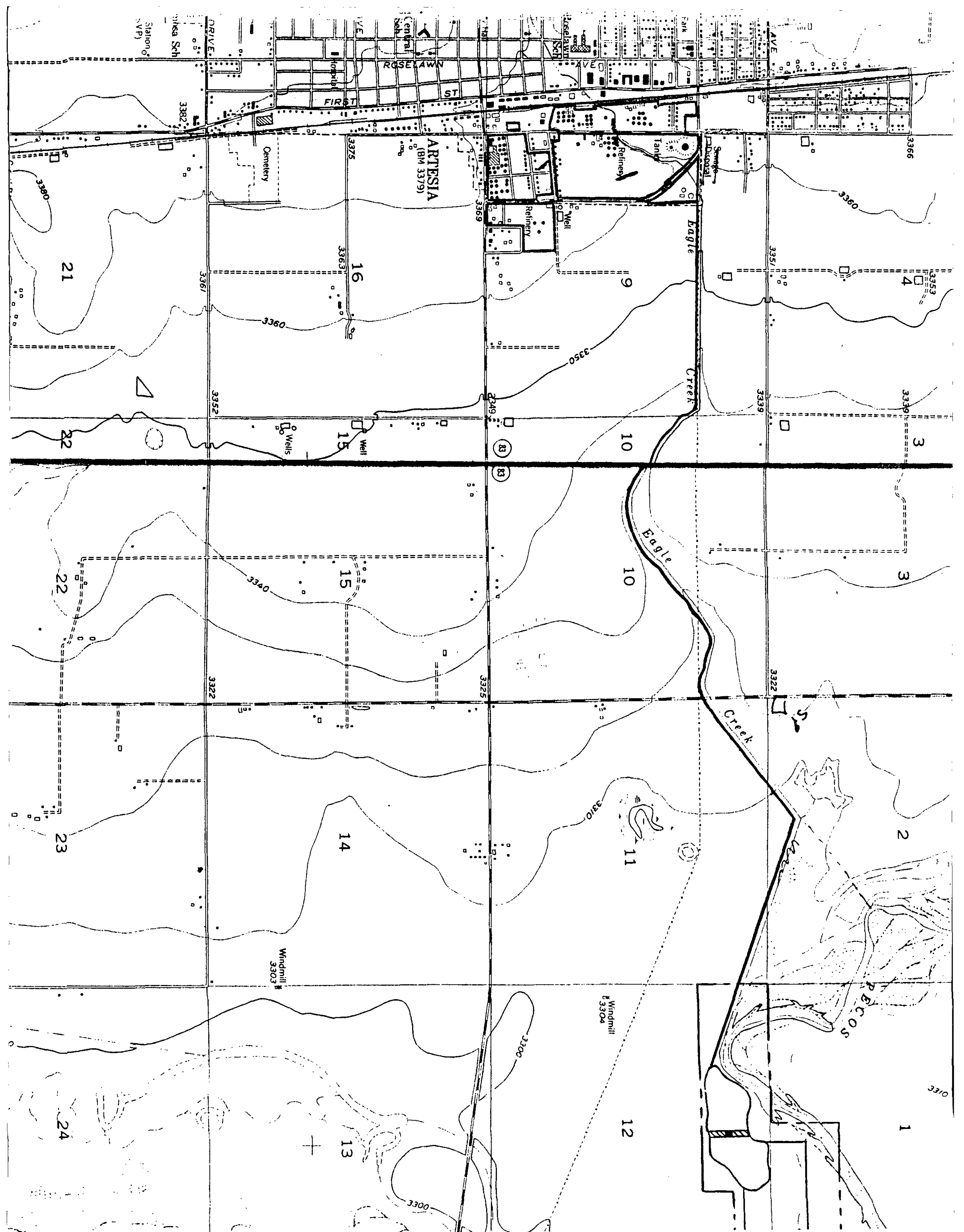
AVE
AVE
DRIVE
Hospital
Central Sch
Roselawn Sch
Park
Station (SVP)
mosa Sch


ARTESIA
(BM 3379)
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DRIVE
AVE
Central Sch
Hospital
Roselawn
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Park
Station
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Cemetery
Refinery
Refinery
Tank
Sewage Disposal
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Well
Wells
Eagle
Creek
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Creek
PECOS
Windmill
3303
Windmill
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