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REPORTS

YEAR(S):

1992

Investigation of the Subsurface Hydrocarbon Plume at the Navajo Refinery, Artesia, New Mexico

Navajo

RECEIVED
JUN 25 1992
OIL CONSERVATION DIV.
SANTA FE

prepared for

Navajo Refinery
501 East Main Street
Artesia, New Mexico 88210

by

K. W. Brown Environmental Services
500 Graham Road
College Station, Texas 77845

MAY 1992

KWBES

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David G. Boyer

David G. Boyer
Project Manager

for W. Wayne Crawley
Vice President of Operations

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EXECUTIVE SUMMARY

In response to a request from Navajo Refinery of Artesia, New Mexico, K. W. Brown Environmental Services investigated the occurrence of a large area of free phase hydrocarbon that extends for several thousand feet east of the refinery. The hydrocarbon plume is a concern because local groundwater supplies are used for drinking and irrigation sources. Furthermore, field and orchard crops are located within the plume area and in the likely path of plume movement. A study was necessary to determine if free phase and dissolved hydrocarbons from this release have impacted these uses and activities, or may potentially impact them in the future.

The free phase hydrocarbon plume extends east from the refinery under mostly agricultural land, flows under Bolton Road and extends several hundred feet into a pecan orchard. Another portion of the plume was found to trend southeastward from near monitor well KWB-6 and extends beneath cultivated fields on the south side of US Highway 82. Plume boundaries were delineated by monitor well drilling and by the drilling of exploratory boreholes. Because spring planting was already underway, no exploratory boreholes were drilled in the fields immediately east of the refinery and no data are available concerning the plume in this area. The apparent product thickness of the plume varied considerably over the area but ranged from 2.0 to 4.5 ft in the vicinity of monitor well KWB-6 and borehole B-87. The actual thickness of the free phase hydrocarbon is enhanced by artesian conditions in the near-surface saturated zone.

The product detected in the monitor wells and boreholes appears to be a light hydrocarbon. Specific gravity analysis of a product sample bailed from a monitor well, together with analysis of the dissolved phase component, indicates the hydrocarbon likely is a weathered gasoline.

Although the area of hydrocarbon extends over approximately 170 acres and includes free product in much of the area, no contamination of drinking water wells within the plume area was detected. Only trace levels of volatile aromatic hydrocarbons (i.e., benzene, toluene, ethylbenzene and xylenes [BTEX]), at levels less than applicable federal drinking water or state groundwater standards, were found in wells used for irrigation or nondrinking water use.

Dissolved phase hydrocarbons were detected in several water samples. Several domestic and irrigation water wells had trace levels of toluene and xylene. Two domestic wells outside the plume area showed trace levels of toluene (less than 1.1 microgram per liter [ppb]) but resampling or duplicate sample analysis did not verify the contamination. One of two irrigation wells with trace levels of contamination was outside of the plume area and had concentrations of toluene and xylene totaling 1.4 ppb. A potential source for these hydrocarbons is "drip" oil used to lubricate the turbine pumps that lift water from deep wells used for irrigation. Analysis of this "drip" oil found toluene and xylene, but no detectable concentrations of benzene or ethylbenzene. This oil also was composed of heavier components than gasoline or diesel fuel. Conversely, a sample from an irrigation well next to the refinery detected benzene and ethylbenzene totaling 3.8 ppb, and toluene and xylenes at similar levels which is more indicative of a gasoline or diesel fuel.

Background water quality of the impacted zone varies between 3,100 and 4,700 milligrams per liter total dissolved solids (mg/L TDS) with calcium, magnesium and sulfate being the major constituents. There is no evidence that the hydrocarbon discharge has increased the quantity of TDS in the near-surface saturated zone. Average total dissolved solids concentrations of the deep artesian aquifer and the producing zones of the valley fill aquifer in the study area are 2,700 and 1,900 mg/L TDS, respectively.

The water saturated zone nearest the surface was found at depths from 17 to 31 ft. In the study area, the zone varies from slightly to highly artesian with water levels in most monitor wells and boreholes rising from a low of several feet to a maximum of 10 ft after drilling. The artesian effect was due to the confining nature of the clay and fine grained sandy clays that overlay this upper saturated zone. The permeable sediments in this zone consist of clayey sands, silty sands and some gravels.

Aquifer tests conducted as part of the study show hydraulic conductivities ranging from 175 to 293 gallons per day per square foot. The measured hydraulic gradient averaged 0.0045 ft/ft, generally easterly, but with an east-southeasterly component south of US Highway 82. The average linear velocity of groundwater movement is estimated to range between 0.53 and 0.88 ft per day, or 194 to 321 ft per year. The time for water to travel from the east side of the refinery to 200 ft east of Bolton Road is estimated to be from 11 to 18 years. Due to various retardation mechanisms such as sorption by clays and other sediments, the rate of free phase hydrocarbon movement is less than that of water.

The origin of the water in the near-surface zone is unknown. Possible recharge sources include: (1) one, or both, of the unlined fresh water fire ponds on the refinery property, (2) Eagle Creek upstream of the US Highway 285 crossing west of the refinery, (3) recharge from landscape irrigation in the urban park which extends for several miles in the Eagle Creek channel west of the refinery, and (4) return seepage from irrigation immediately east of the refinery complex.

A possible discharge area for the near-surface groundwater is the river terrace deposits on the west side of the Pecos River about 3 miles east of the refinery. Topographic map examination shows an area of marshes and, further south, drainage channels that are above current river levels. Since the impacted zone is under artesian pressure in the study area and because the deeper aquifers have a lower potentiometric head, there is a possibility of downward flow of groundwater if the clay confining layers are discontinuous.

In contrast to the conclusions of some earlier studies, the geologic evidence indicates the subsurface in the area of the refinery is composed of about 300 ft of valley fill alluvial sediments and is not a bedrock outcrop of the gypsum-dominated Seven Rivers formation.

No agricultural activities have been impacted by the hydrocarbons from this release. Agricultural impacts in the future, if any, are expected to be minimal. Impacts that may occur would be limited to the stability of mature pecan trees which may not be able to extend tap roots below the 17-ft depth where contamination exists. The absence of deep tap roots may not provide adequate wind protection. This would affect only the largest trees and then only if the grove was thinned so that individuals were able to grow exceedingly large.

Recommendations of this study are:

1. Frequent testing of drinking water wells located within the plume of contamination, or alternately, installation of a replacement water supply.
2. Installing hydrocarbon recovery systems at the leading edge of the plume in the Bolton Road area and south of US Highway 82. Conditions at both locations favor a trench system which can be designed to recover oil and minimize water recovery.
3. Continued water level monitoring.
4. Additional monitor well installations and investigation of the next lower saturated zone to provide additional data on horizontal movement and vertical extent of contamination.

SECTION 1.0

1.0 INTRODUCTION AND SCOPE OF WORK

In October 1991, staff of Navajo Refinery became aware of a large free phase hydrocarbon plume on groundwater adjacent to the east side of the refinery and extending eastward for several thousand feet. The surface land use in the area of the plume includes several homes and businesses, and a large area of commercial agriculture, including row crops and a young pecan orchard. The extent of the plume, location of human activity, and deep and shallow water wells within the plume area, dictated an extensive investigation to define the current and future impacts caused by hydrocarbons in the groundwater, and the likely fate of the free phase and dissolved contaminants.

The objectives of the study were to: (1) identify the most sensitive areas that have been, or are likely to be affected by the contamination and, (2) define the near-surface hydrogeology and its relationship to deeper fresh water zones. To perform this investigation, a scope of work was proposed and accepted by the refinery. The workplan included efforts in several scientific areas including soil science and hydrogeology.

The initial work involved a reconnaissance visit to the refinery to collect available information which included previous studies in the area and interviews with local landowners. Information necessary to evaluate area soils, geology and near-surface hydrology was obtained from the U.S. Soil Conservation Service, U.S. Geological Survey, and the New Mexico State Engineer Office. During a meeting and subsequent visits with landowners, land use and crop histories were discussed and water samples were obtained for hydrocarbon and selected inorganic chemical analysis.

Field investigations defined the nature and extent of the near-surface saturated zone in the area east of the refinery. Monitor wells installed adjacent to drinking water and irrigation wells provided water quality data and background information on water level elevations prior to the beginning of the irrigation season. Information from these wells also provides early warning on possible water quality impacts due to the movement of the hydrocarbon.

Further onsite investigation focused on the need to better define the location and apparent product thickness of the free phase hydrocarbon plume. An intensive boring program using a hollow-stem auger provided information on the presence of hydrocarbons in the shallow zone immediately below the surface soils. The information obtained included product thickness measurements and the extent of soil impact above the saturated zone.

This report details the investigation procedures, and the study findings are reviewed and discussed. The conclusions of this study provide a strong scientific basis to guide future efforts at the site. The recommendations provide specifics on action needed to protect sensitive receptors, recover hydrocarbon, and proceed with additional work to define the relationship between the contaminated zone and other protectable groundwater.

SECTION 2.0

2.0 PHYSICAL SETTING

The Navajo Refinery is situated in the Pecos River Valley in Southeast Eddy County, New Mexico (Figure 1). The refinery is located on the east side of the city of Artesia about one-quarter mile east of the intersection of U.S. Highway 82 with U.S. Highway 285, and is approximately four miles west of the Pecos River. Eagle Creek, an ephemeral watercourse, flows through the northern part of the refinery and empties into the Pecos River about one mile north of the Highway 82 river crossing. The Artesia area is located in T 18 S, R 26 E, NMPM Eddy County. Activities for the current study were conducted in the south one-half of Section 9, the southwest one-quarter of Section 10, the northwest one-quarter of Section 15, and the north one-half of Section 16.

2.1 REGIONAL GEOLOGY

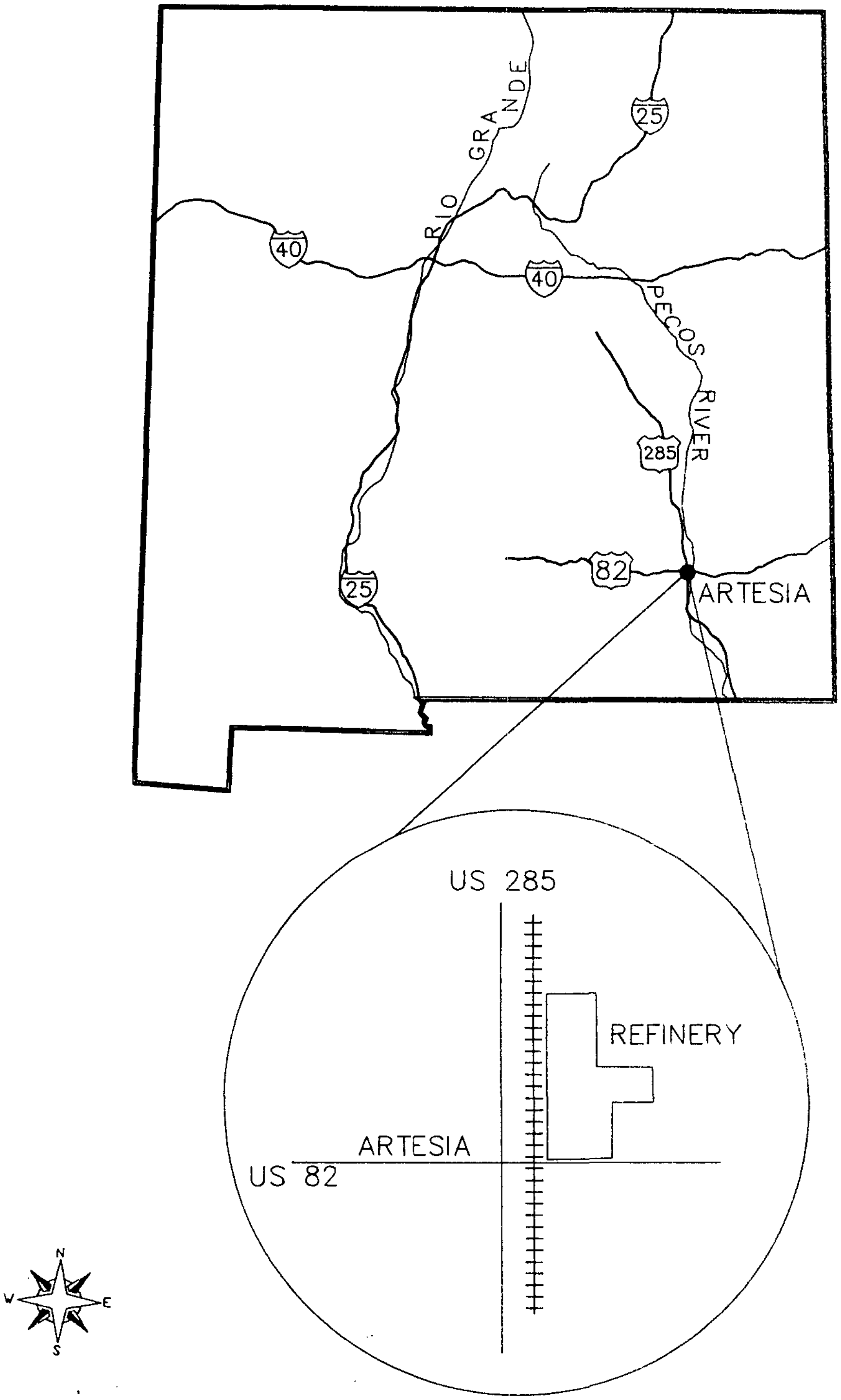
The Pecos River valley consists of Quaternary alluvial sediments that can be up to 300 ft thick. Beneath these sediments are Permian age sedimentary rocks that comprise the northwest shelf area of the Permian Basin. These rocks are composed of the Artesia Group, the San Andres formation and older Permian rocks. The Artesia group consists of (in descending order) the Tansill, Yates, Seven Rivers, Queen and Grayburg formations. The remaining older rocks beneath the San Andres include the Glorieta Sandstone and the Yeso formation. Kelley (1971) includes the Glorieta Sandstone within the San Andres in the area of the refinery. Collectively, the thickness of the Permian age rocks beneath the valley fill in the vicinity of the refinery exceed 2,000 ft (Welder, 1983).

The regional setting and geology have been described by numerous authors in previous reports to Navajo Refinery (i.e., IT Corporation, 1989) and further review is not provided in this report unless germane to the investigation.

2.2 BASIN HYDROGEOLOGY

The hydrogeology of the Roswell groundwater basin has been the subject of numerous investigations over the past 90 years with groundwater studies beginning in the 1900's. Pioneers in the study of hydrology who have contributed to knowledge of this area include O.E. Meinzer, C.V. Theis, M.S. Hantush and C.E. Jacob. Their work in the Roswell basin assisted in the

Figure 1. Site location map.



KWBES

Site location map.

prepared for:

Navajo

PROJECT:	622092001-237 (ARTAREA)		
LOCATION:	ARTESIA, NEW MEXICO		
APPR:		DATE:	5/19/92
DRAWN BY:	SSA	SCALE:	NO SCALE
DATE:	5/19/92	FIGURE:	1

development of many of the techniques of aquifer analysis in common use by modern hydrologists, including methods used to analyze the aquifer test results presented later in this report.

Various authors have used differing terminologies to describe the groundwater system in the Roswell basin. As used by Welder (1983), the Roswell groundwater basin consists of an eastward-dipping carbonate aquifer overlain in the eastern part by a leaky confining bed which in turn is overlain by a shallow aquifer. The shallow aquifer is composed mostly of alluvial valley fill sedimentary material (Lyford, 1973) and is in hydraulic connection with the Pecos River along much of the eastern basin boundary. In Welder's study, the alluvial valley fill aquifer was referred to as the "shallow aquifer" while the deeper, carbonate aquifer is called the "artesian aquifer."

However, the current study investigates a near-surface water-bearing zone in the valley fill aquifer, apparently limited in vertical extent, that is shallow with respect to the surface and also exhibits artesian properties at some monitor wells. To avoid confusion and for consistency, the deeper carbonate aquifer will be labeled the "deep artesian" aquifer while the water-bearing zones of the shallower, alluvial valley fill aquifer will referred to collectively as the "valley fill" aquifer. The water bearing zone investigated as part of this study will be referred to as the "near-surface" zone or "first saturated" zone.

2.2.1 Deep Artesian Aquifer

The deep artesian aquifer is closely related to the San Andres Limestone and generally consists of one or more water-producing zones of variable permeability located in the upper portion of the carbonate rocks. However, in the Artesia area, the producing interval rises stratigraphically and includes lower sections of the overlying Grayburg and Queen formations. Beneath the refinery, the depth to the top of the producing interval is about 670 ft and the aquifer thickness is about 440 ft (Welder, 1983).

The Seven Rivers formation and the other members of the Artesia group are generally considered confining beds, although some pumpage occurs from fractures and secondary porosity in the lower Queen and Grayburg members. Although locally important, Welder (1983) estimates that only 10% of the total volume of groundwater produced in the Roswell basin is from confining beds.

The deep artesian aquifer was first declared an "underground water basin" in 1931 by the New Mexico State Engineer Office (SEO), and later SEO orders expanded state control to the valley fill aquifer. The designation of an aquifer as a declared basin requires users to obtain drilling permits and apply for the appropriation of water for irrigation and industrial use. Domestic users (i.e., homeowners, ranchers, small businesses) can apply for a permit that allows minimal use (up to 3 acre ft per year) for domestic consumption, and lawn and stock watering.

Further discussion of the deep artesian system is presented with the results of the well survey in Section 5.3.1.

2.2.2 Valley Fill Aquifer

Quarternary alluvial deposits of sand, silt, clay, and gravel are the main components of the valley fill aquifer. These sediments are about 300 ft thick in the area between the refinery and the Pecos River. Lyford (1973) researched these deposits and describes the three principal units in the valley fill as quartzose, clay, and carbonate gravel.

The quartzose unit is considered the primary production unit in the valley fill aquifer. Away from the Pecos river, the unit consists of fragments of sandstone, quartzite, quartz, chert, igneous, and carbonate rocks. The fragments range from medium grained (1/4 mm) to pebble size (16 mm), and commonly are cemented with calcium carbonate (Lyford, 1973). By contrast, in the vicinity of the river, the unit contains principally medium to coarse, uncemented quartz grains.

Silt and clay deposits in the valley fill aquifer are not continuous, but occur as isolated lenses, generally overlying the quartzose unit. Although the clay unit is not identified by Lyford as occurring in the Artesia area, most logs of wells located immediately to the north and east of the refinery show considerable thickness of clays, or clay mixtures (e.g., "clay and gyp", "gumbo"). Thickness of these clay/gypsum mixtures range from 20 ft to 160 ft. The intervals of occurrence differ from well to well and thin zones of sand or gravels are interspersed in the upper 100 ft. Many drillers seeking deep artesian water drill through the valley fill zone and log large sections of the intervening zones as "clay and gyp". The lack of detail makes it difficult to correlate specific zones of coarse grained sediments within silt and clay deposits. However, drillers wanting to complete wells in the valley fill, tend to be more careful in their descriptions and small changes in lithology are likely to be recorded. Although both types of drilling logs were reviewed, the detailed logs were much more useful for construction of geologic cross-sections.

The carbonate-gravel unit described by Lyford (1973) blankets the other valley fill units and forms a fairly uniform slope from Permian rock outcrop areas on the west side of the valley east to the Pecos River flood plain. The unit generally consists of coarse gravel along major drainages, and calcareous silt and thin masses of caliche in interstream areas.

Welder (1983) believes the carbonate-gravel unit includes the Lakewood, Orchard Park, and Blackdom terrace deposits described in detail by earlier authors and summarized by Kelley

(1971) in his study of the Pecos Valley. The Lakewood deposits, the lowest of the three terrace units, essentially are the current alluvial sediments in the flood plain along the river. Lakewood deposits consist of sandy brown silt with lenses of gravel and some localized caliche in higher parts.

Sediments of the Orchard Park deposit are 5 to 25 ft higher than those that make up the Lakewood terrace deposits, while west of Artesia, sediments of the Blackdom terrace are 40 to 60 ft higher than Orchard Park deposits.

After examination of drillers' reports, Welder (1983) reported that valley fill wells will tap from one to five water producing zones. Thickness up to 170 ft have been reported for water production zones, but most are less than 20 ft. Producing zones are principally sand and gravel separated by less permeable lenses of silt and clay. However, Welder does not present information on the depths at which these producing zones are likely to be found.

The general direction of groundwater flow in the valley fill aquifer is easterly toward the Pecos River, then southward subparallel to the river. Above Artesia the river has been a gaining stream for most of the period of record (Welder, 1983). However, between 1938 and 1975, heavy pumping near Artesia reversed the hydraulic gradient. In the vicinity and immediately east of U.S. Highway 285, water in the pumped zones of the valley fill aquifer flows westward (Welder, 1983, Fig. 16). The original flow direction is unlikely to be reestablished as long as heavy irrigation pumping continues.

2.2.3 Near-Surface Saturated Zone

The agricultural land at Artesia is a part of the Orchard Park deposit. The Orchard Park is described as a thin veneer (up to 20 ft thick) that overlies older alluvium and consists of silt and sand, with some thin clay lenses and pebbly beds. Chalky caliche is common in upper areas of the deposit.

During this study, both the caliche and thin pebble beds were observed while drilling monitoring wells and borings, which confirms that sediments with Orchard Park characteristics are located in the study area. However, thick, extensive clay zones were found in these deposits.

In the area of this study, fine to coarse grained water saturated sediments are found immediately beneath the clay zones. In this report, this zone is referred to as the near-surface saturated zone and extensive discussion on its characteristics and water quality are presented in subsequent sections.

2.2.4 Water Well Survey

Numerous deep artesian and shallow valley fill water wells are in service in the vicinity of the study area. Most are used for farm irrigation, but others serve domestic and industrial users. Wells used for domestic purposes are mostly completed in the valley fill and are mainly used for lawn and yard irrigation although some serve as a drinking water source for residences.

Although previous efforts to locate well records had been performed, for this study KWBES sought to complete the record of wells in the area south of Eagle Creek in Sections 9 and 10, and south of Highway 82 in the north one-half of Sections 15 and 16. Toward that goal, additional logs and well location maps were acquired from the SEO in Roswell to supplement logs already provided by refinery staff and previous consultants. Landowners in the study area were interviewed to verify well records and to acquire additional information. The results of the survey are discussed in Section 5.3.1 and copies of the water well records and landowner survey results are provided in Appendices A and B, respectively.

SECTION 3.0

3.0 WELL INSTALLATION, DEVELOPMENT, AND SURVEY

Information presented in this section describes the installation and completion of monitor wells by KWBES personnel during field activities conducted February 10-20, 1992.

3.1 WELL INSTALLATION

Twelve monitor wells were installed and completed on land owned by Navajo Refinery and on adjacent properties. The purposes of the monitor wells were to provide hydrologic information (aquifer characteristics and hydrologic gradient) on the first near-surface water saturated zone in the area of suspected hydrocarbon contamination, and to provide water quality and water level information for areas immediately adjacent to possible contaminant receptors (i.e., water wells used for domestic or irrigation use located within or near the contaminated area).

3.1.1 Monitor Well Locations

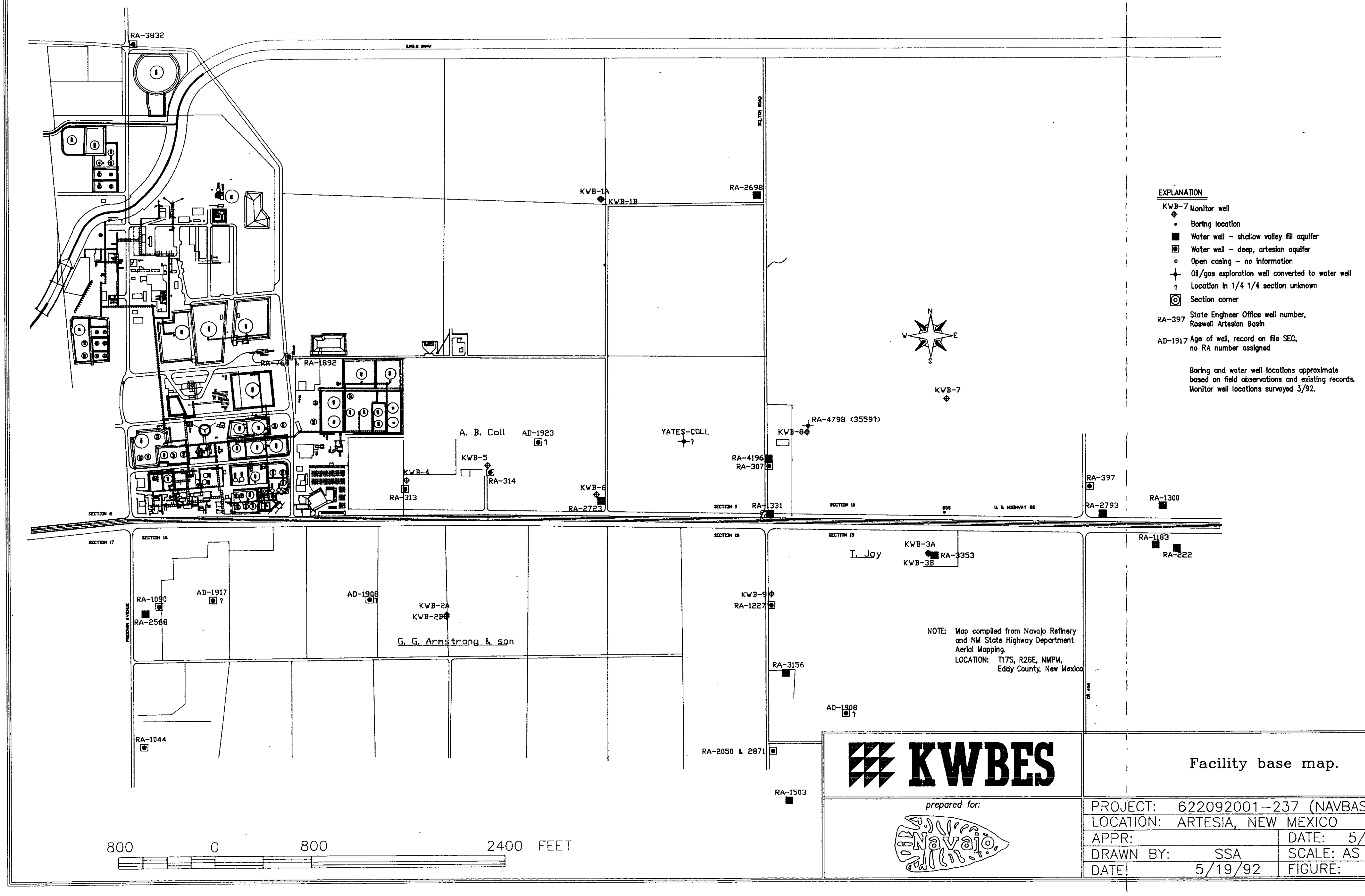
Locations for the wells were selected based on information provided by previous Navajo borings and the presumed direction of groundwater flow. The prefix KWB is used to denote these 12 wells on Figure 2. Wells KWB-3, KWB-4, KWB-5, KWB-6, KWB-8 and KWB-9 were located within 30 ft of existing water wells to provide information on possible hydrologic connection between the zone of saturation nearest the surface and the deeper zones in the valley fill and artesian aquifers where the pumping wells are completed. KWB-7 was placed at a location assumed to be downgradient from the contamination to act as an indicator of further contaminant movement. In addition to providing information on possible interzone fluid movement, Wells KWB-3 and KWB-9 also serve as downgradient detectors of early contamination.

Six wells, KWB-1A and KWB-1B, KWB-2A and KWB-2B, KWB-3A and KWB-3B, were placed in pairs to conduct aquifer tests. These three well pairs are located in diverse areas outside the contaminated area to better define aquifer characteristics.

3.1.2 Well Drilling and Construction

Installation of the wells was performed by Precision Engineering, an environmental drilling firm headquartered in Las Cruces, New Mexico. A CME 75 Hi-Torque hollow stem auger rig was used to drill each well boring. Tools and augers were cleaned at the refinery steam rack before

Figure 2. Facility base map.



Boring and water well locations approximate
based on field observations and existing records.
Monitor well locations surveyed 3/92.

NOTE: Map compiled from Navajo Refinery and NM State Highway Department Aerial Mapping.
LOCATION: T17S, R26E, NMPM, Eddy County, New Mexico

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Navajo

Facility base map.

PROJECT: 622092001-237 (NAVBASE)
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 5/30/92
DRAWN BY: SSA
SCALE: AS SHOWN
DATE: 5/19/92
FIGURE: 2

being used to drill other wells. Well casings are constructed of schedule 40 PVC with flush threads and 0.010 machine slot screen. Four-inch casing is used for the pumping wells, KWB-1B, KWB-2B, and KWB-3B, and for well KWB-4. The other well casings are 2-inch in diameter. A 4-inch casing was not available for installation at KWB-6 although free product was encountered.

Monitor well completion involved CSSI 16-40 silica sand being tremied into the annular space around the well screen to a point at least 2 ft above the screen. A bentonite seal was then placed above the sand pack by pouring 1/4-inch Volclay pellets into the annular space until a thickness of 2 ft or more was achieved. The bentonite was allowed to hydrate overnight and then 3,000-psi concrete mixed with 5% bentonite was placed from seal to surface. The well head assembly for all but two wells consists of an aboveground locking steel casing. Well head assembly for KWB-3A and KWB-3B consists of steel flush mount casings with bolted caps. Concrete pads were constructed around each well with maximum dimensions of 4 ft by 4 ft by 4 inches. Where interference with agricultural activities was a problem, the pads were built to occupy a smaller area. Specific construction details for each well are included with the well completion logs presented in Appendix C.

3.1.3 Monitor Well Logs

Continuous soil samples were obtained from all but three borings using a 5-ft split core barrel recovery system. Wells KWB-1B, KWB-2B, and KWB-3B were advanced without sampling but were visually classified using auger cuttings. This was considered acceptable since the paired wells, KWB-1A, KWB-2A, and KWB-3A had been continuously sampled and were located within 12 ft. The auger was advanced into, and through, the first water bearing zone, then continued to at least 1 ft into a less permeable soil strata. All soil removed from the borings was placed on plastic sheeting for later collection and disposal by Navajo Refinery personnel. Philip Cadarette, a KWBES geologist, completed a boring log based on cores and cuttings recovered for each well (Appendix C).

3.2 WELL COMPLETION

3.2.1 Well Development

A 2-inch submersible pump was used to purge at least three well casing volumes of water. Electrical conductivity (EC), pH, and visual estimation of turbidity were parameters monitored during the purging phase to ensure stabilization was reached. Water and other liquids purged from each well were collected in 55-gallon drums provided by the refinery. This practice prevented any surface contamination by possibly tainted groundwater. Navajo personnel collected the drums and disposed of the fluids in their refinery wastewater system.

3.2.2 Groundwater Sampling

Groundwater sampling from each well began after development and a short recharge period. Groundwater samples were retrieved with a dedicated, disposable bailer and placed in appropriate containers with preservatives used where necessary. Monitor wells KWB-1B, KWB-2B, and KWB-3B were not tested due to the proximity of their paired wells that are screened over the same intervals. Each sample was logged on a chain-of-custody form and packed in ice for shipment. The ice chests were sealed and transported by Federal Express to Inter-Mountain Laboratories, Inc. (IML) in College Station, Texas, for analysis.

IML performed analyses for benzene, toluene, ethylbenzene and xylenes (BTEX), major cations and anions, conductivity, and pH. Copies of IML's testing results, their quality control checks, and chain-of-custody forms are contained in Appendix D. Results of the sampling are discussed in Section 5.3.4 on groundwater quality, which includes a table containing a compilation of results for each monitor well.

3.3 LOCATION SURVEY

A land survey of the 12 monitor wells was performed in March 1992 by John D. Jaquess & Associates, of Roswell, New Mexico, NM license 6290. The survey team measured three elevations on each well: top of steel casing, top of concrete pad, and natural ground surface. The survey was referenced to existing benchmarks and the prepared plat shown in Appendix E. Follow-up measurements were made to determine distances from the top of the PVC well pipe to the steel casing top.

SECTION 4.0

4.0 EXPLORATORY BORINGS

Information presented in this section describes the exploratory boring program undertaken by KWBES personnel during field operations, March 1 through 10, 1992. The objectives of this program were to better delineate the areal extent of hydrocarbon contamination, determine apparent product thickness, and extrapolate contaminant volume and direction of flow. This information will assist refinery, consultants, and regulatory personnel in decisions on product recovery, methods and location priority.

4.1 BORING LOCATIONS

Twenty-eight boreholes were advanced on properties adjacent to the Navajo refinery under the supervision of KWBES personnel. Locations for these 28 borings were selected based on subsurface information provided by 66 borings undertaken by Navajo personnel in October, 1991, and the 12 monitor wells installed by KWBES in February, 1992. Figure 2 presents the location of all 94 borings and the 12 monitor wells.

Although the borings were expected to be completed before spring planting, several farmers decided to cultivate crops which have an early planting date. Because fields were already under cultivation, no borings were augered west of B-85 to the refinery and no subsurface information is available for that area.

Also, the two northwest-southeast rows of borings (B-74 to B-77 and B-78 to B-81) were augered through the bottom of shallow irrigation trenches. This was done at the request of the farmer since in other areas of that field alfalfa was already beginning spring growth and drilling was restricted. Normally, boring in such locations should be avoided due to concern about possible downward migration of contaminants resulting from infiltration along the boring pathway. In this instance the zone was known to have already been severely contaminated and possible risk of slight additional contamination was outweighed by the subsurface information acquired. Nonetheless, the holes were carefully backfilled and compacted to prevent later surface subsidence at their locations.

4.2 BOREHOLE DRILLING

The drilling was performed by Pool Environmental Drillers headquartered in Roswell, New Mexico. A Mobile Drill hollow-stem auger rig was used to advance all borings. Typical borehole completion involved advancing the auger flights until the first saturated strata was encountered. The borehole was then allowed to remain open overnight to accumulate groundwater and floating product. The next day a digital oil/water interface meter was used to determine thickness of product by reading depth to product and depth to water. Upon completion of measurements, the boreholes were backfilled with the excavated soil by refinery personnel under KWBES supervision. The contaminated soil was placed in the hole first followed by clean cuttings from the upper portion of the hole. This was followed by compaction of mounded soil by driving over the soil with a pickup truck.

Details on drilling the boreholes are discussed in Section 5.3.3. Information presented in that section includes data from this investigation and information from earlier Navajo boring operations.

4.3 BOREHOLE LOGGING AND SAMPLING

Philip Cadarette, a KWBES geologist, developed a geologic log for each boring based on observation of auger cuttings (Appendix F). Because of the large surface area to be investigated and because the auger was to be advanced only a short distance into the saturated zone, cores of the boreholes were not obtained. Soil contamination was indicated by gray to blue-gray colored staining of the cuttings accompanied by a strong hydrocarbon odor. As an aid in quantifying contaminated soil, bag samples of stained cuttings were collected and checked with a photoionization detector (PID) for volatile vapors. Additionally, randomly collected, contaminated soil samples were packaged, placed on ice, and shipped to IML in College Station for hydrocarbon analysis.

IML performed analyses for benzene, toluene, ethylbenzene and xylenes (BTEX). A discussion of the results of the soil sampling is presented in Section 5.3.3 together with tables summarizing results for the six samples, and the highest PID readings for each boring. IML's sampling results for six soil samples and the quality controls are included with Appendix D.

SECTION 5.0

5.0 RESULTS OF THE INVESTIGATION

This section discusses the results of the geologic and hydrogeologic portions of the study and presents the interpretations and conclusions of the investigation. Detailed discussions of the specific investigation activities were presented earlier in the report.

5.1 SOILS

5.1.1 Introduction

Due to the agricultural use of the land found at the study area, this area was previously mapped at high intensity by the U.S. Soil Conservation Service (SCS). The mapping of these soils was verified by a soil scientist with KWBES and found to be consistent with the mapping as it appears in the soil survey (USDA-SCS, 1971). The soils mapping for this area is presented in Figure 3. Within this area a rotation of cropland uses, and pasture or hayland uses are employed. Irrigated crops which are grown include chile, cotton, winter small grains, and pecan trees. Irrigated pastures and haylands produce alfalfa and include sheep and cattle operations at certain times of the year. Additional information on agricultural uses was provided by landowners during interviews prior to the start of field work. Summaries of the landowner surveys are provided in Appendix B.

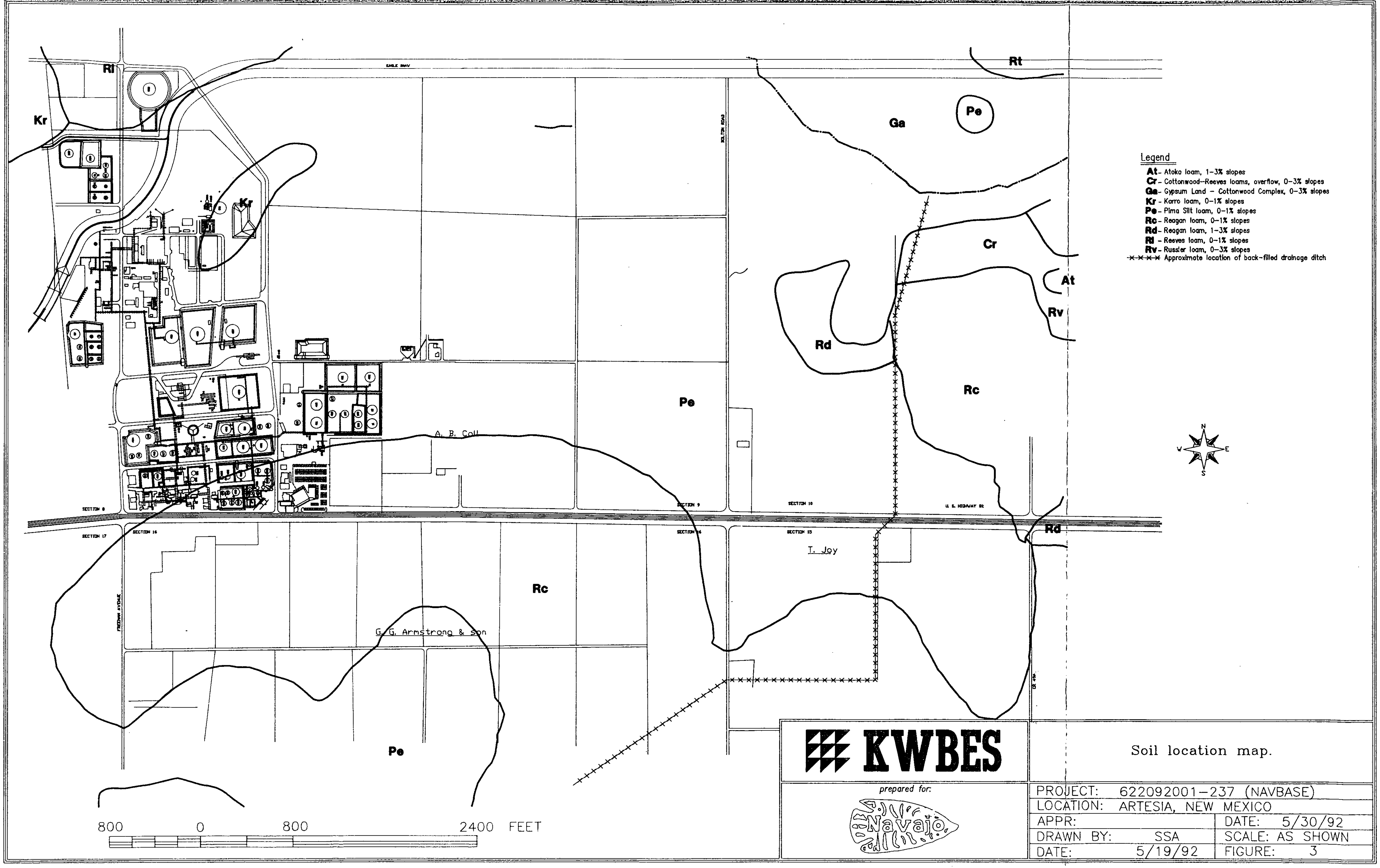
5.1.2 Soils in the Area

There are predominantly two soil series located in the study area. These are the Reagan loam with 0 to 1% slopes (Re) and the Pima silt loam with 0 to 1% slopes (Pe). A small inclusion of Upton gravelly loam on a 0 to 9% slope was found just outside of the study area near the barn centrally located on the Armstrong property.

The Reagan and Pima series are deep soils derived from calcareous alluvium. Both soil series form weakly cemented caliche layers but contain very little gravel. These soils have a high water holding capacity and good nutrient status. Both series can be used for intensive crop cultivation, but are not listed as Prime Farm Land as defined by USDA due to high potential for soil erosivity.

The Reagan loam unit occurs on 0 to 1% slopes in the uplands area west of the Pecos River. These soils are deep, well drained loams with moderate permeability, high water holding

Figure 3. Soil location map.



KWBES

prepared for:

Navajo

Soil location map.

PROJECT: 622092001-237 (NAVBASE)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 5/30/92
DRAWN BY: SSA	SCALE: AS SHOWN
DATE: 5/19/92	FIGURE: 3

capacity, and slow runoff. The rooting zone varies from 6 to 10 ft with some calcareous nodules within this zone. Due to the semiarid environment, these brown loamy soils are low in organic matter and, without good ground-cover, are susceptible to wind erosion.

The Pima silt loam soil tends to occur in low lying areas on 0 to 1% slopes on flood plains and in association with drainageways. These soils are deep, well to moderately well-drained soils that are subject to periodic flooding and slight deposition. These soils may have a slight increase in clay content but still maintain 6 to 10 ft of good rooting depth. Pima soils in the study area tend to have a reduced permeability and a higher silt content. Water may drain slowly from this map unit, possibly limiting equipment use in some areas, but is unlikely to cause serious deposition or adversely impact crops or pastures.

To facilitate the drainage of Pima soils, a drainage ditch was excavated during the 1920's at the edge of the fields on the Joy property and, after a jog to the east, continued north onto the Chase property. The drainage ditch was 4 to 6 ft deep and probably extended further north to connect with Eagle Creek. The likely location of the drainage ditch is shown in Figure 3. This ditch is no longer in use and was filled and covered in the early 1950's. The surface location of the ditch has become obscured with the passage of time and cultivation.

The Upton unit contains greater than 15% gravel and overlies a hard caliche. These soils are typically found on small ridges or outcrops, generally are very shallow, tend to be infertile, and are not suitable for intensive crop management. The Upton gravelly loam is primarily managed for nonirrigated rangeland or some irrigated pasture conditions. Rooting depths are typically limited to less than 10 inches. These soils tend to have low water holding capacity and are subject to moisture deficiencies during periods of drought. Wind erosion may be a problem especially during the establishment of cover systems.

5.1.3 Vegetative Impacts By Hydrocarbons

Field crops which are grown in this area include chile, cotton, small grains and alfalfa. (Alfalfa is generally thought of as a pasture crop, but, based on the rotation used in the study area by the various farmers, will be considered a field crop.) The other major crop in the study area is pecans grown in an orchard on the east side of Bolton Road.

Of the crops mentioned, alfalfa and the pecan trees are the only crops potentially impacted. This impact would be to create an oxygen deficient zone associated with the subsurface hydrocarbon contamination. A root above a hydrocarbon impacted zone may travel laterally above the zone of the impact or penetrate the zone. Although roots can not penetrate a zone that is in a totally anaerobic (oxygen deficient) condition (Mengel and Kirby, 1982), the presence of hydrocarbon impacts does not necessarily mean complete anaerobic conditions. If parts of the system remain aerobic, it may be possible for some roots to penetrate the layer of impact.

If penetration does occur, the root likely will become oxygen deficient and die since plants are not able to assimilate hydrocarbons. Root uptake of moisture and nutrients requires root-soil contact. Hydrocarbons in the soil may surround and permeate the root but can not be translocated throughout the plant due to the size of organic molecule and the lack of ionic charge associated with the molecule which facilitates movement. As a consequence, hydrocarbon which has permeated the root system remains and eventually deprives the root of oxygen, impeding the growth of the root.

The depth of the liquid hydrocarbons usually is important in evaluating the potential effect of hydrocarbons on plants. During the current study, hydrocarbons were found no higher than about 17 ft below the surface. But, based on soil staining observed during the borings, capillary forces or past product levels have resulted in hydrocarbons as shallow as 7 ft, in the past. However, the depth of the hydrocarbons does not appear to be an issue since these crops are being flood irrigated which means all of their water requirement is applied surficially. Furthermore, these soils are moderately to slowly permeable and water can be expected to infiltrate slowly. Most moisture is maintained near the surface which encourages surface versus deep root growth.

Of the crops currently grown in the study area, only alfalfa and the pecan trees potentially could be impacted by hydrocarbons as a result of deep penetration to procure more water. It is unlikely alfalfa roots have or will penetrate 17 ft. If alfalfa was planted dryland this might be an issue, but, since the crop is surficially irrigated, such deep root penetration (17 ft) would not be necessarily good for plant survival and yield. Since the crop is rotated with the other crops every few years, surface irrigation and crop rotation may preclude development of deep root systems. This same reasoning also applies to other field crops.

The only possible vegetative implication concerns the pecan trees where tap roots will penetrate in excess of 15 ft in the soil. With surface irrigation, the main function of the pecan's tap root is not for moisture or nutrient uptake but for structural stability. Based on the soil in the study area, which contains significant silt and clay fractions, stability should not be a problem. This statement could be subject to revision should the pecan trees be managed differently. This different management style would include the thinning of the pecan grove and not pruning or topping the trees on a regular interval. This would allow the trees to become larger. If the tap root is unable to penetrate the hydrocarbon zone for the reasons given above, large trees may become slightly top heavy creating the potential for the trees to blow down in heavy wind.

5.2 NEAR-SURFACE GEOLOGY

5.2.1 Introduction

One of the objectives of the study was to review available geologic information to ascertain the characteristics of the near-surface formations. One of the specific questions to be answered was whether the Seven Rivers formation exists beneath the refinery at depths as shallow as 15 to 20 ft. The conflict arose with the presentation to Navajo, in earlier consultant reports, of information purporting to show the existence of such a zone.

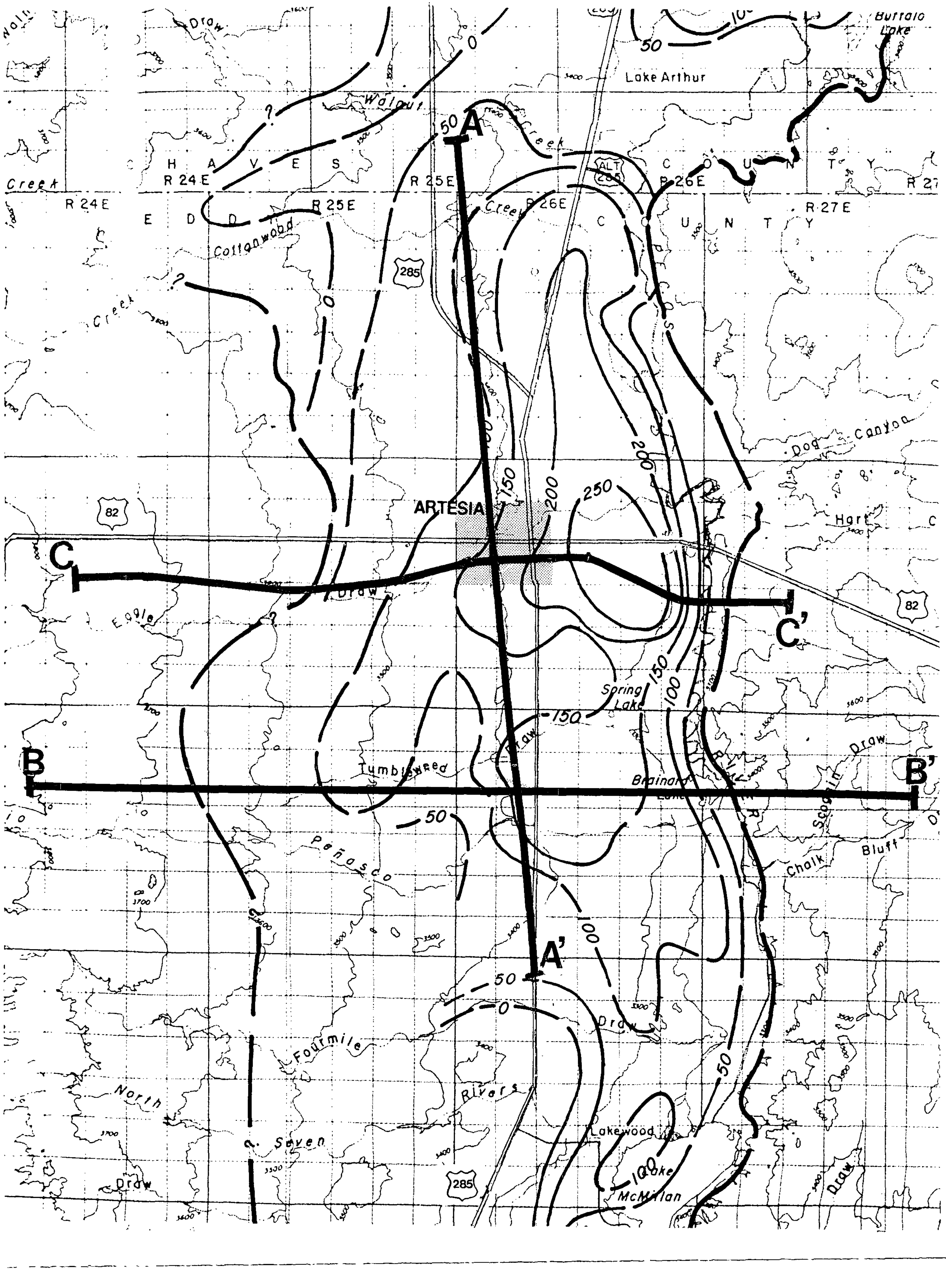
5.2.2 Occurrence and Lithology

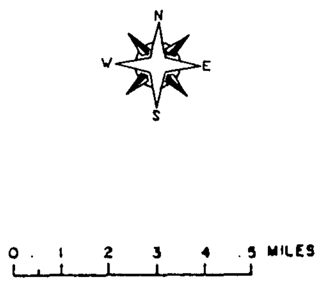
The lithology of the Seven Rivers formation, as described by Kelley (1971), consists of reddish gypsum, mudstone and thin dolomitic beds in the northern section of the basin with the gypsum becoming more carbonitic to the south as the formation approaches the buried escarpment of the Capitan reef. In a figure showing distribution of Artesia Group formations, Kelley (1971, Fig.7) placed the western limit of the Seven Rivers formation about 7 miles west of the Artesia, which, if correct, would locate the formation beneath the refinery. However, in an east-west cross-section located near Spring Lake 4 miles south of the refinery, Welder (1983, Fig.4) places the western edge at the approximate location of Highway 285.

Whether the Seven Rivers formation thins and disappears in the vicinity of the refinery, or 10 miles to the west is irrelevant if the formation is only present at depth. Neither Kelley (1971) nor Welder (1983) indicate that exposure of the formation occurs at or near the surface. Kelley (1971, p. 32) estimates alluvial gravels up to 300 ft in thickness overlie the Seven Rivers formation, while Lyford (1973) and Welder (1983) present information indicating a similar thickness. Figure 4 shows locations of cross-sections from reports by the latter two authors. The cross-sections, shown in Figures 5 and 6, show a thick valley fill sequence of sediments above the consolidated Permian rocks. In the vicinity of Artesia, the total thickness of the fill material is estimated to be in excess of 300 ft. Not all the valley fill is saturated. Figure 4 also presents an estimate by Welder (1983) of the 1975 saturated thickness of the valley fill in the Roswell basin.

Examination of several logs from water wells within one-half mile of the refinery show apparent wide disparities in geology. The near-surface portion of logs of wells being drilled to the artesian aquifer (900 to 1,200 ft) commonly shows numerous thick sections, some up to 100 ft, of "gyp and clay" with occasional thin zones of sand. However, logs of shallow wells (to 300

Figure 4. Map showing 1975 saturated thickness of the valley fill, and Roswell basin cross-sections, Artesia area, New Mexico.





NOTE: Thickness map from Welder (1983)

KWBES

Map showing 1975 saturated thickness of the valley fill, and Roswell basin cross-sections, Artesia area, New Mexico.

prepared for:

Navajo

PROJECT: 622092001-237	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 5/12/92
DRAWN BY: SSA	SCALE: AS SHOWN
DATE: 5/12/92	FIGURE: 4

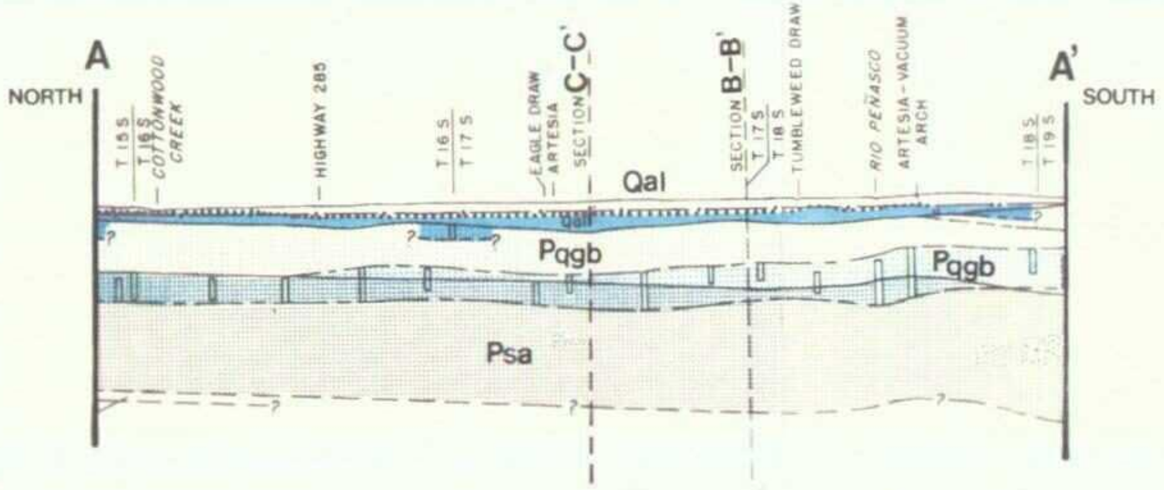
Figure 5. Regional cross-sections A-A' and B-B'.

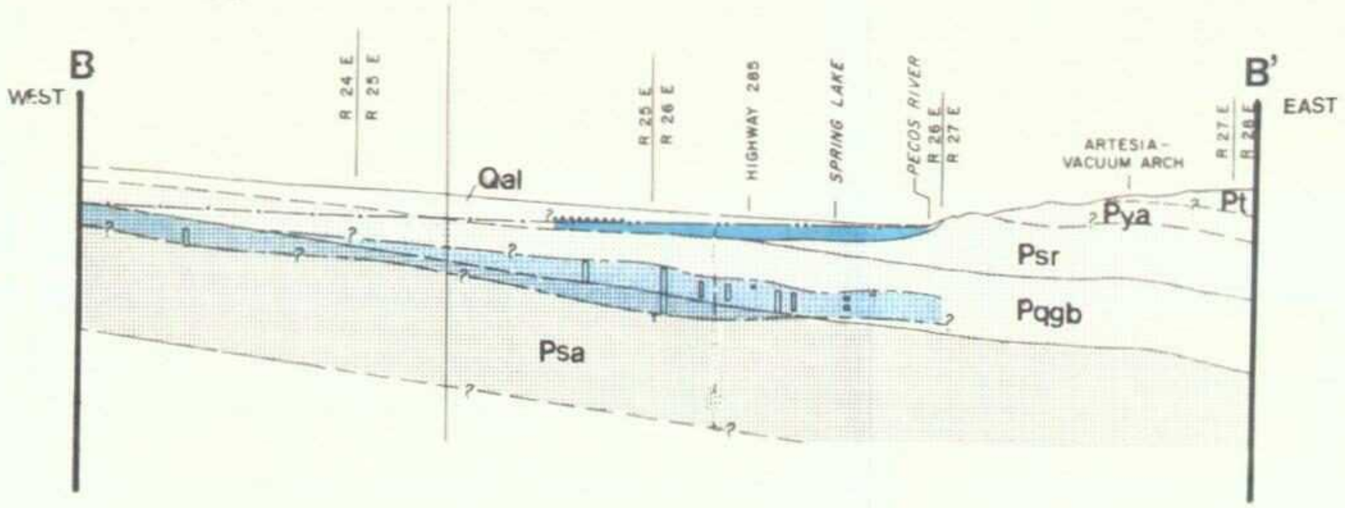
EXPLANATION

Qal	Alluvial deposits— Not mapped in detail might include rocks of Pliocene age and part of the Gatuna Formation of Pleistocene age. Contains the main part of the shallow aquifer of the Roswell basin.
Pt	Tansill Formation
Pya	Yates Formation
Psr	Seven Rivers Formation— (A large part of the shallow aquifer near Lake McMillan)
Pqgb	Queen and Grayburg Formations, undivided. Includes upper part of San Andres Limestone where it is solution altered.
Psa	San Andres Limestone— Contains the main part of the artesian aquifer north of T. 19N. Also includes the "Slaughter zone" (local usage)
— —?—	Formation contact——Dashed where approximately located; queried where probable
··············	Water-level surface in the shallow aquifer of the Roswell basin, January 1975
—·——·—	Potentiometric surface——Shows level to which water will rise in wells tapping the artesian aquifer of the Roswell basin, January 1975.
—··——··—	Water-level surface and potentiometric surface——Where the two are separated by less than about 20 feet.
—— — —?—	Aquifer boundary——Marks the generalized boundaries of the shallow and artesian aquifers of the Roswell basin where their boundaries do not coincide with a formation contact: queried where probable.
▯	Water-producing interval——Projected into the sections from wells generally less than 2 miles away.
■	Shallow aquifer of the Roswell basin. Shows general distribution only. Contains some nonproductive zones.
▤	Artesian aquifer of the Roswell basin. Shows general distribution only. Contains some nonproductive zones.

0 1 2 3 4 5 6 7 8 9 10 MILES

VERTICAL EXAGGERATION X 10
NATIONAL GEODETIC VERTICAL DATUM OF 1929





NOTE: Modified from Welder (1983)

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Regional cross-sections A-A' and B-B'.

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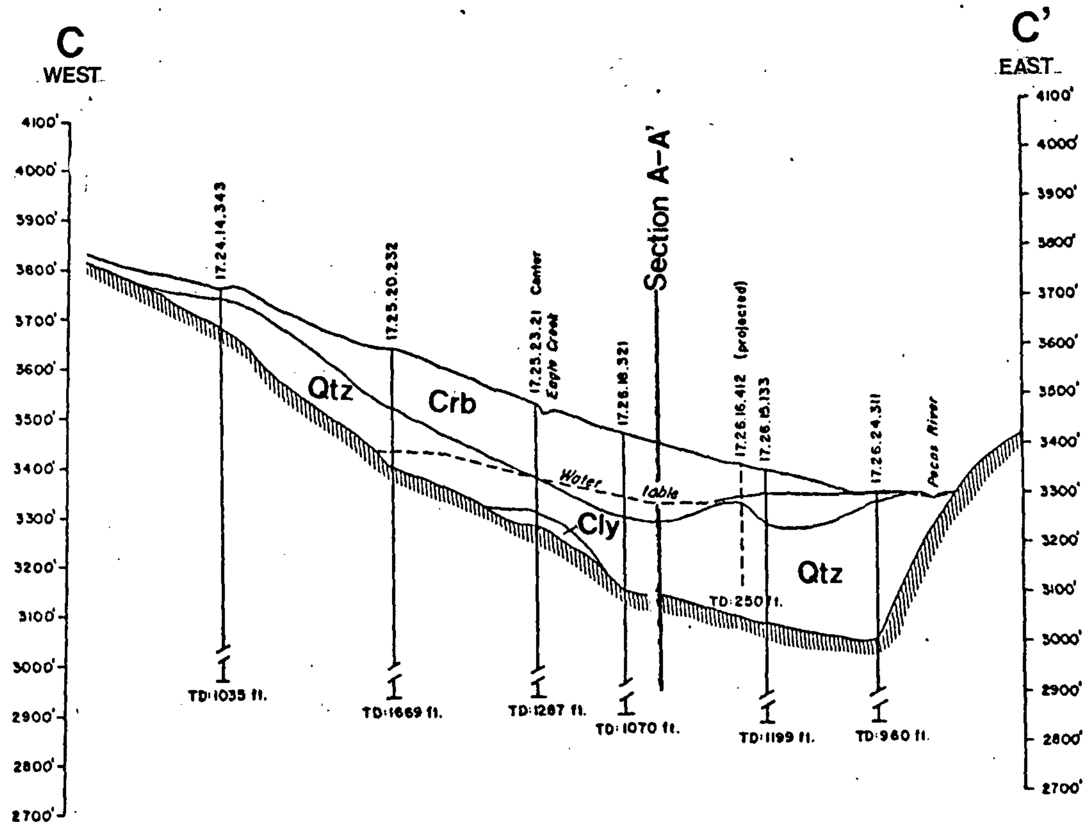
PROJECT: 622092001-237
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 5/19/92
DRAWN BY: SSA
SCALE: AS SHOWN
DATE: 5/19/92
FIGURE: 5

Figure 6. Regional cross-section C-C'.

EXPLANATION

Crb	Carbonate–gravel unit
Cly	Clay unit
Qtz	Quartzose unit
▨	Top of Permian rocks
—	Appropriate contact between lithologic units
-----	Water table determined from January 1969 water levels. Dashed where approximately located.



NOTE: Modified from Lyford (1973)

0 1 2 MILES

Vertical exaggeration x 53
Datum is mean sea level

KWBES

prepared for:

Navajo

Regional cross-section C–C'.

PROJECT:	622092001–237		
LOCATION:	ARTESIA, NEW MEXICO		
APPR:		DATE:	5/19/92
DRAWN BY:	SSA	SCALE:	AS SHOWN
DATE:	5/19/92	FIGURE:	6

ft) nearby, are much more detailed and show several sand zones from 3 to 14 ft in thickness surrounded by rocks of much lower permeability. Reliance on the artesian logs could lead to an erroneous conclusion that a consolidated rock formation occurs near the surface. The logs from valley fill wells provide a much more accurate picture of the sedimentary features above the Permian formations.

Rock outcrops with attributes somewhat similar to those attributed to the Seven Rivers formation can be found in soils mapped as the Upton series for this report. The Upton soils consist of calcareous, gravelly soils that developed in old alluvium derived from sedimentary rocks. Caliche and cemented gravel is found at depths as shallow as 20 inches (USDA-SCS, 1971). Outcrops of caliche occur frequently near the surface of the valley fill near Artesia. Those nearest the refinery occur in the east center of the Armstrong farm south of the refinery and on the north side of Highway 82 about one-half mile east of Bolton Road. In his description of the valley fill terrace deposits, Kelley (1971) also describes chalky caliche as being common in the upper part of the terrace deposits. Although caliche is commonly thought of as being composed entirely of calcium carbonate, in zones where alluvial deposits have evaporitic parent material, the cemented matrix can be gypsum gravels or pebbles. Possibly, under ideal conditions, the matrix can be bound by anhydrite cement making the entire structure gypsiferous.

5.2.3 Summary

The weight of geologic evidence does not support the statements made by earlier consultants regarding the near-surface occurrence of the Seven Rivers formation. The valley should be considered alluvial in nature with discontinuous sands, silts, clays, gravels and conglomerates of varying thickness and extent occurring as the fill material.

5.3 SITE HYDROGEOLOGY

5.3.1 Water Well Survey

The survey of the water wells in the study area was conducted and completed with the cooperation of the homeowners and the SEO, Roswell. The locations of the wells are shown on Figure 2 and summarized in Table 1. Copies of the logs for the four sections east and south of the refinery are reproduced in Appendix A. Wells are completed in both the deep (artesian) and the shallow (valley fill) aquifer in the study area. Most wells classified as “domestic wells” are completed in the valley fill. However, one deep well (RA-4798) in the study area, plugged in 1956

Table 1. Water wells in study area — Section 9, Section 10, Section 15, and Section 16.

Table 1. Water wells in study area — Section 9.

Location of Study Area: T17S, R26E Eddy County

State Engineers #	Location	Mapped Figure 2	Type	Aquifer	Total depth, ft	Age	Saturated zone, ft	Saturated strata	Depth to perforations	Remarks
RA-7	9.213	No	Irrigation	Artesian	1205	1958	1105 - 1135	Water rock	> 730'	
RA-313	9.344	Yes	Irrigation	Artesian	1157	1940	1085 - 1157	Water rock	> 900'	
RA-314	9.430	Yes	Irrigation	Artesian	1196	1952	960 - 1196	Water rock	> 900'	
RA-602	9.113	No	Irrigation	Artesian	1180	1963	858 - 897 1103 - 1157	Water rock Water rock	>859'	Redrill of 1909 well B-35
RA-768	9.323	Yes	Refinery	Artesian	1214	1943	875 - 880	Water rock	> 800'	
RA-1440	9.213	No	Irrigation	Valley fill	320	1941	196 - 225 285 - 320	Sand Sand	202 - 320	
RA-1533	9.000	No	Refinery	Valley fill	258	1937	238 - 258	Sand & gravel	> 200'	
RA-2698	9.244	Yes	Stock	Valley fill	140	1951	18 - 30 50 - 80 130 - 140	Gypsum Clay & gravel Gravel	> 40'	
RA-2723	9.434	Yes	Domestic	Valley fill	318	1951	240 - 318	Sand & gravel	240 - 318	
RA-3225	9.112	No	Unknown	Valley fill	100	1954	65 - 70 80 - 94	Sand Sand	> 50'	
RA-3282	9.112	No	Unknown	Valley fill	125	1954	80 - 92 105 - 123	Sand Sand & gravel	105 - 125	
None	9.430	Approx. loc.	Unknown	Artesian	1250	1923	1000 - 1225	Water rock	> 1000'	Labelled AD-1923 on map
None	9.440	Approx. loc.	Unknown	Unknown	—	—	—	—	—	Exp. oil well converted to water well use. Labelled on map "Yates-Coll"

Table 1. Water wells in study area — Section 10.

Location of Study Area: T17S, R26E Eddy County

State Engineers #	Location	Mapped Figure 2	Type	Aquifer	Total depth, ft	Age	Saturated zone, ft	Saturated strata	Depth to perforations	Remarks
RA-307	10.33	Yes	Irrigation	Artesian	1263	1926	1086 - 1106	Limerock	> 900'	
RA-397	10.433	Yes	Irrigation	Artesian	1095	1954	1040 - 1095	Limerock	> 900'	Redrill of 1909 well RA-3195
RA-1300	10.43	Yes	Irrigation	Valley fill	210	1937	23 - 25	Sand		
							36 - 40	Gravel		
							40 - 43	Sand		
							157 - 175	Sand		
							206 - 210	Sand	Unknown	
RA-1331	10.33	Yes	Irrigation	Valley fill	278	1938	Unknown	—	Unknown	
RA-2793	10.433	Yes	unknown	Valley fill	—	—	Unknown	—	Unknown	No SEO log
RA-4196	10.333	Yes	Domestic	Valley fill	294	1960	280 - 292	Sand & gravel	275 - 294	
RA-4798	10.33	Yes	Domestic	Artesian	850	1963	840 - 850	Limerock	840 - 850	Redrill of RA-3559, converted oil exp. well
RA-4922	10.11	No	Domestic	Valley fill	218	1963	25 - 35	Sand		
							96 - 139	Sand	118 - 139	
RA-6550	10.12323	No	Domestic	Valley fill	125	1979	95 - 120	Sand	90 - 120	
RA-7180	10.12323	No	Domestic	Valley fill	220	1983	100 - 210	Sand	180 - 220	

Table 1. Water wells in study area — Section 15.

Location of Study Area: T17S, R26E Eddy County

State Engineers #	Location	Mapped Figure 2	Type	Aquifer	Total depth, ft	Age	Saturated zone, ft	Saturated strata	Depth to perforations	Remarks
RA-222	15.21	Yes	Unknown	Valley fill	—	—	Unknown	—	—	No SEO log
RA-1183	15.12	Yes	Irrigation	Valley fill	225	1934	20 - 25 155 - 225	Gravel Gravel	> 150'	
RA-1227	15.111	Yes	Irrigation	Valley fill	240	1935	175 - 240	Water sand	> 190'	
RA-1503	15.133	Yes	Irrigation	Valley fill	240	1940	10 - 15 73 - 83	Sand Sand	Unknown	
RA-2050	15.133	Yes	Irrigation	Artesian	1231	1955	1016 - 1030	Rock	> 1000'	Same location as RA-2871
RA-3156	15.131	Yes	Domestic	Valley fill	—	—	—	—	—	No SEO Log
RA-3353	15.121	Yes	Domestic	Valley fill	295	1951	260 - 295	Sand	232 - 296	
RA-4684	15.133	No	Domestic	Valley fill	220	1962	25 - 30 185 - 200	Sand Sand & gravel	185 - 220	
RA-4765	15.14	No	Domestic	Valley fill	185	1963	20 - 50 150 - 185	Sand Sand	155 - 185	
P-3	15.13	Approx. loc.	Unknown	Artesian	1285	1908	1046 - 1050 1124 - 1202	Limerock Limerock	> 900'	Mapped as AD-1908

Table 1. Water wells in study area — Section 16.

Location of Study Area: T17S, R26E Eddy County

State Engineers #	Location	Mapped Figure 2	Type	Aquifer	Total depth, ft	Age	Saturated zone, ft	Saturated strata	Depth to perforations	Remarks
RA-1044	16.311	Yes	Irrigation	Artesian	1225	1960	1095 - 1105	Water rock	> 1000'	
RA-1090	16.11	Yes	Irrigation	Artesian	1233	1930	912 - 913	Water rock	> 900'	
							958 - 960	Water rock		
							996 - 1000	Water rock		
							1027 - 1032	Water rock		
							1058 - 1060	Water rock		
							1118 - 1132	Water rock		
							1218 - 1220	Water rock		
RA-2568	16.113	Yes	Domestic	Valley fill	232	1950	216 - 220	Sand	216 - 232	
N/A	16.12	Approx. Loc.	Unknown	Artesian	932	1962	715 - 932	Sand & rock	> 800'	Converted from 1908 well. AD-1908 on map
N/A	16.11	Approx. Loc.	Unknown	Artesian	1182	1917	1025 - ?	Limerock	> 1000'	AD-1917 on map

Data Source: New Mexico State Engineer office records, Roswell, NM.

after being drilled as an oil exploration hole, was reentered and completed as a domestic water well in 1963. This well is currently in use as a drinking water well for a family living at that location.

Drillers logs for wells in the immediate vicinity of the refinery show zones of artesian water beginning at depths of 880 ft and continuing to about 1,225 ft. These logs show the presence of "limerock" with water in fractures or solution zones, which are rock types typically encountered in carbonate formations.

The potentiometric surface in the artesian aquifer rises close to the surface in the absence of pumping. Some wells were reported to have flowed at the surface this winter for the first time in memory of local observers (Boyer, 1992 and Fresquez, 1992). Without pumping, the artesian aquifer discharges upwards to the valley fill aquifer through the slightly to moderately permeable confining beds of the Grayburg, Queen and Seven Rivers formations. Because of irrigation, water levels in the artesian aquifer have generally declined. SEO water level records since 1926 document an elevation decline of about 75 ft with 70 ft occurring since 1950. For comparison purposes, the yearly readings are taken during the winter after irrigation ceases.

In 1975 the deep aquifer's water level elevation near the refinery (referenced to Mean Sea Level) was approximately 3,309 ft (Welder, 1983). The west Coll well (RA-313), undergoing repair and measured by KWBES on January 30, 1992, had a depth to water of 35.8 ft, or an elevation of about 3,330 ft MSL, which is 21 ft higher than in 1975. Similar results were seen for 1992 measurements at the Artesia recorder well (18.26.05.333), 5 miles south of the city center. The water surface was at 3,308 ft MSL in 1975 and 3,331 ft on January 28, 1992, an increase of 23 ft. Despite recent increases in water elevations, it is important to note that artesian water levels can fluctuate considerably during the irrigation season. Water levels for the Artesia recorder well fell nearly 90 ft between February and July 1990 (measured by the U.S. Geological Survey; Boyer, 1992, and USGS, 1992).

The water level elevation at the Lanning shallow recorder well (18.26.06.44221), located near the Artesia recorder well, was 3,288 ft MSL in January 1992. This represents a water level elevation increase of 3 ft above the level reported by Welder (1983) for 1975. In the study area, the Gurley well (RA-3156) was measured on January 30, 1992 and depth to water was 43.1 ft. This water level elevation of 3,307 ft MSL was about 6 ft higher than that estimated by Welder for the year 1975.

Water levels in the valley fill aquifer are subject to the same seasonal variations as the artesian aquifer, but with much less total change in elevation. This is probably due as much to the difference in the way artesian aquifers respond to pumping as to differences in pumping quantity. For 1990, water level elevations in the valley fill aquifer varied nearly 23 ft between early March and late September.

In addition to finding recent significant increases in water levels, the water well survey documented another source of oil contamination in both the shallow and deep aquifer that may be common in the area. The high capacity irrigation wells use deep well vertical turbine pumps to lift the water from the perforated interval to the surface. Either water or oil is used to lubricate the bearings in the high speed shaft powering the pump sections deep in the well. Interviews with the landowners and one pump installer (Pete & Sons, Artesia) revealed that between one quart and one-half gallon of lubricating oil per day is used to lubricate the bearings. "Drip oil" is commonly gravity fed to the pump column through an oil line from a small tank. If provisions are not made to provide an automatic shutoff, the oil is fed continuously unless manually stopped. Therefore, use of oil-lubricated pumps commonly results in oil leakage and contamination of the well (USDI-BOR, 1985).

During the survey, several irrigation wells with turbine pumps were found to have oil on top of the water table. This oil did not have the odor or color of free product found in several of the monitor wells and boreholes. On January 30, 1992, RA-4196, a valley fill "domestic" well with a submersible pump located immediately north of RA-307 (a deep well), was found to have oil on the water which precluded measurement by the electric depth to water meter. Sampling was not possible due to equipment in the well, but the oil on the meter probe had the same characteristics as pump oil in a nearby container. A sample of drip oil was obtained from the pump installer and tested for volatile organic hydrocarbons. While high in toluene (18,000 ppb) and total xylenes (27,000 ppb) no benzene or ethylbenzene hydrocarbons were found above the 7,000 ppb detection limit. Further comparison and analysis by IML determined that the pump oil does not have the chromographic characteristics of either gasoline or diesel products. The laboratory sample results are presented with the other water and soil analyses in Appendix D.

Because pump oil was already present in several wells on the northeast corner of Bolton Road and Highway 82 and none of the three wells was used a drinking water source, no monitor wells were located at that site.

Better housekeeping practices are needed at some well sites. At one well, used motor oil and filters were discarded in an old stock tank. At one domestic well used for drinking water, chickens were using the well house for shelter and warmth during the winter months. If well surface and sanitary seals are not intact, such practices can introduce contamination into the well (e.g., chemicals, hydrocarbons, bacteria, human and animal wastes).

5.3.2 Monitor Well Lithology and Observations

Monitor wells were drilled and completed as discussed in Section 3.0. This section discusses the results of the drilling program, the occurrence of free product in the monitor wells, and possible sources for the water in the saturated zone. Depth to water, product, product thickness and corrected water levels are shown in Table 2. Drilling logs of the monitor wells are provided in Appendix C.

5.3.2.1 Sediment Lithology

Geologic sediments encountered while installing monitor wells were mostly fined-grained, especially near surface, but increasing coarse material in thin beds was encountered at depth. Sandy clay is the predominant material to depths of 15 to 20 ft where pebbles and thin seams of gravel are found. Fine grained material and thin beds of coarser material alternate until at least 40 to 50 ft, which were the depths of the deepest monitor well borings. However, even the coarser grained material was usually in a matrix that included fine grained clays and silts. Gravel zones ranging from 2 inches to 15 ft (KWB-2) in thickness were observed, but the median thickness appeared to be 1 to 2 ft. Some small (1/2-inch) gravels, but no gravel seams were encountered in drilling KWB-4 or KWB-5, the two wells closest to the eastern side of the refinery.

The three cross-sections of the investigation site's soils presented in Figures 7 through 10 illustrate the complexity of valley fill deposition. Correlation of strata between monitor wells is difficult with the exception of the first 10 to 15 ft of soil that consists of brown sandy clay to clayey sand. (The fourth cross section [D-D'] shown on Figure 14 is discussed in Section 5.4)

5.3.2.2 Monitor Well Fluids

During the drilling of the wells, several borings encountered hydrocarbon stained and/or hydrocarbon saturated soils. Staining was observed in KWB-4, KWB-5, KWB-6 and KWB-8. Except for KWB-4, staining began at 14 to 16 ft. KWB-4, which is the closest monitor well to the refinery, had staining beginning at about 8 ft. The soil cuttings of these four wells exhibited a strong hydrocarbon odor.

Water was encountered at various depths ranging from 17 to 31 ft. The water was slightly to highly artesian in that it usually rose into the wells to an elevation several feet higher than when first encountered. The increase above first saturation ranged from 0.1 ft in KWB-7 to 10.2 ft in KWB-5. Although well placement in the hole was designed to avoid liquids above the screen, upon subsequent measurement, one well (KWB-5) was found to have liquids above the screened interval but below the bentonite seal.

Table 2. Groundwater elevations at the Navajo Refinery.

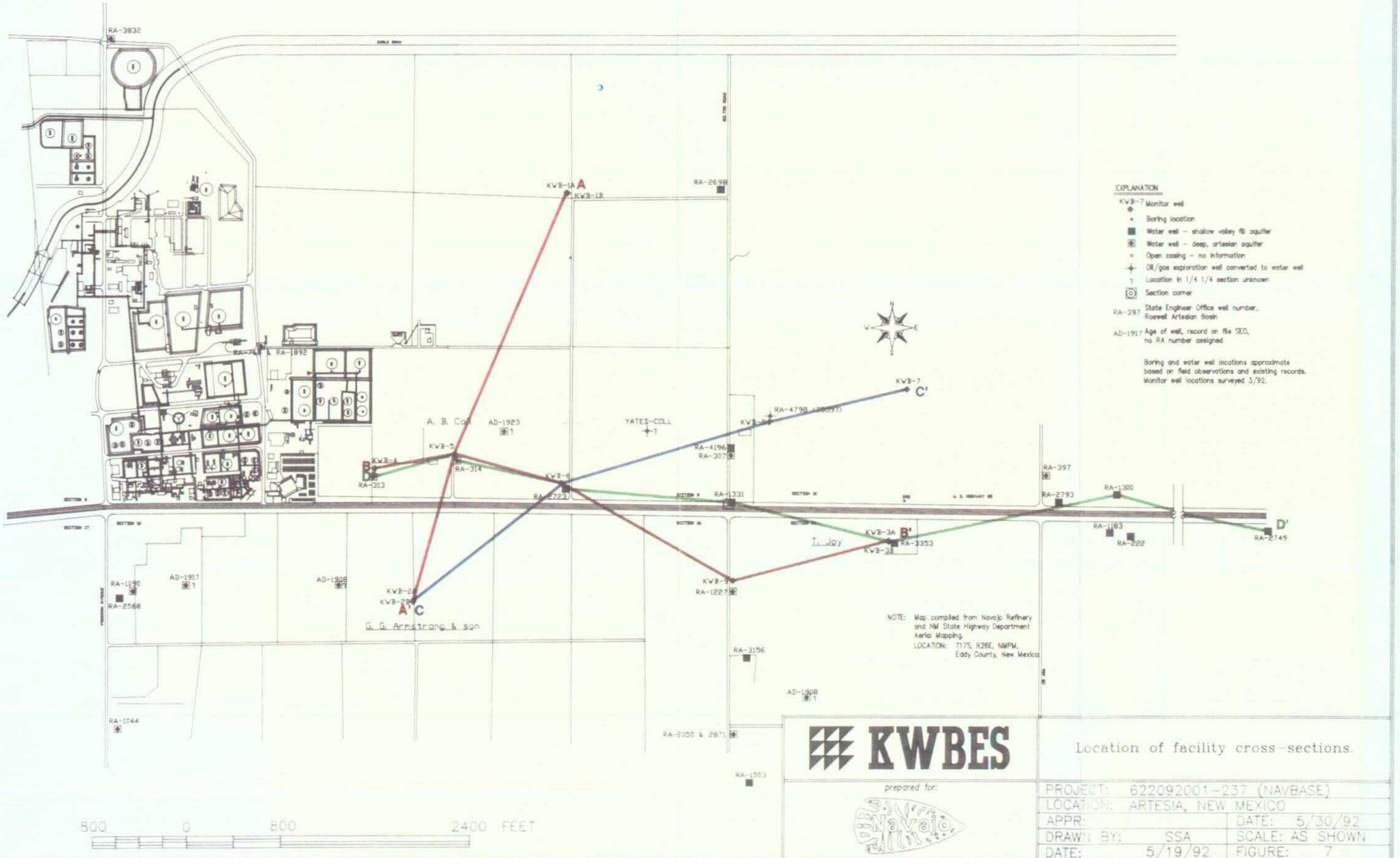
Table 2. Groundwater elevations at the Navajo Refinery.

Well no.	Elevation*	Date	Depth to product, ft	Depth to water, ft	Corrected depth to water, ft**	Groundwater elevation
KWB-1A	3350.87	2/19/92		14.50		3336.37
KWB-1B	3350.83	2/19/92		14.35		3336.48
KWB-2A	3366.04	2/19/92		29.03		3337.01
KWB-2B	3366.26	2/19/92		28.88		3337.38
KWB-3A	3345.31	2/19/92		20.70		3324.61
KWB-3B	3345.10	2/19/92		20.97		3324.13
KWB-4	3368.12	2/19/92		24.20		3343.92
KWB-5	3362.87	2/19/92		23.10		3339.77
KWB-6	3358.55	2/19/92	21.58	24.83	22.33	3336.22
KWB-7	3344.00	2/19/92		19.51		3324.49
KWB-8	3352.97	2/19/92		20.64		3332.33
KWB-9	3352.53	2/19/92		24.88		3327.65
KWB-1A	3350.87	3/10/92		14.67		3336.20
KWB-1B	3350.83	3/10/92		14.50		3336.33
KWB-2A	3366.04	3/10/92		29.33		3336.71
KWB-2B	3366.26	3/10/92		29.20		3337.06
KWB-3A	3345.31	3/10/92		20.99		3324.32
KWB-3B	3345.10	3/10/92		21.25		3323.85
KWB-4	3368.12	3/10/92	23.97	26.08	24.46	3343.66
KWB-5	3362.87	3/10/92	< .06"	23.36		3339.51
KWB-6	3358.55	3/10/92	21.83	25.11	22.59	3335.96
KWB-7	3344.00	3/10/92		20.80		3323.20
KWB-8	3352.97	3/10/92	< .06"	21.05		3331.42
KWB-9	3352.53	3/10/92		25.25		3327.28

* Surveyed elevation at top of casing (msl).

** Corrected depth to water = depth to water — (product thickness x specfic gravity).

Figure 7. Location of facility cross-sections.



EXPLANATION

KWB-7 ◆ Monitor well
• Boring location
■ Water well – shallow valley fill aquifer
▣ Water well – deep, artesian aquifer
▫ Open casing – no information
✦ Oil/gas exploration well converted to water well
? Location in 1/4 1/4 section unknown
◎ Section corner
RA-397 State Engineer Office well number, Roswell Artesian Basin
AD-1917 Age of well, record on file SEO, no RA number assigned

Boring and water well locations approximate based on field observations and existing records. Monitor well locations surveyed 3/92.

NOTE: Map compiled from Navajo Refinery and NM State Highway Department Aerial Mapping.
LOCATION: T17S, R26E, NMPM,
Eddy County, New Mexico

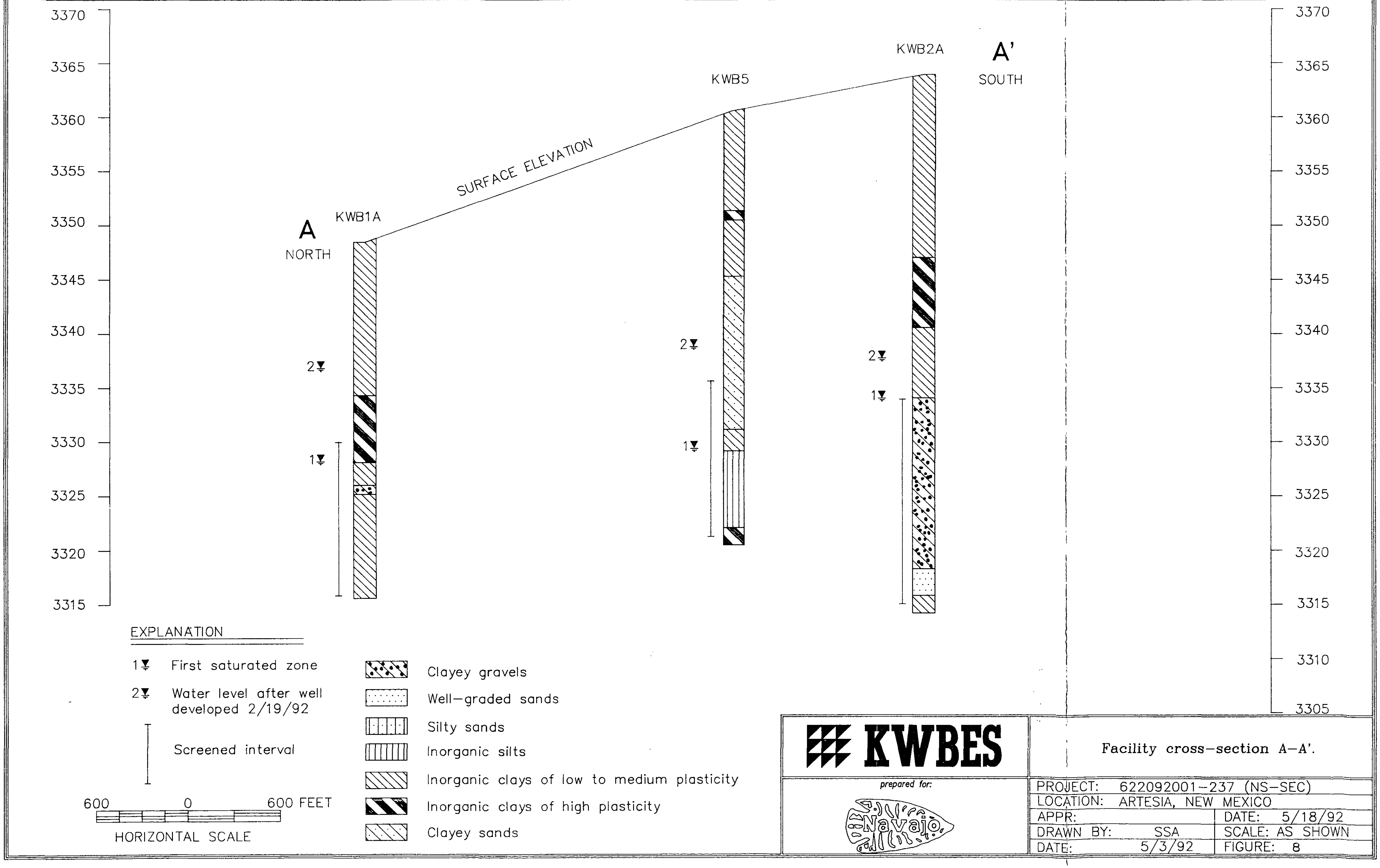
KWBES

prepared for:
Navajo

Location of facility cross-sections.

PROJECT: 622092001-237 (NAVBASE)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 5/30/92
DRAWN BY: SSA	SCALE: AS SHOWN
DATE: 5/19/92	FIGURE: 7

Figure 8. Facility cross-section A-A'.



KWBES

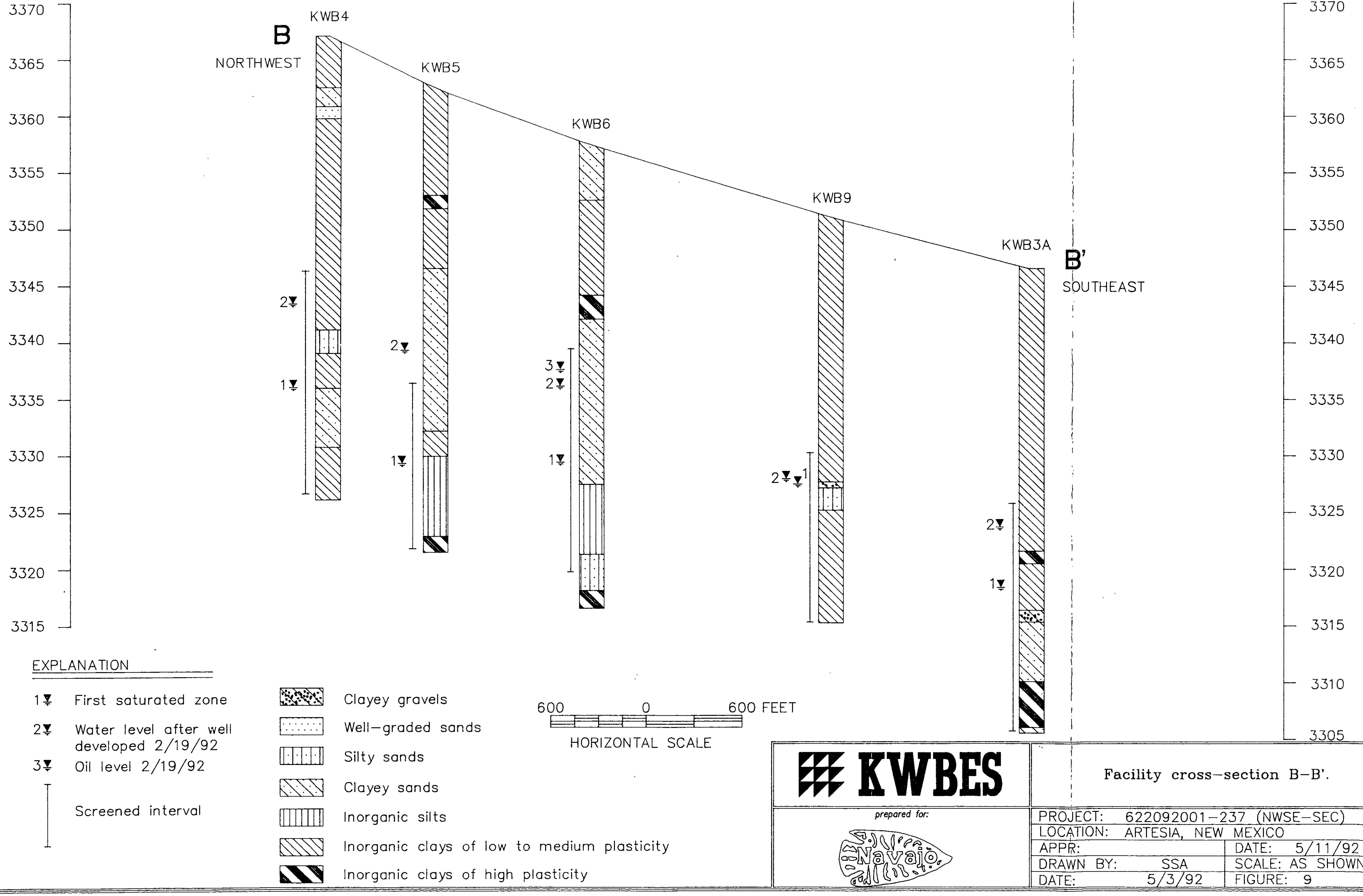
prepared for:

Navajo

Facility cross-section A-A'.

PROJECT: 622092001-237 (NS-SEC)
LOCATION: ARTESIA, NEW MEXICO
APPR: DATE: 5/18/92
DRAWN BY: SSA SCALE: AS SHOWN
DATE: 5/3/92 FIGURE: 8

Figure 9. Facility cross-section B-B'.



KWBES

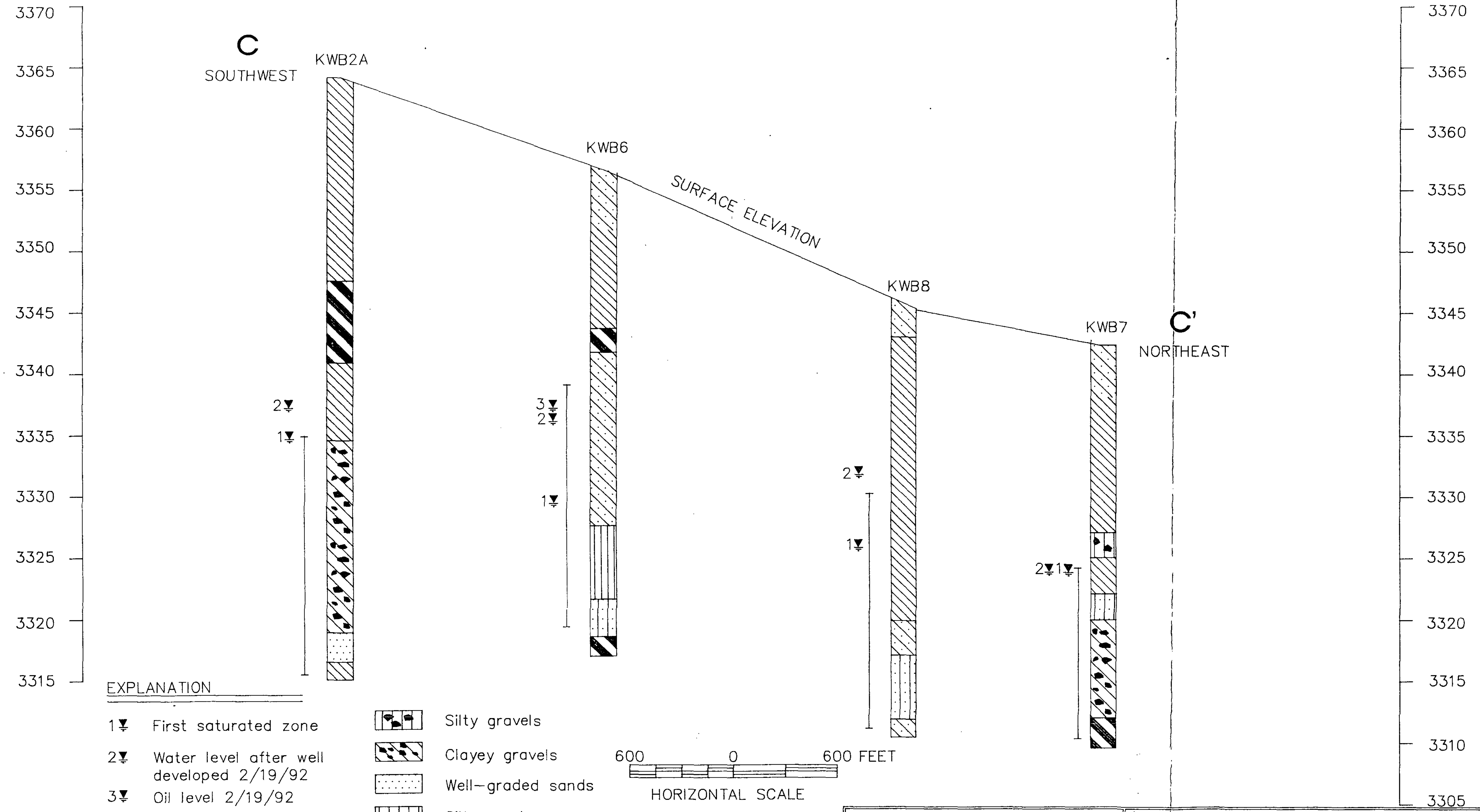
prepared for:

Navajo

Facility cross-section B-B'.

PROJECT: 622092001-237 (NWSE-SEC)
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 5/11/92
DRAWN BY: SSA
SCALE: AS SHOWN
DATE: 5/3/92
FIGURE: 9

Figure 10. Facility cross-section C-C'.



EXPLANATION

1▼ First saturated zone

2▼ Water level after well developed 2/19/92

3▼ Oil level 2/19/92

Ɪ Screened interval

▨ Silty gravels

▨ Clayey gravels

▨ Well-graded sands

▨ Silty sands

▨ Clayey sands

▨ Inorganic silts

▨ Inorganic clays of low to medium plasticity

▨ Inorganic clays of high plasticity

KWBES

prepared for:

Navajo

Facility cross-section C–C'.

PROJECT: 622092001–237 (SWNE-SEC)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 5/11/92
DRAWN BY: SSA	SCALE: AS SHOWN
DATE: 5/3/92	FIGURE: 10

Upon completion, wells KWB-4 and KWB-6 (and likely KWB-5) were found to be located within a plume of free product. KWB-8 was located in a zone of dissolved phase contamination. Two days after completion KWB-6 was observed to have 3.2 ft of product in the well (February 19, 1992) and wells KWB-4, KWB-5 and KWB-8 had hydrocarbon sheens. On March 10, the product thickness in KWB-6 had increased to 3.3 ft, and 2.1 ft of product was observed in KWB-4 which previously did not exhibit free product. No product was observed in KWB-5 as the fluid level, which rose 10 ft after drilling, remained above the top of the screen. KWB-4, KWB-5, KWB-6 and KWB-8 were all installed adjacent to operating water wells to monitor water levels and ascertain the existence of contamination that may pose a threat to users of the wells. Wells KWB-4 and KWB-5 are adjacent to irrigation wells while KWB-6 and KWB-8 are next to wells used for domestic consumption, including drinking water.

5.3.2.3 Source of Water

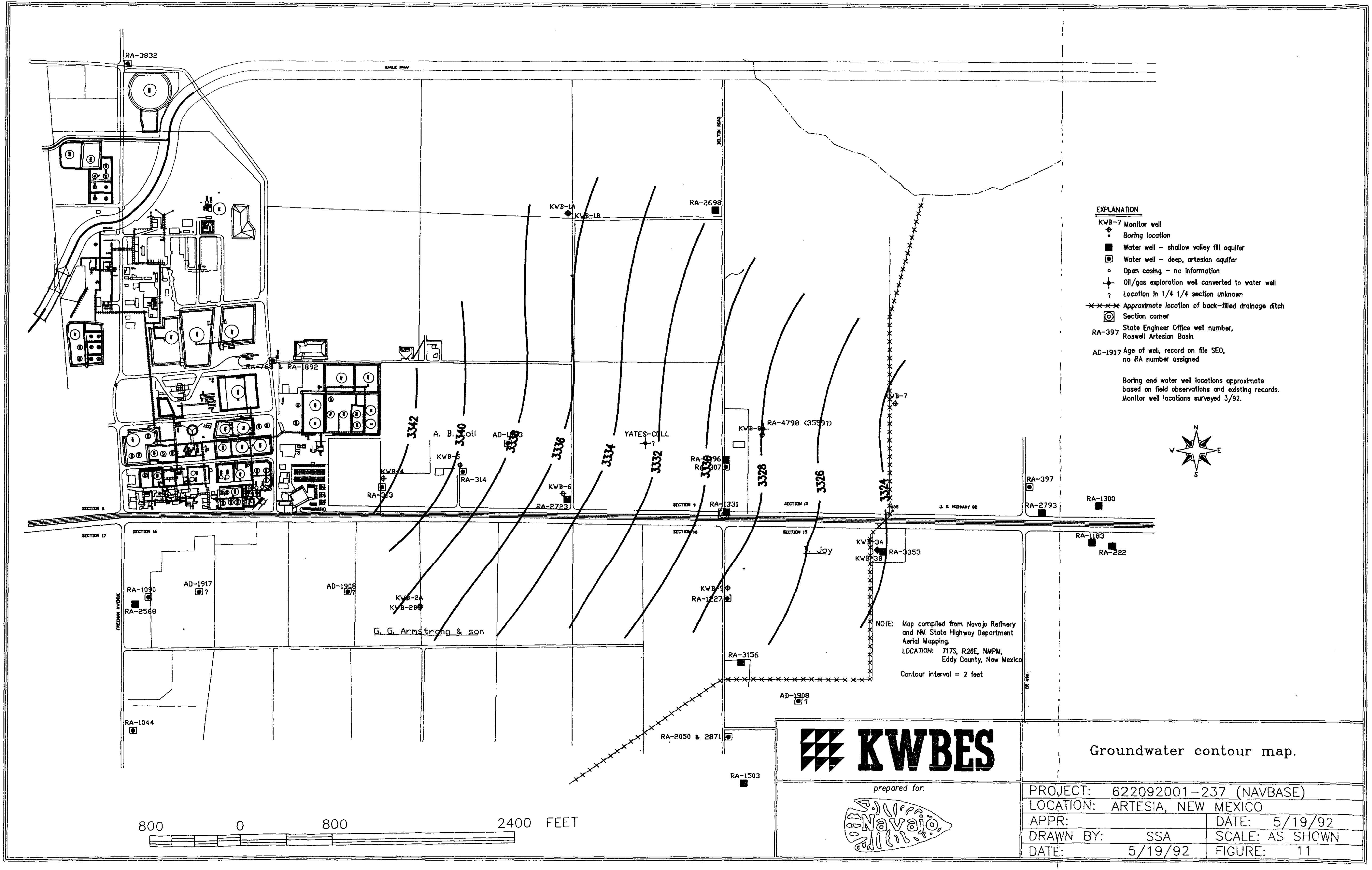
The water potentiometric map of the site is shown in Figure 11. The potentiometric contours on this map show general west to east movement of groundwater from the area of the refinery. Evidence of groundwater movement eastward from areas located further to the west of the refinery can be seen on the potentiometric surface map of this saturated zone prepared for Navajo by IT Corporation (1989, Fig. 3-9). On that map, the contours also show west to east water movement, but with contours on the north side of the refinery curving north, in the direction of the Eagle Creek channel.

The study results do not show evidence of a gradient reversal in the near-surface saturated zone in the vicinity of the refinery. However, deeper zones in the valley fill may have been affected by pumping as described earlier (Section 2.2.2).

Examination of these maps and knowledge of the area provides several possibilities to account for the presence of water in the saturated zone near the surface. One of these includes recharge from Eagle Creek at locations west of the refinery. For several miles west of Highway 285, the creek bottom is used as an urban park and is a likely source of recharge at times when runoff events cause flow in the creek. At other times, water from park irrigation may infiltrate beneath the soil zone. Either possible source of recharge would lead to elevated TDS as water migrates through near-surface unconsolidated soils.

Additional sources may include seepage from Navajo's unlined freshwater fire water ponds, or downward percolation of unused irrigation water where not restricted by low vertical permeability of intermediate sediments.

Figure 11. Groundwater contour map.



NOTE: Map compiled from Novajo Refinery and NM State Highway Department Aerial Mapping.
LOCATION: T17S, R26E, NMPM, Eddy County, New Mexico

Contour interval = 2 feet

KWBES

prepared for:

Navajo

Groundwater contour map.

PROJECT: 622092001-237 (NAVBASE)
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 5/19/92
DRAWN BY: SSA
SCALE: AS SHOWN
DATE: 5/19/92
FIGURE: 11

5.3.3 Results of the Test Boring Program

The combined Navajo-KWBES test boring program augered 94 boreholes. The Navajo borings were done in October 1991, and the KWBES borings were completed in March 1992. Table 3 summarizes these data and includes available information from the Navajo portion of the boring investigation. Tables 4 and 5 present photoionization detector (PID) readings taken during sampling and laboratory analysis of several soil samples. Boring logs for the KWBES holes are presented in Appendix F. Locations for both sets of borings are shown on Plate 1.

The boring program detailed both the lateral and vertical extent of the contamination. Although the general areal extent of the problem was known from the preliminary work by Navajo in Fall 1991, the KWBES work more clearly delineated the boundaries and determined the thickness of the deep soil profile affected by the hydrocarbon. The boring program established that free phase hydrocarbon extends over a large area east of the refinery to the vicinity of Bolton Road. Specifically, the leading edge of the free product is believed to be about 200 to 300 ft east of Bolton Road in the pecan grove (a distance of about 3,300 ft from the refinery). The free product has an approximate maximum lateral width of 2,250 ft along a north-south line extending from the vicinity of B-82 on the north to B-70 on the south. Using these approximations, the area of free product contamination is estimated to be 170 acres.

5.3.3.1 Apparent Product Thickness

From measurements taken during the boring program, product thickness was estimated for the affected area. However a number of factors affect the thickness of product in a well or auger borehole and, without interpretation can lead to erroneous conclusions. Therefore, product thickness should be referred to as "apparent" product thickness until verification or calculation of actual values.

The apparent product thickness mapped from the boring and monitor well program is shown in Figure 12. The map was produced by the "Surfer" computer program from Golden Graphics and is generated using the borehole and well locations, and the measured thickness (for boreholes) 16 to 24 hours after drilling. Figure 12 shows a zone of high product thickness in the vicinity of KWB-4 and KWB-6, and in a series of boreholes extending generally easterly from B-88 to B-91 and southeasterly from B-84 across Highway 82 to B-71. Boreholes east of B-91 and southeast of B-71 showed product sheens but no large accumulations.

Table 3. Boring and monitoring well product thickness at the Navajo Refinery.

Table 3. Boring and monitoring well product thickness at the Navajo Refinery.

Boring no.	HC thickness (ft)	Taken by	Date	Comments
1	sheen	Navajo-Z.R.S.	10/3/91	HC product thickness too thin to measure, field notes
2	sheen	Navajo-Z.R.S.	10/3/91	HC product thickness too thin to measure, field notes
3	~0.25"	Navajo-Z.R.S.	10/4/91	Field notes
4	sheen	Navajo-Z.R.S.	10/4/91	HC product thickness too thin to measure, field notes
5	sheen	Navajo-Z.R.S.	10/4/91	HC product thickness too thin to measure, field notes
6	sheen	Navajo-Z.R.S.	10/4/91	HC product thickness too thin to measure, field notes
7	none	Navajo-Z.R.S.	10/4/91	Field notes
8	none	Navajo-Z.R.S.	10/4/91	Field notes
9	sheen	Navajo-Z.R.S.	10/4/91	HC product thickness too thin to measure, field notes
10	sheen	Navajo-Z.R.S.	10/4/91	HC product thickness too thin to measure, field notes
11	~2.0	Navajo-Z.R.S.	10/7/91	Field notes
12	~0.25"	Navajo-Z.R.S.	10/7/91	Field notes
13	~0.25"	Navajo-Z.R.S.	10/11/91	Field notes
14	~0.25"	Navajo-Z.R.S.	10/11/91	Field notes
15	none	Navajo-Z.R.S.	10/11/91	Field notes
16	none	Navajo-Z.R.S.	10/11/91	Field notes
17	sheen	Navajo-Z.R.S.	10/11/91	HC product thickness too thin to measure, field notes
18	sheen	Navajo-Z.R.S.	10/11/91	HC product thickness too thin to measure, field notes
19	~2.0	Navajo-Z.R.S.	10/11/91	Field notes
20	sheen	Navajo-Z.R.S.	10/11/91	HC product thickness too thin to measure, field notes
21	none	Navajo-Z.R.S.	10/11/91	Field notes
22	none	Navajo-Z.R.S.	10/11/91	Field notes
23	none	Navajo-Z.R.S.	10/11/91	Field notes
24	none	Navajo-Z.R.S.	10/11/91	Field notes
25	none	Navajo-Z.R.S.	10/11/91	Field notes
26	~0.25"	Navajo-Z.R.S.	10/11/91	Field notes
27	sheen	Navajo-Z.R.S.	10/9/91*	NFMR**
28	none	Navajo-Z.R.S.	10/11/91*	NFMR**
29	none	Navajo-Z.R.S.	10/11/91*	NFMR**
30	>1.0"	Navajo-Z.R.S.	10/11/91*	NFMR**
31	none	Navajo-Z.R.S.	10/11/91*	NFMR**
32	none	Navajo-Z.R.S.	10/15/91*	NFMR**
33	>1.0"	Navajo-Z.R.S.	10/15/91*	NFMR**
34	none	Navajo-Z.R.S.	10/15/91*	NFMR**
35	none	Navajo-Z.R.S.	10/15/91*	NFMR**
36	none	Navajo-Z.R.S.	10/15/91*	NFMR**
37	sheen	Navajo-Z.R.S.	10/16/91*	NFMR**
38	sheen	Navajo-Z.R.S.	10/16/91*	NFMR**
39	none	Navajo-Z.R.S.	10/16/91*	NFMR**

Table 3. Continued.

Boring no.	HC thickness ft	Taken by	Date	Comments
40	sheen	Navajo-Z.R.S.	10/16/91*	NFMR**
41	none	Navajo-Z.R.S.	10/16/91*	NFMR**
42	none, slight HC odor	Navajo-Z.R.S.	10/16/91*	NFMR**
43	sheen	Navajo-Z.R.S.	10/16/91*	NFMR**
44	sheen	Navajo-Z.R.S.	10/16/91*	NFMR**
45	none, slight HC odor	Navajo-Z.R.S.	10/16/91*	NFMR**
46	sheen	Navajo-Z.R.S.	10/16/91*	NFMR**
47	none	Navajo-Z.R.S.	10/16/91*	NFMR**
48	none	Navajo-Z.R.S.	10/16/91*	NFMR**
49	sheen	Navajo-Z.R.S.	10/16/91*	NFMR**
50	*none, slight HC odor*	Navajo-Z.R.S.	10/22/91*	NFMR**
51	none	Navajo-Z.R.S.	10/22/91*	NFMR**
52	none	Navajo-Z.R.S.	10/22/91*	NFMR**
53	sheen	Navajo-Z.R.S.	10/22/91*	NFMR**
54	none	Navajo-Z.R.S.	10/22/91*	NFMR**
55	none	Navajo-Z.R.S.	10/22/91*	NFMR**
56	sheen	Navajo-Z.R.S.	10/22/91*	NFMR**
57	none	Navajo-Z.R.S.	10/22/91*	NFMR**
58	none	Navajo-Z.R.S.	10/22/91*	NFMR**
59	none	Navajo-Z.R.S.	10/22/91*	NFMR**
60	none	Navajo-Z.R.S.	10/22/91*	NFMR**
61	none	Navajo-Z.R.S.	10/22/91*	NFMR**
MW-28	>1.0"	Navajo-Z.R.S.	?	NFMR**
67	sheen	KWBES	3/4/92	
68	sheen	KWBES	3/4/92	
69	0.56	KWBES	3/4/92	
70	0.04	KWBES	3/4/92	
71	2.22	KWBES	3/4/92	
72	0.02	KWBES	3/4/92	
73	sheen	KWBES	3/4/92	
74	2.91	KWBES	3/5/92	
75	0.21	KWBES	3/5/92	
76	0.01	KWBES	3/5/92	
77	sheen	KWBES	3/5/92	
78	4.64	KWBES	3/6/92	
79	2.47	KWBES	3/6/92	
80	2.56	KWBES	3/6/92	
81	2.35	KWBES	3/6/92	
82	sheen	KWBES	3/6/92	
83	none	KWBES	3/6/92	

Table 3. Continued.

Boring no.	HC thickness ft	Taken by	Date	Comments
84	2.93	KWBES	3/7/92	
85	3.77	KWBES	3/7/92	
86	2.49	KWBES	3/7/92	
87	4.56	KWBES	3/7/92	
88	2.58	KWBES	3/8/92	
89	0.03	KWBES	3/8/92	
90	none	KWBES	3/8/92	
91	1.04	KWBES	3/8/92	
92	0.78	KWBES	3/10/92	
93	0.5	KWBES	3/10/92	
94	none	KWBES	3/10/92	
MW-1A	none	KWBES	2/19/92	
MW-1B	none	KWBES	2/19/92	
MW-2A	none	KWBES	2/19/92	
MW-2B	none	KWBES	2/19/92	
MW-3A	none	KWBES	2/19/92	
MW-3B	none	KWBES	2/19/92	
MW-4	none	KWBES	2/19/92	
MW-5	none	KWBES	2/19/92	
MW-6	3.25	KWBES	2/19/92	
MW-7	none	KWBES	2/19/92	
MW-8	none	KWBES	2/19/92	
MW-9	none	KWBES	2/19/92	
MW-1A	none	KWBES	3/10/92	
MW-1B	none	KWBES	3/10/92	
MW-2A	none	KWBES	3/10/92	
MW-2B	none	KWBES	3/10/92	
MW-3A	none	KWBES	3/10/92	
MW-3B	none	KWBES	3/10/92	
MW-4	2.11	KWBES	3/10/92	
MW-5	< 0.06"	KWBES	3/10/92	
MW-6	3.28	KWBES	3/10/92	
MW-7	none	KWBES	3/10/92	
MW-8	< 0.06"	KWBES	3/10/92	
MW-9	none	KWBES	3/10/92	

* Date given is the date of boring completion rather than date of measurement.

** NFMR - No field measurement recorded.

Table 4. Results of borehole photo-ionization detection measurements, Navajo Refinery, March 1992.

Table 4. Results of borehole photo-ionization detection measurements, Navajo Refinery, March 1992.

Boring	Depth (ft)	PID (ppm)
B67	28 to 29	545
B68	26 to 27	612
B69	28 to 29	520
B70	27 to 28	998
B71	18 to 19	826
B72	24 to 25	159
B73	--	--
B74	16 to 17	650
B75	21 to 23	545
B76	21 to 23	47
B77	26 to 27	372
B78	15 to 16	633
B79	17 to 18	435
B80	10 to 11	553
B81	12 to 14	470
B82	13 to 14	455
B83	18 to 19	9
B84	15 to 16	530
B85	9 to 10	12
B86	11 to 12	740
B87	11 to 12	675
B88	14 to 15	273
B89	26 to 27	1,116
B90	14 to 15	575
B91	14 to 15	574
B92	16 to 17	1,529
B93	21 to 23	561
B94	25 to 26	background (1 ppm)

Table 5. Results of borehole soil analysis, Navajo Refinery, March 1992.

Table 5. Results of borehole soil analysis, Navajo Refinery, March 1992.

	Soil Samples					
	B71	B74	B85	B87	B89	B92
	Anderson-5	Coll/ALF-1	Coll/NS-4	Coll/EW-1	Coll/House-1	Chase-3
Sample depth	25 ft	22 ft	21 ft	21 ft	29 ft	21 ft
Benzene (mg/kg)	50	133	34	ND	20	29
Toluene (mg/kg)	95	227	93	ND	74	69
Ethylbenzene (mg/kg)	79	236	92	ND	44	89
p, m-Xylene (mg/kg)	130	417	1,539	ND	73	106
o-Xylene (mg/kg)	45	145	52	ND	27	41

ND — Not detected at 0.1 mg/kg.
Note: Copies of laboratory forms with detection limits are shown in Appendix D.

Plate 1. Facility base map.

EXPLANATION

- KWB-7 Monitor well
- ● Boring location
- ■ Water well – shallow valley fill aquifer
- ▣ Water well – deep, artesian aquifer
- ○ Open casing – no information
- ✦ Oil/gas exploration well converted to water well
- ? Location in 1/4 1/4 section unknown
- ×–×–×–× Approximate location of back-filled drainage ditch
- ◎ Section corner
- RA-397 State Engineer Office well number, Roswell Artesian Basin
- AD-1917 Age of well, record on file SEO, no RA number assigned
- Pecan trees

Boring and water well locations approximate based on field observations and existing records. Monitor well locations surveyed 3/92.

NOTE: Map compiled from Navajo Refinery and NM State Highway Department Aerial Mapping.
LOCATION: T17S, R26E, NMPM,
Eddy County, New Mexico

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SANTA FE

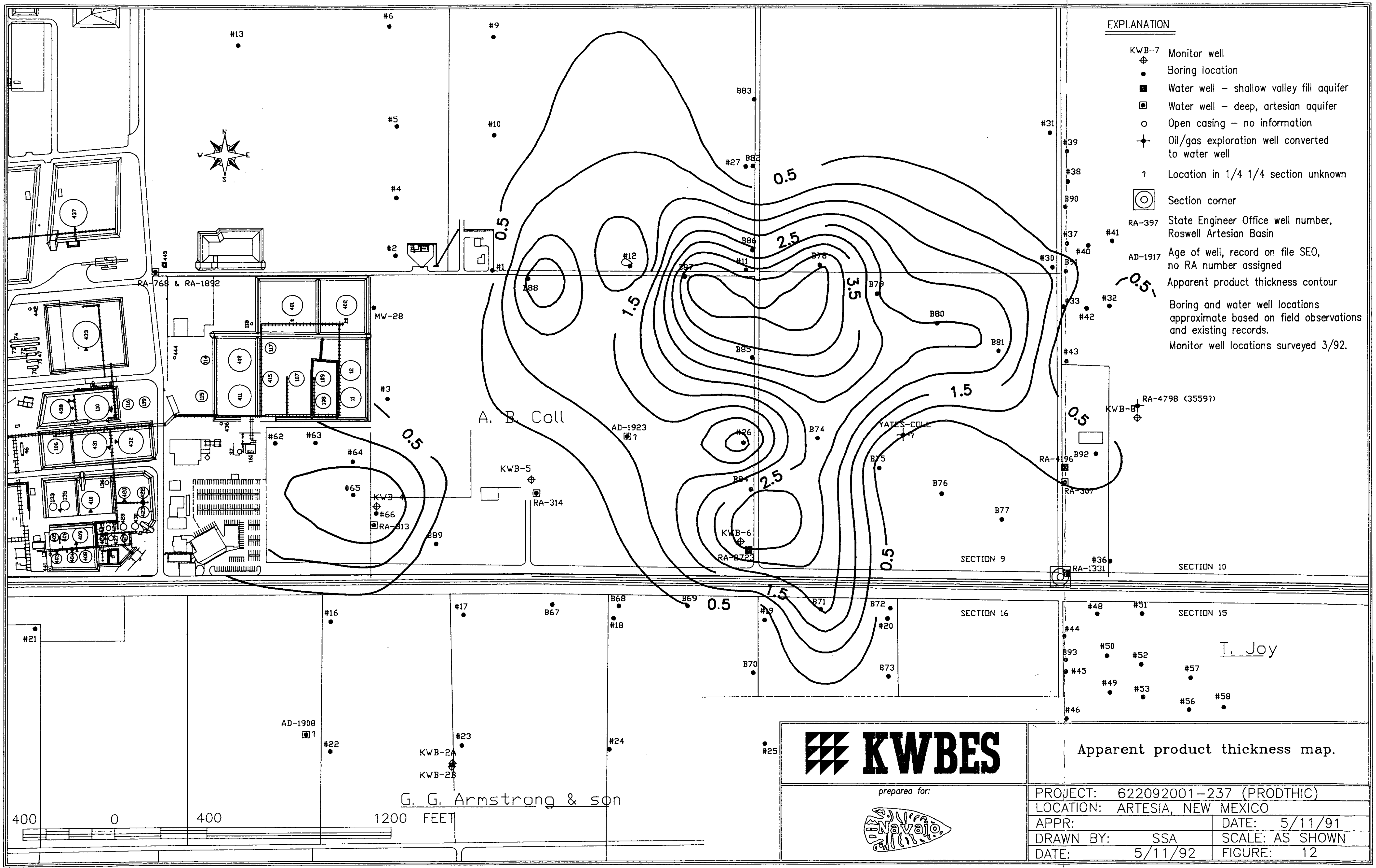
KWBES

prepared for:
Navajo

Facility base map.

PROJECT: 622092001-237 (BASE2)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 5/6/92
DRAWN BY: SSA	SCALE: AS SHOWN
DATE: 4/21/92	FIGURE: PLATE I

Figure 12. Apparent product thickness map.



KWBES

Apparent product thickness map.

prepared for:

Navajo

PROJECT: 622092001-237 (PRODTHIC)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 5/11/91
DRAWN BY: SSA	SCALE: AS SHOWN
DATE: 5/11/92	FIGURE: 12

Determination of actual product thickness in a confined aquifer, as described by Kimberlin and Trimmell (1988), requires determination of a number of parameters including total apparent product thickness and top of the confining layer (Figure 13). Total apparent thickness is determined by multiplying measured product thickness by product specific gravity (PT x Sg). However, this thickness can not be determined unless oil in the borehole has reached equilibrium with oil in the formation (i.e., oil is present in the borehole or well to its total apparent thickness in the formation). Only one measurement was taken during the short period the boreholes were open and the extent to which the oil reached equilibrium is uncertain. The fact that oil in the two monitor wells continued to increase in thickness from February 19 to March 10 indicated that the oil had not reached equilibrium one month after drilling.

A second problem is determining the top of the confining layer. In the area east of the refinery, the soil profile (with the exception of some thin discontinuous gravel seams) exhibits mostly gradual changes in vertical lithology with changes from clayey sands to sandy clays occurring over a distance of several vertical feet. This makes clear definition of the top of a confining bed extremely difficult. In the vicinity of boreholes B-92 and B-93, very little change in water levels occurred above where water was first encountered during drilling. Since the water appears unconfined at these locations, the product thickness (0.5 to 0.78 ft) may either be representative of thickness in the absence of confining pressures, or may be thin because the main product plume has not yet reached that location.

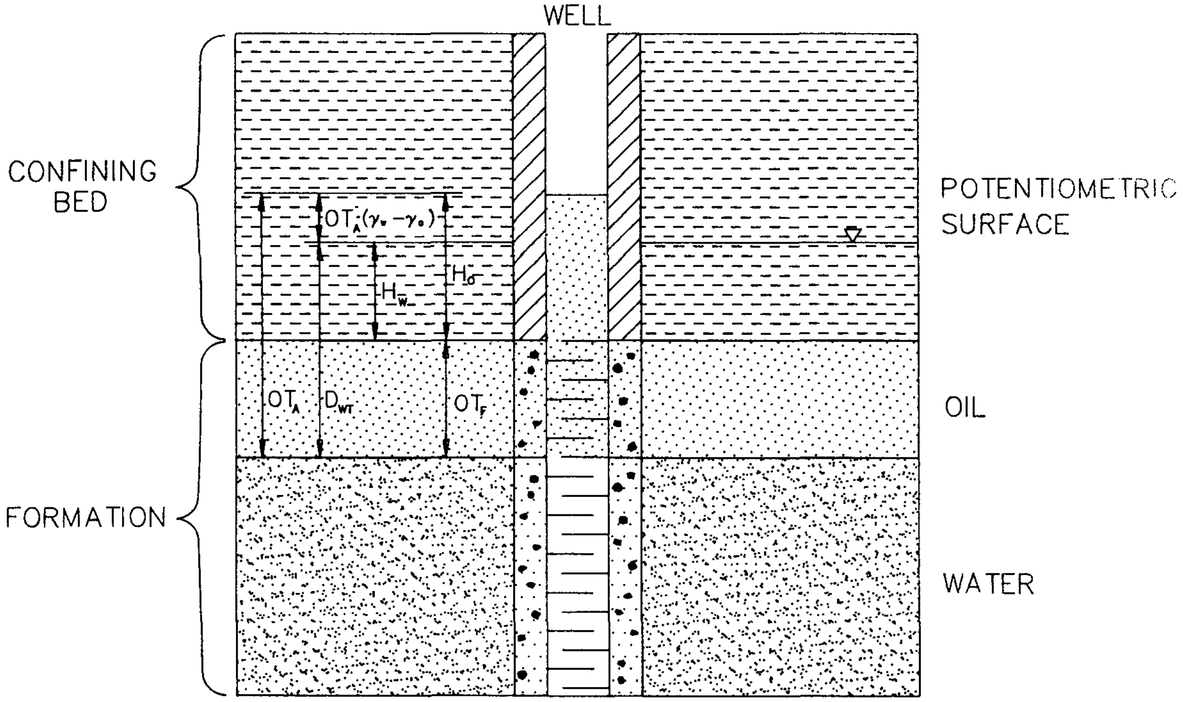
In summary, variations in observed product thickness, lithology and confining pressures, greatly increase the complexity of actual product thickness determination. For that reason, further analysis was not pursued during this first phase of the investigation. If desired, KWBES can continue to examine this problem in an attempt to better define conditions affecting the actual product thickness.

5.3.3.2 Soil Staining

Soil staining extended over a considerable thickness of the soil column. This gray to blue-gray staining of the soil extended well above the current saturated zone in many borings, and is usually indicative of fluctuations in past water levels. However in this situation, there actually may be several causes, none related to water level changes.

Near the refinery in KWB-4 and B-89 staining was present as shallow as 8 to 12 ft below ground surface although the current potentiometric surface is at a depth of 24 ft. There is some evidence that at these two locations the higher elevation of staining is due to hydrocarbon existing at a higher level in the subsurface at some time in the past. KWB-4 shows staining at about 8 ft with stain and odor disappearing from 15 to 16 ft and returning below that level. The soil is a sandy clay with a pebble bed at 18 ft. The log of B-89, located 300 ft southeast of KWB-4

Figure 13. Oil-water relationships in a confined aquifer.



NOTE: To evaluate, oil–water interface and bottom of confining bed must be known.

NOTE: Modified from Kimberlin and Trimmell 1988.

KWBES

Oil–water relationships in a confined aquifer.

prepared for:

Navajo

PROJECT: 622092001–237 (OILWAT)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 5–19–92
DRAWN BY: JW	SCALE: NONE
DATE: 5–19–92	FIGURE: 13

shows a stained sandy clay overlying a stained clay at 13 ft. The sandy clay was dry but had a strong hydrocarbon odor, while the clay soil below was moist. Additional clay zones with some thin lenses of coarser grained material were encountered down to total depth of the boring.

From the information derived from KWB-4 and B-89, it can be concluded that fluids containing hydrocarbons did exist at a depth of 8 to 12 ft at one time. However, the presence of a dry, coarse material and an uncontaminated intermediate clay zone suggest it was a transient event that moved laterally from the refinery into these zones (vs. upward saturation from a rising water table) and did not remain long enough to penetrate deeply into underlying clays in KWB-4.

Staining was also found at relatively shallow depths in other wells away from the refinery. Staining was found from 6 to 11 ft below ground surface in the west to east line of boreholes from B-88 to B-81. However, a different mechanism is believed to have caused the hydrocarbon staining in this area.

These borings have thick clay zones and were found to be under considerable artesian pressure compared to some other locations. Clays were 8- to 15-ft-thick above where fluids were first encountered. The fluids were typically found at depths from 17 to 23 ft along this line of borings. Under slightly artesian conditions, fluids (water and product) rose from 3 to 6 ft above the depth they were first encountered.

Under atmospheric conditions, a soil composed entirely of clay will absorb fluids (product or water) due to the attractive forces in the capillary pores and will hold the moisture indefinitely. This results in fluids in the capillary zone above the water table. When fluids other than water move into the capillary zone, their presence can be ascertained by a color change in the clay. When the fluids are under artesian pressures, these natural pressures are supplemented by the additional hydraulic pressure of the upward pressing fluids causing a rise in moisture above the level due to capillary forces alone.

Supporting evidence of the impact of confining pressures on hydrocarbon movement in clays can be seen in boreholes B-92 and B-93 which also had clay lenses (though thinner) and where the elevation of the water changed very little from where it was first encountered. Even though product was seen in both of these borings, staining at levels much higher than where product was first encountered was not observed.

5.3.4 Results of Water Quality and Free Product Testing

Water quality analyses were performed on groundwater samples collected from domestic wells, irrigation wells, and the monitor wells installed by KWBES. Additionally, analyses were performed on a sample of the free product collected from a monitor well and on a sample of the pump oil used in the deep well turbine pumps.

Inter-Mountain Laboratories, Inc. (IML) performed analyses for the volatile aromatic hydrocarbons benzene, toluene, ethylbenzene, and xylenes (BTEX), major cations and anions, conductivity, and pH. Results of all groundwater analyses and quality control checks are contained in Appendix D. Table 6 contains a compilation of sample results for the water wells and pump oil, and includes the New Mexico Water Quality Control Commission (WQCC) Groundwater Standards. Monitor well results are presented separately.

5.3.4.1 Water Well Water Quality

In the study area, all operable water wells used for domestic purposes were sampled. Domestic use does not necessarily limit use to a residence. In the study area well RA-4196 is used to provide water for nonirrigation use in the commercial pecan operation. Groundwater samples from irrigation wells were obtained when feasible. However, the latter wells had been out of service since the previous fall and it was necessary for the owners to arrange to have them turned on. Because of the depth of the wells and the fact they were used solely for irrigation, the decision was made to sample these wells only where acquiring a sample was convenient. Review of the BTEX results for the landowner water wells shows that four of the wells have low levels of dissolved hydrocarbons. Wells RA-2050, 2568 and 3156 have toluene and/or xylene close to the detection limit of 0.2 micrograms per liter (or parts per billion, ppb). Sampling of the fourth well, RA-313, detected low levels of benzene and ethylbenzene in addition to toluene and xylene. However, with the possible exception of RA-313, the information at this time does not indicate that hydrocarbons in any of the other three wells are associated with the free product plume adjacent to the refinery.

Wells RA-2568 and RA-3156 are completed in the valley fill aquifer and used for domestic purposes. Toluene, with a state groundwater standard of 620 ppb, was identified in both wells but at concentrations of 1 ppb or less. The Armstrong well (RA-2568) provides water for domestic uses including drinking. It was sampled only once, but toluene was detected and verified in the duplicate sample analyzed as part of the quality control program. Neither well is believed to be affected by the hydrocarbon problem under investigation in this study. The Armstrong well is upgradient and outside of the free product plume of contamination in the near-surface saturated zone as determined by a Navajo boring (#21) and the direction of groundwater movement (Figure 11).

Toluene was detected in the Gurley well (RA-3156) during the January sampling but not in the resampling done in March. As a result of the first detection of contamination at the Gurley residence, borehole B-94 was augered at the upgradient corner of the property (Plate 1).

Table 6. Results of water well chemical analyses, Navajo Refinery, January/February 1992.

Table 6. Results of water well chemical analyses, Navajo Refinery, January/February 1992.

		Water well name and SEO number														
Constituent	Units	Chase RA-307	Coll RA-313	Chase RA-1331	Chase RA-2050	Armstrong domestic RA-2568	Coll-Horner domestic RA-2723	Gurley domestic RA-3156		Joy domestic RA-3353	Chase shallow domestic RA-4196	Chase Bolton North, house domestic RA-4798	Duplicate 1		Pump oil	NM WQCC
								Jan. 30	Mar. 19				(Armstrong)	(IML dup.)		
Benzene	µg/L	ND	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10
Toluene	µg/L	ND	0.8	ND	0.7	ND	ND	0.6	ND	ND	ND	ND	1.1	0.8	18000	750
Ethylbenzene	µg/L	ND	2.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	750
p, m-xylene	µg/L	ND	1.4	ND	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	18000	400
o-xylene	µg/L	ND	2.4	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	9000	
pH	s.u.	7.4	7.3	7.4	7.3	7.3	7.5	7.2	—	7.4	7.5	7.7	7.5	—		6 — 9
Conductivity	µmhos/cm	3770	976	2400	8080	1270	1290	3680	—	2880	3740	2750	1290	—		—
Calcium	mg/L	343	132	317	530	184	194	465	—	366	340	408	186	—		—
Magnesium	mg/L	128	43	98	198	59	58	155	—	115	126	135	59	—		—
Potassium	mg/L	2	1.1	1.8	2.8	1.2	1.2	2.7	—	2	2.1	2	1.2	—		—
Sodium	mg/L	348	16	106	861	24	22	150	—	108	357	92	24	—		—
Total alkalinity	mg/L	170	73	166	166	158	145	175	—	181	171	188	162	—		—
Bicarbonate	mg/L	207	88	203	203	193	178	213	—	221	0	229	197	—		—
Carbonate	mg/L	0	0	0	0	0	0	0	—	0	0	0	0	—		—
Chloride	mg/L	573	21	225	1420	32	18	232	—	151	536	103	34	—		250
Sulfate	mg/L	1130	428	913	1770	516	583	1580	—	1210	1130	1370	521	—		600
TDS	mg/L	2710	696	1830	5170	952	992	2820	—	2160	2662	2110	960	—		1000
Formation		Artesian	Artesian	Valley fill	Artesian	Valley fill	Valley fill	Valley fill		Valley fill	Valley fill	Artesian	Valley fill	—		

Notes:
ND — Not detected. ND level is 0.2 µg/L except for pump oil.
NM WQCC — New Mexico Water Quality Control Commission Ground Water standard.
TDS — Total dissolved solids by evaporation. TDS RA-4196 by calculation.
• — Xylene standard is for total xylenes.

Groundwater was encountered at a depth of 25 ft, but no odor or indication of hydrocarbon staining was noted at that location. Although this water well is used for lawn and garden use only, it should be watched since the well is downgradient from the southeast edge of the hydrocarbon plume.

Low levels of non-benzene hydrocarbons were also detected in well RA-2050. This deep artesian well had toluene and xylenes detected at minimal levels. This well was sampled after repair, and after being dormant for several months. Like most deep well pumps in the area, this one uses drip oil to lubricate the downhole equipment. However, equipment on this well includes a regulator valve that prevents discharge of lubricating oil to the well when the pump is cycled off.

At RA-313, the possibility does exist that the well may be minimally affected by the type of free product found at the site. RA-313, a deep artesian well with a turbine pump used for irrigation, is located immediately adjacent to the southeast corner of the refinery and about 40 ft from KWB-4 which has several feet of free product. This is the only water well where benzene and ethylbenzene were detected, although at minimal values. The benzene level of the sample was 1.7 ppb (vs. 10 ppb NM Water Quality Control Commission groundwater quality standard and 5 ppb USEPA drinking water standard).

The sample was taken during a period when the well was undergoing inspection as a result of complaints of oil in irrigation ditches. On October 28, 1991, a representative from the State Engineer Office conducted a leakage test between 80 and 400 ft below the land surface using a meter to detect vertical flow. The depth to water at the time was 62.7 ft. A video camera also inspected the casing and did not detect any obvious holes.

During the time period between the casing test and the OCD sampling on January 30, 1992, the well was open except for a temporary cover placed over the open hole. At the time of the sampling, the well was not purged because of its size and depth and the water sample was obtained after several bails with a clean bailer. No odor was detected nor was a sheen noticed on the water. The well was not resampled and was placed back in service shortly after the KWBES sampling. The source of the hydrocarbons is unknown, but their effect on use of the water from the well is minimal. At these concentrations and with the absence of free product, there will be not an impact on the use of the water for irrigation. However, the issue should be investigated further if oil is observed that can not be attributed to pump lubrication leakage.

It should be emphasized that the two shallow valley fill wells (RA-2723 and RA-4798), currently used by the tenants on the Coll and Chase farms for household purposes, including drinking water, show no evidence of any hydrocarbon contamination although free product and/or dissolved phase hydrocarbons were detected in their respective monitor wells (KWB-6 and KWB-8). However, because of the serious hydrocarbon contamination at these two locations, these water wells should continue to be monitored on a regular basis if they remain in service.

Water wells sampled for BTEX were also sampled to determine general water chemistry parameters to compare with those obtained from the monitor well sampling (Section 5.3.4.2). Wells completed in the valley fill generally had overall better water quality than the deeper artesian wells. The average total dissolved solids (TDS) for the six valley fill wells was 1,903 milligrams per liter (mg/L) while that for the four deep wells was 2,672 mg/L. However, one deep artesian well (RA-313) had the lowest value of TDS while another artesian well (RA-2050) had the largest. Constituents measured in individual wells varied considerably between wells, even within the same aquifer. For example, chloride varies between 18 mg/L and 536 mg/L in valley fill water and between 21 mg/L and 1,420 mg/L in the artesian aquifer. Sulfates are high in both aquifers, ranging between 428 mg/L and 1,580 mg/L. While two wells, RA-2568 and RA-2723, appear to be receiving water from the same zones of the valley fill aquifer, the other valley fill wells appear to be be completed in zones with differing water quality.

5.3.4.2 *Monitor Well Quality*

Results of water quality testing of the monitor wells are shown in Table 7. Monitor wells KWB-1B, KWB-2B, and KWB-3B were not tested due to the proximity of a paired well which is screened over the same interval. Volatile aromatic hydrocarbons were detected in each of the nine monitor wells except KWB-1A. However, BTEX levels detected are at, or just slightly above, method detection levels of 0.2 ppb in wells KWB-2A, KWB-3A, and KWB-9. Low level contamination in KWB-3A was confirmed with a duplicate sample. KWB-7 values were from 5 to 10 times the detection level. The remaining four wells were grossly contaminated with benzene values ranging from 1,400 ppb in KWB-4, to 33,100 ppb in KWB-6. Total BTEX levels ranged from 4,700 ppb in KWB-8 to 51,600 ppb in KWB-6. Three of the four wells (KWB-4, KWB-5, and KWB-6) are located in the plume of free product (as determined during drilling) while KWB-8, at the easternmost edge of the plume, had a sheen (less than 0.06 inches) detected. NM WQCC standards for BTEX (shown on Table 6) are exceeded at these four wells.

Major water chemistry constituents are calcium and sulfate with significant levels of magnesium, sodium, chloride and bicarbonate. The constituents reflect the wide diversity of the source rocks that make up the surface alluvium. Gypsum provides calcium and sulfate, limestone provides calcium and bicarbonate, and dolomite provides calcium, magnesium and bicarbonate. The high concentrations of total dissolved solids, which average 4,100 mg/L for KWB-1A, KWB-2A, and KWB-3A, reflect the near-surface occurrence of the water. The water is moving through unconsolidated soils and likely is impacted by both recharge from surface activities, including irrigation drainage, and evapotranspiration if the water elevation is close to

Table 7. Results of monitoring well chemical analyses, Navajo Refinery, February 1992.

Table 7. Results of monitoring well chemical analyses, Navajo Refinery, February 1992.

	Monitoring Well											
Constituent	Units	1A	2A	3A	4	5	6	7	8	9	3A dup	5 dup	Travel blank
Benzene	µg/L	ND	0.9	0.2	1400	11200	33100	1.5	1500	ND	ND	-	ND
Toluene	µg/L	ND	0.4	ND	2300	4000	8300	2	1000	1	0.7	-	ND
Ethylbenzene	µg/L	ND	0.3	ND	900	3000	3100	1.2	1100	ND	ND	-	ND
p, m-Xylene	µg/L	ND	0.5	ND	1600	2300	5300	1.2	800	0.2	0.2	-	ND
o-Xylene	µg/L	ND	0.2	ND	700	900	1800	1	300	0.3	0.3	-	ND
pH	s.u.	7.1	7.4	7.1	6.7	7.2	7.1	7.2	7.3	7.1	7.2	7.2	
Conductivity	µmhos/cm	5741	4116	6460	3730	2310	2540	3410	3530	3390	5710	2310	
Calcium	mg/L	577	477	688	260	191	210	291	471	276	652	180	
Magnesium	mg/L	379	231	258	162	116	124	185	204	186	261	117	
Potassium	mg/L	5	4	8.5	1.2	1	1.2	0.8	0.9	0.6	3	1	
Sodium	mg/L	285	144	400	279	104	138	203	148	219	435	112	
Total alkalinity	mg/L	373	282	347	566	757	736	459	388	624	236	754	
Chloride	mg/L	275	155	412	629	248	275	279	124	330	428	244	
Sulfate	mg/L	2661	1804	2547	432	65	179	1090	1750	787	2690	66	
TDS, calculated	mg/L	4555	3067	4660	2329	1482	1538	2058	3086	2423	4705	1474	

ND — Not detected at detection level of 0.2 µg/L.

TDS — Total dissolved solids. Calculated by sum of constituents using alkalinity.

Note: Copies of laboratory forms with detection limits are shown in Appendix C.

the surface. If downward movement is impeded by clays, dissolved solids remain in the near-surface zone and may concentrate further due to these impacts. Eventual removal under these conditions is through lateral movement and downward seepage in zones where clays are thin.

Sulfate concentrations in KWB-4, KWB-5, and KWB-6 are much lower than in the other wells. This probably results from sulfate reduction due to oxygen depletion caused by the change from aerobic to anoxic conditions in free product plume. Sulfate in KWB-8 at the easternmost edge of the plume has only a sheen of free product and does not yet appear to be greatly affected by a change in the oxygen environment.

In wells KWB-1A, KWB-2A and KWB-3A, background concentrations of total dissolved solids, sulfate, and, with one exception, chloride all exceed NM WQCC groundwater standards. There is no evidence that the plume has contributed major water chemistry constituents (e.g., sodium, chloride) to the groundwater. Minor constituents and trace elements (e.g., nitrates and heavy metals) were not tested. Changes to inorganic water chemistry appear limited to those resulting from oxygen deficiency discussed above.

5.3.4.3 Free Product Testing

Two distinct types of free product were identified through the water quality testing program. The first is pump or "drip" oil associated with lubrication of the deep well turbine pumps, and the second is the light hydrocarbon detected in the monitor wells and test borings. While confirmation of identity through laboratory analysis was necessary, observant onsite personnel detected differences in color and odor.

Laboratory analyses of a sample of "drip" oil provided by a local pump installer were performed by IML, College Station. The sample was analyzed for BTEX, and for chromographic similarity to gasoline and diesel oil. Also, a sample of product from KWB-6 was analyzed for API gravity and other characteristics (but not BTEX) by the refinery. The results of the dissolved phase BTEX analysis of the water sample from KWB-6 were used in the comparison.

The pump oil was from a container labeled "Farmland (Brand) Lubricants, Drip Oil 200" manufactured by Farmland Industries of Kansas City, Missouri. The analysis, with a detection limit of 7,000 ppb, did not show benzene or ethylbenzene present but toluene and xylenes were present at 18,000 and 27,000 ppb, respectively. The comparative analyses by IML determined that the sample contained hydrocarbons in the range of C18 to C30 whereas both gasoline and diesel are lighter. Gasoline components are considerably less than C18 and diesel does not have components heavier than C24.

The sample from KWB-6 analyzed by the refinery had an API gravity of 52.7 which is equivalent to a specific gravity (Sg) of 0.768 at a temperature of 60 degrees Fahrenheit. By comparison, Sg of gasoline ranges from 0.68 to 0.74, that of diesel fuel from 0.82 to 0.94, and Sg of lubricating oil ranges from 0.88 to 0.92 (Colt Industries, 1979). Although a chromographic comparison with gasoline or diesel was not performed by IML for the KWB-6 sample, examination of the refinery API data supports a conclusion that the free product in KWB-6 is a light hydrocarbon, most likely a weathered gasoline. The large amount of benzene and ethylbenzene in the dissolved phase sample support that conclusion.

5.3.5 Aquifer Testing

5.3.5.1 Introduction

Three aquifer tests were conducted from March 4 to 10, 1992, to determine the hydraulic properties of the near-surface saturated zone in the vicinity of the Navajo Refinery. The locations of the wells used in the aquifer tests are presented in Figure 2. These locations include wells on Navajo-owned land east of the refinery, the Armstrong property south of the refinery, and the Joy property southeast of the refinery. The wells used during each test are presented in Table 8. The following sections document the test procedures and present the results of each aquifer test.

Table 8. Wells used during the pump tests in the vicinity of the Navajo Refinery.

Property	Pumping well	Observation well
Navajo	KWB-1B	KWB-1A
Armstrong	KWB-2B	KWB-2A
Joy	KWB-3B	KWB-3A

The performance of each pump test involved the temporary installation of a submersible pump with the associated plumbing and the installation of data collection instrumentation into selected wells. The test was conducted by withdrawing water from a 4-inch diameter pumping well and recording the water levels in an adjacent 2-inch diameter observation well screened at a similar depth.

5.3.5.2 Test Preparation

For each aquifer test, a 2-inch diameter (Redi-Flo) electric submersible pump was used to withdraw water from the pumping well and discharge the water into a nearby field. Limited discharges to the field were not considered detrimental to test results because the fine-grained nature of the surface soils minimized downward seepage, and because of the artesian nature of the aquifer as demonstrated during monitor well drilling. Also, the results of the monitor well sampling showed that, at most, only trace levels of dissolved organics were present in the monitor wells. Power to the electric pump was supplied by a gasoline-powered generator. A pump controller and a flow-meter were used to regulate and determine the pumping rate during the test.

To collect the necessary data, an automated (In-Situ Hermit 1000C) data logger was used to collect water level measurements via pressure transducers in the pumping and observation wells. The pressure transducers in the observation wells were placed at a depth within the screened interval of the casing, below the expected level of drawdown. The pressure transducer in the pumping wells was placed at the top of the pump, below the expected level of drawdown.

Prior to the start of test pumping, a maximum pumping rate was determined by performing a step-drawdown test. During a step-drawdown test, the well is pumped at progressively higher rates until it is deemed the water-bearing zone could not produce the volumes of water necessary to maintain a higher pumping rate (i.e., the level of drawdown was such that the water level was drawn below the pressure transducer).

5.3.5.3 Test Procedures

The aquifer test consisted of three phases of data collection: background, pumping, and recovery. In the first phase, water level measurements were collected from both the pumping well and the observation well prior to the start of any pumping. Data collected during this phase are useful for identifying static water levels in each well and the influence of barometric pressure, if any, on the water levels. The background data from each pump test are presented in Appendix H-1. In the second phase, water level measurements were collected from both wells after pumping was started. Data collected during the pumping phase are evaluated to determine the hydraulic properties of the uppermost water-bearing zone. The pumping data from each pump test are presented in Appendix H-2. In the third phase, water level measurements were collected from both wells after pumping was stopped. As with the pumping data, data collected during the recovery phase are evaluated to determine the hydraulic properties of the uppermost water-bearing zone. The recovery data from each pump test are presented in Appendix H-3.

Armstrong Property

KWB-2B was used as a pumping well, while KWB-2A was used as an observation well. The collection of background data began at 4:18 pm on March 3, and continued for approximately 885 minutes (14.8 hours). The test began at 7:21 am on March 4, and continued for a total of approximately 30 hours. The pumping phase of the test ended at 2:47 am after 1,165 minutes (19.4 hours). The wells were allowed to recover for a period of 610 minutes (10.2 hours). The constant pumping rate was approximately 2.1 gallons per minute (gpm).

Joy Property

KWB-3B was used as the pumping well, and KWB-3A was used as an observation well for this test. The collection of background data began at 2:42 pm on March 5, and continued for 975 minutes (16.3 hours). The test began at 7:36 am on March 6, and continued for a total of approximately 29 hours. The pumping phase of the test ended at 1:36 am after 1,075 minutes (17.9 hours). The wells were allowed to recover for a period of 670 minutes (11.2 hours). The constant pumping rate was approximately 4.6 gpm.

Navajo Property

KWB-1B was used as a pumping well, while KWB-1A was used as an observation well. The collection of background data began at 4:15 pm on March 7, and continued for approximately 2,325 minutes (38.8 hours). The test began at 7: 29 am on March 9, and continued for a total of approximately 28 hours. The pumping phase of the test ended at 1:02 am after 1,030 minutes (17.2 hours). The wells were allowed to recover for a period of 640 minutes (10.7 hours). The constant pumping rate was approximately 6.7 gpm.

5.3.5.4 Test Results

Analytical methods were used to evaluate the results of the aquifer test for determination of transmissivity (T) and storage coefficient (S) of the near-surface saturated zone. Hydraulic conductivity (K) of the saturated zone was obtained using the transmissivity and dividing by the screened interval (assumed equal to zone thickness). Before applying the analytical methods, graphing of the test data was required. Time values (*t*) were plotted on the horizontal axis while drawdown (*s*) was plotted on the vertical axis. The graphical results of the pumping and recovery phases of the aquifer test, together with the background data, are shown in Appendix H.

Review of data graphs for background readings obtained prior to each test (Appendix H-1) shows that only slight fluctuations (less than 0.09 ft) in water levels were observed in the observation wells. Small water level declines were observed in KWB-1A and KWB-3A while a slight rise (0.03 ft) was observed in KWB-2A. There were no obvious large scale fluctuations (such as diurnal pressure changes) observed during the background period that would require adjustments to the pumping data

At a constant pumping rate of approximately 6.7 gpm, maximum drawdowns of 6.9 ft and 0.60 ft were recorded for KWB-1B and KWB-1A, respectively, on the Navajo property. At a constant pumping rate of approximately 2.1 gpm, maximum drawdowns of 15.5 ft and 0.03 ft were recorded for KWB-2B and KWB-2A, respectively, on the Armstrong property. At a constant pumping rate of approximately 4.6 gpm, maximum drawdowns of 11.2 ft and 0.46 ft were recorded for KWB-3B and KWB-3A, respectively, on the Joy property. While pumping of KWB-1B and KWB-3B had only a slight influence on their respective observation wells, pumping of KWB-2B had minimal influence on KWB-2A. Water levels in KWB-2A remained essentially constant during pumping, and changes observed in this well approximated and could not be differentiated from background readings. Graphs of drawdown versus time for the pumping and recovery phases of the pumping and observation wells are shown in Appendices H-2 and H-3.

The graphical time-drawdown plots for observation well data obtained during the pumping and recovery phases were used to determine transmissivity and storage coefficient. Only transmissivity was determined from pumping and recovery data obtained from the pumped wells ("B" wells). Prior to analysis of the pumped well data, data values were corrected to eliminate the effects of vertical flow in the formation near the pumping well. The test methods utilized to analyze the observation and pumping well data are discussed below while Table 9 is a summary table showing the average of the test results for each well.

5.3.5.5 *Discussion of Results*

A variety of analytical methods were used to estimate the aquifer characteristics at each well. Not all were found to be applicable for analysis of these data and, after comparison with results from other methods, were eliminated from use in the evaluation.

The pumping phase of each test was analyzed using both the Theis equation (type-curve matching) and the Cooper-Jacob equation (Jacob straight-line method). The curve matching procedure involves matching plots of $W(u)$ versus u and drawdown (s) versus inverse time ($1/t$) on log-log scale paper. The Jacob straight-line method involves plotting drawdown (s) versus time (t) on semilog scale paper. Examples of both are shown in Appendix H-2. Due to minimal drawdown in the observation well on the Armstrong property (KWB-2A), only water level measurements recorded for the pumping well (KWB-2B) were analyzed.

Transmissivity is a measure of the ease with which fluids can pass through a saturated aquifer. Due to this fact, an aquifer with a high transmissivity will produce a broad cone-of-depression extending from the pumping well and have a large radius of pumping influence. Conversely, an aquifer having a low transmissivity will produce a cone-of-depression which remains relatively close to the pumping well and have a small radius of pumping influence.

Table 9. Summary of aquifer test results.

Table 9. Summary of aquifer test results.

Observation wells

Well	Transmissivity * (gal/day/ft)	Screened interval	Hydraulic conductivity (K, gal/day/ft^2)	Storage coefficient (S)	Remarks
KWB-1A	4100	14	293	1.8×10^{-3}	Best match with Hantush-Jacob "Leaky Aquifer" method. No match with water table graphs for late data.
KWB-2A	—	19	—	—	No response to pumping.
KWB-3A	3320	19	175	1.6×10^{-3}	Best match with Hantush-Jacob "Leaky Aquifer" method. Very poor match with water table graphs for late data.

Pumping wells

Well	Transmissivity ** (gal/day/ft)	Screened interval	Hydraulic conductivity (K, gal/day/ft^2)	Pumping rate (gal/min)	Remarks
KWB-1B	342	14	24	6.7	Drawdown corrected for vertical flow effects, possible casing storage effect.
KWB-2B	77	19	4.0	2.1	Corrected drawdown, likely casing storage effects for early data.
KWB-3B	281	19	15	4.6	Corrected drawdown, possible casing storage effect.

* Average of Theis, Hantush-Jacob and Theis recovery values.

** Average of Theis and Hantush-Jacob values.

The value of storage coefficient also determines the shape of the cone-of-depression. Unconfined aquifers typically have storage coefficients in the range of 0.02 to 0.30, while confined aquifers have storage coefficients on the order of 0.005 or less (Fetter, 1988). An aquifer with a low storage coefficient, for a given pumping rate, will generate more drawdown than an aquifer having a higher storage coefficient (Freeze and Cherry, 1979). A low storage coefficient, indicating a confined aquifer, causes the cone-of-depression to extend over a wider area than would be the case in an unconfined aquifer.

The values for transmissivity *(T)* and storage coefficient *(S)* calculated by the Theis equation for aquifer test data are based upon a graphical solution of the data. The following equations are used to determine *T* (per day per foot) and *S* (dimensionless),

$$T = \frac{114.6QW(u)}{s} \quad \text{and} \quad S = \frac{Tut}{1.87\,r^2}$$

where

Q = constant pumping rate (in gallons per minute)
$W(u)$ = well function of u
s = drawdown (in feet)
u = well constant
t = time since pumping started (in days)
r = radial distance from the pumping boring (in feet)

The Theis equation assumes nonsteady, radial flow in a confined aquifer without vertical leakage from overlying or underlying confining beds, and a constant well discharge. '

The Cooper-Jacob semilog method, a modification of the Theis equation, assumes a small value of u (<0.05). The values of transmissivity and storage coefficient calculated by this equation are also based upon a graphical solution and make use of the following equations,

$$T = \frac{264Q}{\Delta s} \quad \text{and} \quad S = \frac{0.3T\,t_o}{r^2}$$

where

Q = constant pumping rate (in gallons per minute)
Δs = change in drawdown over one log cycle
t_o = intercept of the straight line at zero drawdown (in days)
r = radial distance from pumping boring (in feet)

Because *r* is measured from the center of the pumped well, a value for the storage coefficient can not be calculated for a pumping well.

Using the Theis equation (type-curve matching), transmissivity values of 3,840 and 2,640 gallons per day per foot (gpd/ft), and storage coefficient values of 1.7 x 10^{-3} and 1.6 x 10^{-3} were calculated for observation wells KWB-1A and KWB-3A, respectively. KWB-2A had only minimal response to pumping. Pumping well values of transmissivity using the Theis equation ranged from 82 to 334 gpd/ft.

Only early time data were used in the Theis evaluation. Data points for both observation and pumping wells usually varied from the Theis curve after only one minute of pumping and always before 10 minutes of the test had elapsed. The reason for this deviation and its implication for aquifer behavior is discussed later in the section.

The deviation from the Theis curve also affected values of transmissivity and storage coefficient calculated using the Cooper-Jacob equation. Values of transmissivity using this method were generally two to four times larger than calculated by the Theis equation, and they were not used further in the evaluation.

The recovery phase of the test was analyzed using the Theis recovery method. The calculation for the recovery phase involved plotting residual drawdown t/t' on semilog scale paper, where t equals the time since pumping started and t' equals the time since pumping stopped. Residual drawdown (s') is plotted on the vertical axis as before and t/t' is plotted on the horizontal axis. Transmissivity is calculated using the Cooper-Jacob method with $\Delta s'$ used in place of Δs. This method can be used only to calculate transmissivity since it is based on a time ratio obtained from the test values. Values of transmissivity calculated from water level recovery data for the observation wells were 4,420 and 3,920 gpd/ft for KWB-1A and KWB-3A, respectively. Although pumped well recovery data were used in calculating transmissivity, several values were obtained for each borehole. For reasons explained below, these results were not used further in the evaluation.

Difficulty was experienced in analyzing data collected during the test and this led to use of several other procedures to assist with interpretation of the results. The most difficulty was encountered in evaluating data from the pumping wells, although some data from the observation wells were also troublesome.

The major problems were caused by (1) aquifer behavior that deviated from the assumptions which allow use of the Theis and Cooper-Jacob methods, (2) casing storage and borehole configuration effects in the pumped wells, and (3) vertical flow components in the pumped wells.

As mentioned above, the plotted data for all tests deviated from the Theis curve after about a minute of pumping. The deviation showed less drawdown than would be predicted from use of the Theis equation alone. Comparison with other analysis techniques led to use of the Hantush-Jacob Leaky Aquifer method for analysis of test data (Fetter, 1988). The Hantush-Jacob method is similar to the Theis method in that a curve matching technique is used. However, in place of a single curve, a series of curves representing differing leakage factors are compared with the test drawdowns.

A "leaky aquifer" is a semiconfined aquifer that receives water through overlying material. Such situations are common in alluvial valleys where deeper sand and gravel zones are overlain or underlain by finer grained material with a lower hydraulic conductivity. The finer grained material is considered a semiconfining layer or an "aquitard."

Review of the boring logs for the pumped wells at the Navajo site shows finer grained material located opposite or above the screened interval. Though finer grained, this clayey sand or sandy clay material is still permeable though much less so than sands or gravels. When a well is first pumped, water moves to the well through the most permeable sand and gravel zones. A short time later, water from the finer grained material is transmitted to the more permeable zones. To provide easy analysis, it is assumed the leaky zone acts only to transmit water and that no water comes from storage in the less permeable confining zone. However, this assumption is only valid for early test data. In the Hantush-Jacob analysis, deviations from the type-curves occurred about 10 minutes into the test for both observation and pumped wells.

Data matched using the Hantush-Jacob method resulted in transmissivity values of 4,040 and 3,400 gpd/ft for the KWB-1A and KWB-3A observation wells, respectively, and values between 72 and 349 gpd/ft for the pumped wells. Storage coefficient values for the two observation wells were 1.9×10^{-3} and 1.6×10^{-3}, respectively.

"Leaky aquifer" conditions are also the reason that data plotted for analysis using the Jacob-Cooper straight line method showed one or more deviations from a single straight line. Only the early data are representative of actual aquifer characteristics. Later data are usually interpreted to show a "recharge" boundary which actually is the effect of slow drainage of water from fine grained aquifer sediments. However, the straight line method is not valid for early time periods (before u is less than 0.05). Therefore, the method seldom can be used to analyze "leaky aquifers" since the "recharge" effect is usually observed before u becomes less than 0.05.

Casing storage and borehole configuration greatly affect pumped well data analysis. If the pumping rate is low compared to well diameter, much of the early water pumped from the well actually comes from storage in the casing. This was most evident in KWB-2B which was pumped at only 2.1 gallons per minute during the test. Additional effects were caused from the dewatering of the well casing to below the top of the screen. When above the screen, the decline in the artesian water levels reflect only the water volume pumped from the casing. When levels decline below the top of the screen, additional time is required to lower the water since borehole volumes have increased to include the sand pack outside the screen. This will appear to slow drawdown which, in the absence of borehole effects, would indicate the presence of a more permeable zone. The combination of casing storage and borehole configuration makes analysis of pumped well pumping and recovery data difficult. However, in this instance the effect is overshadowed by the large difference between observation and pumped well values of transmissivity as shown in Table 9.

The final difficulty in use of the pumped well data was due to the necessity to correct for vertical flow effects in the unconfined aquifer in the vicinity of pumping well. Though normally an easily applied correction (Driscoll, 1986), it was complicated here by the change in status of the pumped wells from artesian to water table conditions during the test. The change occurred when pumping water levels dropped below the top of the aquifer confining bed, and aquifer dewatering began. Although the correction was applied to the entire data set for each pumped well, its effect on water levels was slight during the first few minutes of pumping before significant drawdown occurred. Therefore, it did not affect the results calculated for this test.

The test results showed significant differences between aquifer characteristics for the observation wells and the pumped wells. Observation well values of transmissivity were about 10 times pumping well values for each paired well. At first the reason for this difference was believed to be poor communication between the pumped and observation well. This would make the pumped well data more representative of actual well data. However, when both sets of transmissivity values are used in average linear velocity calculations (Section 5.4.1), the observation well values are much more representative of the actual aquifer characteristics. Therefore, the cause of this difference is apparently related to the amount of development of the pumping well. Although purged to clear sediment and turbidity, the wells apparently need further development to remove fine grained material outwards of the screen that prevents efficient movement of water into the well bore.

5.4 FATE OF CONTAMINANTS

The fate of the hydrocarbons at the site is dependent on a number of hydrological and soil characteristics. These include the rate and direction of groundwater movement in the near-surface water zone, the lateral continuity of this zone, the vertical permeability and direction of vertical gradient of the lower confining bed, and the degree of retardation to movement provided by the upper clay confining zones.

5.4.1 Flow Direction and Velocity

The direction and average rate of water movement in the near-surface saturated zone was determined from measurements recorded at the monitor wells. Water level observations for March 10, 1992 (shown in Table 2) were plotted to determine the direction and hydraulic gradient (Figure 11). Based on these data, the direction of flow is generally easterly. Direction and gradient range from N 91° E at 0.00456 ft/ft along a line from B-88 easterly to Bolton Road, and from N 116° E at 0.00444 ft/ft along a line east-southeasterly from KWB-6 to B-71. These two major directions of flow coincide with the major concentrations of apparent free product shown in Figure 12.

An average linear velocity for groundwater movement (often called "seepage velocity") was calculated using Darcy's Law with the gradient information shown above, hydraulic conductivity measurements previously presented in Table 9, and an estimated porosity.

Porosities of alluvial material can range from 25% to 50% for sand, and 40% to 70% for clays (Freeze and Cherry, 1979). However, sand-clay mixtures commonly have much reduced porosities due to the finer grained materials occupying the void spaces between the larger particles. With the assumption that the largest portion of fluid movement is through the coarser grained, but poorly sorted, sediments penetrated by the monitor wells, a porosity of 0.2 is estimated for use in the velocity calculation.

The average linear velocity is calculated as:

$$v = Ki/7.5n$$

where:

v = average linear velocity (feet/day),
K = average hydraulic conductivity of the water bearing zone from Table 9 (gallons/day/square foot),
i = the hydraulic gradient (average 0.0045 ft/ft), and
n = 0.2

Using the above parameters, and K calculated using the observation well data, velocities range from 0.53 ft per day to 0.88 ft per day with a mean of 0.70 ft per day. Using pumped well data, velocities range from 0.012 ft per day to 0.072 ft per day with a mean of 0.042 ft per day.

To determine whether pumped or observation well values of hydraulic conductivity should be used to determine flow velocity, the distance from the refinery to the easternmost location of known dissolved phase contamination (KWB-8) was used together with both of the average hydraulic conductivities to calculate a time of travel. For the distance of 3,400 ft these times are 13.3 years for the observation well data and 222 years for the pumped well data. Since the time calculated using pumped well data is unrealistic, use of the observation well data is necessary. Therefore, it will require between 11 and 18 years for water to travel a distance of 3.400 ft.

The differences in results show the importance of using at least one observation well in each aquifer test. Although the pumped wells were developed sufficiently for withdrawing the amount of water necessary to conduct the test, they apparently do not produce water efficiently enough to make the drawdown data reliable for use in aquifer flow calculations. Given the nature of the water-bearing zone, it is likely that fine-grained sediments in the vicinity of the wellbore and sandpack are preventing efficient transfer of water from the saturated zone to the well. Additional well development efforts would be required to make the pumping wells more efficient if water level measurements from these wells are to be used in calculating aquifer parameters.

5.4.2 Continuity of the Near-Surface Saturated Zone

Information from the KWBES monitor well logs and the available drillers logs for area water wells was used to construct a cross-section showing shallow permeable sediments from KWB-4 east to the vicinity of the river. Logs for a KWBES monitor well and a water well are plotted together where a KWBES well is paired with a water well. Although the elevation of a permeable zone may be offset for monitor-water well pair, well logs for all but one well pair well show a near-surface permeable zone eastward from the site.

The exception was the KWB-5/RA-314 pair. The monitor well log shows clayey sand from 15 to 29 ft followed by 2 ft of sandy clay. Saturated silt is found from 31 to 38 ft with clay below. The log for RA-314 indicates that "clay and gyp stratas" exist from 10 to 56 ft. However, as discussed earlier, drillers of deep artesian wells commonly noted only water zones of substantial thickness on their way to the deep saturated portions of the formation.

From the KWB-6/RA-2723 pair eastward, a continuous gravel bed is noted on the drillers logs and a similar permeable zone of clayey sand and gravel was seen during the drilling of the monitor wells. The gravels shown on the water well logs range from 5 to 10 ft in thickness, but at RA-1300, 2,000 ft east of the KWB-3/RA-3353 pair, the permeable zone expands to 20 ft in thickness and is logged as water sands, sand and gravel, and water gravels. The log at this well notes a 12-ft-thick section of clay beneath the permeable zone and above an additional water sand. Sequences of clay and sand continue downward until the wells' total depth of 210 ft is reached.

Eastward, the first permeable rocks would likely be nearer the surface. Where the surface topographic gradient is steeper than the apparent gradient of the subsurface gravels, an easterly thinning of surface sediments occurs as the river flood plain is approached. Although well RA-2749 appears to have a caliche zone within 5 ft of the surface at about the elevation of the permeable gravel zone, caliche commonly includes cemented gravels as well as fine grained materials. In addition, sands are shown at 18 ft, immediately below the caliche zone on this log.

5.4.3 Vertical Permeability and Gradient

Groundwater in this first near-surface saturated zone has the potential to migrate downward to lower water-bearing zones. The monitor wells completed during the first phase of this study were drilled into and bottomed in fine grained sediments of clay, sandy clay, and clayey sand. The thickness, extent and continuity of these fine grained materials is unknown, but drillers logs of wells such as RA-1300 (Figure 14) show alternating zones of sands and clays of varying thickness in the first 100 ft beneath the surface.

Although not measured at this site, hydraulic conductivities for clays commonly range between 0.001 ft/yr and 0.5 ft/yr. Because of the artesian conditions seen in the monitor wells and borings, the clays encountered in the study area are effective in preventing upward fluid migration and should be similarly effective in preventing downward flow where they are thick and continuous. Since the petroleum hydrocarbons are lighter than water, only dissolved phase hydrocarbons have the potential to migrate downward through the clays.

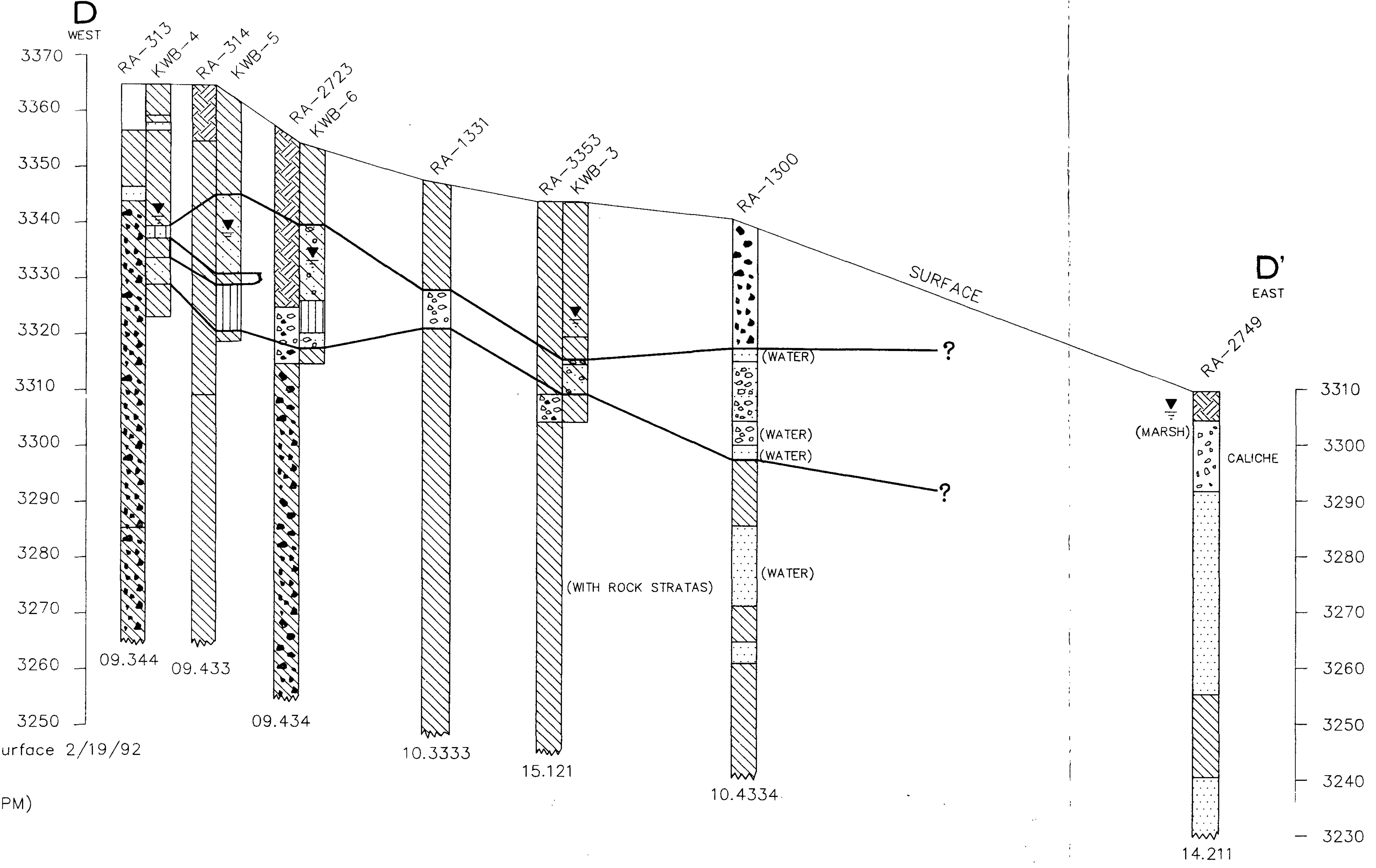
In addition to permeability, downward migration of dissolved phase hydrocarbons is determined by the difference in hydraulic head between the uppermost waterbearing zone and the next lower permeable zone. The difference in hydraulic head over a vertical distance defines the vertical gradient. Water level measurements made in January show a negative (downward) vertical gradient. The difference in elevation between water levels in KWB-4 and artesian well RA-313 is about 14 ft while the difference between KWB-9 and valley fill well RA-3156 was about 20 ft. In both cases water levels in the monitor wells were higher than in the water wells. Therefore, the potential exists for downward water movement between the near-surface saturated zone and lower zones if pathways for movement exist.

Natural pathways allowing fluid migration would be locations where the clay is discontinuous or missing. Other pathways include artificial penetrations such as water wells and oil exploration boreholes. Although both water and oil wells are cased through near-surface zones, problems such as casing corrosion, or heavy pumping (which can cause sand removal next to pipe perforations, followed by surface subsidence around well bores), can allow downward migration of surface fluids. However, no evidence of surface subsidence was seen during the water quality sampling performed on the wells in the area. The impact of irrigation and domestic well pumping on the monitor wells installed to detect water level changes remains to be seen.

5.4.4 Retardation of Hydrocarbons

In addition to area geology and the hydrologic factors of permeability and gradient that determine the fate of the hydrocarbons, the natural characteristics of the upper clay confining bed act to capture the free product and retard its eastward movement. The extent to which this has occurred, and will continue to retard movement of hydrocarbon, was not modeled during this first phase of the study. However, staining was observed to occur for several feet in clays above the zone where water and free product was first encountered. This indicates that hydrocarbons

Figure 14. Facility cross-section D-D' of uppermost permeable zone.



EXPLANATION

- ▼ Potentiometric Surface 2/19/92
- 09.344 SEO Location (T17S, R26E, NMPM)
- ▨ CLAY
- GRAVEL
- GYPSUM ROCK
- SOIL
- SAND
- SILTY SAND
- CLAYEY SAND
- INORGANIC SILT

1200 0 1200 FEET

HORIZONTAL SCALE

KWBES

Facility cross-section D-D' of uppermost permeable zone.

prepared for:

Navajo

PROJECT: 622092001-237(UPPERZON)
LOCATION: ARTESIA, NEW MEXICO
APPR: DATE: 5/20/92
DRAWN BY: SSA SCALE: AS SHOWN
DATE: 5/20/92 FIGURE: 14

have migrated a considerable distance upwards under both capillary forces and pressure of the confined water. Therefore, clays in the confining bed, as well as those in the water zone itself, act to retard both free product and dissolved phase hydrocarbon movement to less than the average linear velocity calculated in Section 5.4.1 above.

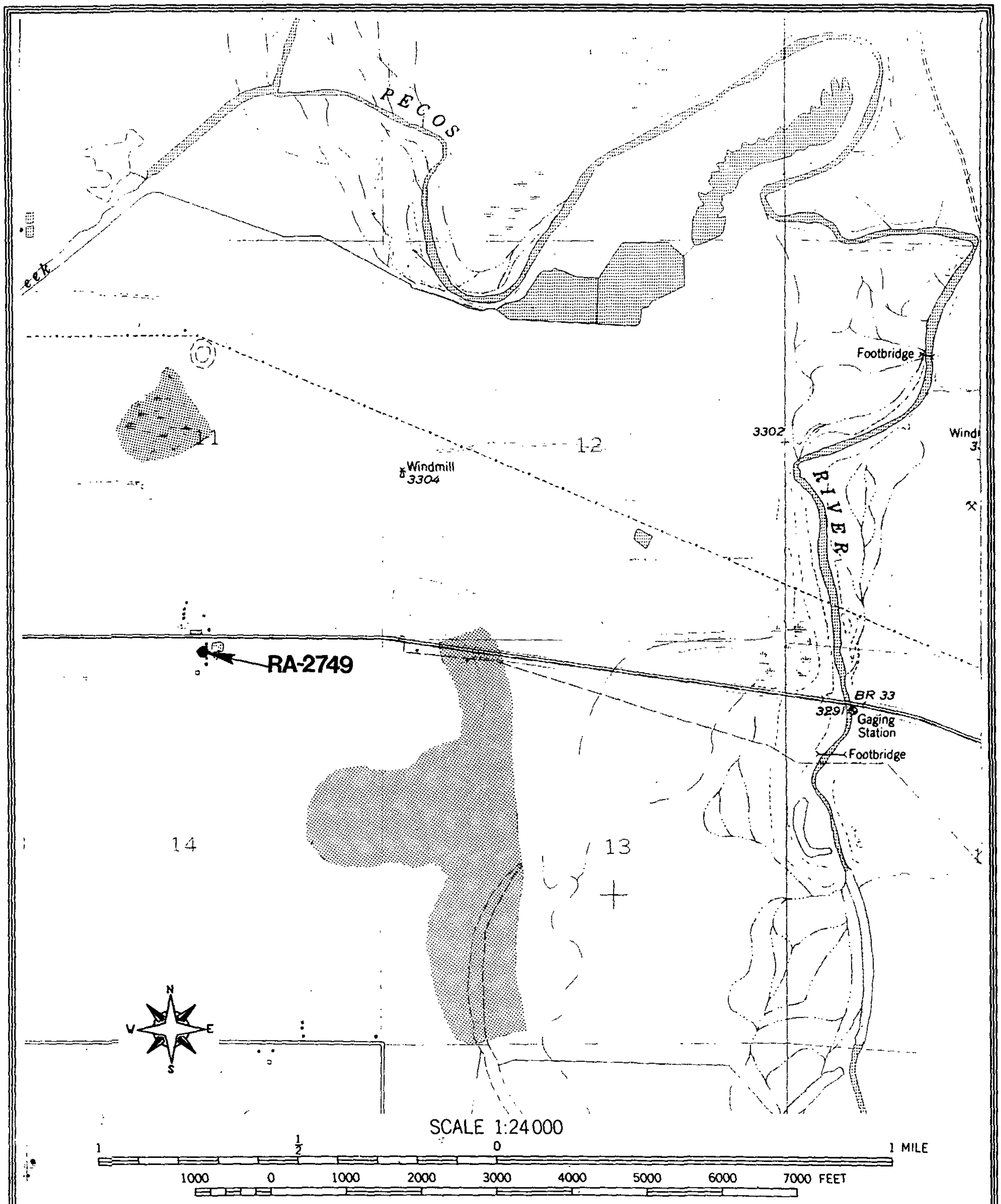
5.4.5 Possible Discharge Locations

Although there is the potential for downward vertical migration, either where clays are absent or along the outside of wellbores, the information available to date indicates that only eastward lateral movement of contaminates is occurring. As mentioned in Section 5.4.2, the surface sediments above the permeable zone thin to the east. From the refinery eastward toward RA-2749, the topographic elevation drops at a gradient of 25 to 30 ft per mile. This allows postulation that some water from the near-surface saturated zone may discharge at the surface prior to reaching the area of the river channel. Lending support to the hypothesis of some surface discharge is the marshy area located in the center of Section 11, one-half mile north of RA-2749 (Figure 15). The elevation of the marsh is about 10 ft above the elevation of the Pecos River channel in this location. In the area of the marsh, there is a noticeable drop in surface elevation from west to east, and east of the marsh the surface gradient markedly flattens with less than an 8 ft change in elevation over the 1.5-mile distance on the flood plain east through Section 12 to the river channel. Similar marshes and some surface water ponds are seen along the west side of the river south of Highway 82 to the area of Spring Lake (T18S, R26E, NE/4 NE/4 Section 3), a distance of about 4 miles.

Some of the water in these marshes no doubt originates from the river. This occurs via upstream infiltration of river water into the alluvial fill followed by movement through the fill for later downstream discharge. However some marshes and ponds appear to be at higher elevations than the river alluvium and must have some other supply of water. The likely source is discharge from the near-surface saturated zone plus any surface return flow of irrigation water. Discharge from this zone not intersecting the surface moves into, and commingles with, the saturated sediments of the Lakewood terrace deposits which were previously described.

If groundwater flow direction does not change between the east end of the study area and the river, the likely areas of discharge are to the river alluvium in the SE/4 NE/4 of Section 14 and the W 1/2 of Section 13. These areas are just east of the location where the slope of the surface sediments changes, indicating the contact between the Orchard Park and Lakewood terrace deposits. East of the contact, river alluvial sediments are exposed at the surface and caliche is generally absent. While topographic maps and Soil Conservation Service maps show no direct

Figure 15. Likely areas of groundwater discharge.



KWBES

Likely areas of groundwater discharge.

prepared for:

Navajo

PROJECT: 622092001-237
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 5/21/92
DRAWN BY: SSA
SCALE: AS SHOWN
DATE: 5/30/92
FIGURE: 15

evidence of a discharge at the surface at this location, depth to groundwater is 10 ft or less based on topographic map examination and work done by previous consultants for Navajo Refinery.

The average linear velocity determined in Section 5.4.1 could be used to calculate the estimated time for groundwater to travel to this possible zone of discharge. However, this number should not be used for calculating free or dissolved phase hydrocarbon movement because of the retardation effects described above and because the hydraulic gradient and/or hydraulic conductivity may vary over the approximately 1.5-mile distance between the east end of the study area and the postulated discharge location.

Groundwater in the possible area of discharge, including the marsh in Section 11, was not investigated during this first phase study, but water quality information is available for the adjoining sediments and the river. Previous observations by consultants and by regulators for the NM Oil Conservation Division have documented that the background quality of the water within several feet of the surface in flood plain sediments near the river is in excess of 5,000 mg/L TDS and commonly approaches and even exceeds 10,000 mg/L TDS. The river itself has been documented by the U.S. Geological Survey as exceeding 10,000 mg/L TDS during periods of low flow (Geoscience Consultants, 1987).

Although New Mexico groundwater with total dissolved solids of 10,000 mg/L or less must be protected from contamination in excess of the state groundwater standards, water in the near-surface saturated zone and in the shallow river alluvial sediments is not currently used or expected to be used for drinking water. Therefore, while protection for these areas is necessary under state regulations, emphasis must be on preventing contamination of currently used drinking water.

SECTION 6.0

6.0 SUMMARY AND CONCLUSIONS

The first phase of this investigation verified the free and dissolved phase hydrocarbon in the study area and approximated the current extent of contamination. The study documented the locations and sampled the water wells in the study area that might be at risk from the hydrocarbon. The results of the study found that two wells located in the plume of contamination that are used for drinking water do not exhibit detectable levels of contamination. Finally, the study established the hydrologic characteristics necessary to provide information on groundwater movement and possible discharge locations for the near-surface saturated water zone. The fate of contaminants in this zone is dependent on rate and direction of travel, continuity of sediments in the zone, vertical permeabilities, and degree of retardation of the pollutants.

Specifically, the following conclusions result from the investigations conducted during the study:

1. The presence of free product with characteristics similar to weathered gasoline was verified for a significant area east of the refinery including a small area east of Bolton Road.
2. The monitor well and boring program determined the extent and apparent product thickness of the free product over most of the study area. The areal extent of the apparent free product is approximately 170 acres. A maximum apparent free product thickness of about 3.3 ft was found in KWB-6, and about 4.5 ft was found in boreholes B-78 and B-87 located approximately 1,300 ft north of Highway 82. The zone of free product continues eastward to a location about 200 ft east of Bolton Road.
3. A second finger of the plume appears located east-southeast from KWB-6 to the vicinity of borehole B-71 south of Highway 82. Maximum product thickness of 2 to 3 ft was found in boreholes in this area.
4. Of the six monitor wells installed adjacent to the existing water wells, free product was verified in two monitor wells, and two other monitor wells had greatly elevated levels of dissolved phase hydrocarbon (BTEX). In one monitor well, the water level rose above the level of the screen, precluding direct determination of free product.
5. Of the four water wells located inside the plume of free product or dissolved phase hydrocarbon, wells RA-2723 and RA-4798 (adjacent to KWB-6 and KWB-8) are used for domestic purposes, including as a drinking water supply. No BTEX above acceptable laboratory detection limits was detected in either of these wells.
6. Low levels of dissolved phase hydrocarbons were detected in four water wells sampled during the study. Hydrocarbons in one of two irrigation wells were characteristic of the pump oil used as a lubricant for the downhole equipment. Hydrocarbons in a second irrigation well located within the plume detected dissolved phase hydrocarbons (including benzene) at levels below those established by the NM Water Quality Control Commission. Toluene at levels slightly above the detection limit was found in two domestic wells, one used for drinking, outside the plume area. However, its presence was not confirmed in a follow-up, or duplicate sample.

7. One water well (RA-4196) was found to contain free oil at the water surface. Although not sampled directly, the characteristics of the oil (color and odor) are similar to pump lubricating oil used in an adjacent well (RA-307) and found stored in a container next to that well. When sampled at a later date after pumping, no dissolved phase hydrocarbon was detected.

8. Some wells completed in the deeper aquifers (both artesian and valley fill) may be contaminated with oil from leakage of lubricating oil from turbine pumps used in the deep wells. If the pump setting and drawdown are below the bottom of the unperforated casing or if casing leaks are present, the lubricating oil can migrate into the aquifer during nonpumping periods.

9. An examination of the published hydrogeologic information does not support the contention by an earlier study that the refinery is located on a surface outcrop of the Seven Rivers formation. Although this geologic formation may exist at depth beneath the refinery, there is ample hydrogeologic information, including reports and water well logs, to support the conclusion that the refinery is located on an unconsolidated terrace deposit overlying the valley fill deposits of the Pecos River Valley.

10. In the vicinity of the refinery, a near-surface, water saturated zone from 3 to 18 ft in thickness was found at depths from 17 to 31 ft. The lithology of this zone is predominantly clayey sand with lenses of small gravels. The zone exhibits artesian properties with water levels in the monitor wells rising 0.1 ft to 10.2 ft from levels where first encountered.

11. The hydrogeologic characteristics of the first saturated zone, as determined by pumping tests, showed hydraulic conductivities (K) ranging from 175 to 293 gallons/day/square foot. This is considered to be in the range of hydraulic conductivities for silty sand.

12. The average hydraulic gradient was found to be 0.0045 foot/foot (24 ft/mile) as determined by water level elevations. The direction of groundwater movement at locations about 1,300 ft north of Highway 82 is N 91° E (easterly), while movement in the vicinity of KWB-6 is N 116° E (east-southeasterly). The hydraulic gradient, together with the hydraulic conductivity and a porosity of 0.2, calculates to an average linear velocity ("seepage velocity") ranging between 0.53 and 0.88 ft per day.

13. The source of water in the near-surface saturated zone may be recharge from Eagle Creek west of the refinery, leakage from the refinery freshwater fire water ponds, or downward seepage of unused irrigation water where not constrained by low vertical permeability sediments beneath the soil zone.

14. The near-surface saturated zone is not used as a source of drinking or irrigation water. Currently operating wells that are located in, or adjacent to, the plume area are completed at depths greater than 230 ft except for one well (RA-3156) on which no information is available.

15. All monitor wells were bottomed in fine grained sediments of clay, sandy clay, and clayey sand. The two wells with measurable free product are completed in clay and sandy clay sediment.

16. In addition to horizontal movement, differences in potentiometric levels between water in the first saturated zone and water levels in wells in both the artesian aquifer and the valley fill show the potential for downward movement of water. However, since vertical permeabilities of confining zones are likely quite small, the major threat from water level differences is downward movement alongside water well casings or movement into a casing in the event of a corrosion leak.

17. Movement of free phase hydrocarbon into the overlying clay confining bed by capillary and artesian pressures, and dissolved phase hydrocarbon contact with clays in the saturated zone, will cause some retardation of the hydrocarbons. Because of this, time-of-travel calculations using the average linear or "seepage" velocity would overestimate the velocity of movement and underestimate the time necessary for contaminants to reach the postulated discharge area.

18. Based on examination of the monitor well logs and drillers logs of the water wells, it appears that the near-surface saturated water zone continues eastward to the vicinity of the river where it discharges to the surface in marshes, or commingles with water present at shallow depths in the alluvial sediments.

19. Agricultural activity is unlikely to be affected by the presence of free product. Crops and residential vegetation are irrigated from the surface and, because of the thick, heavy clay layer beneath the upper soil zone, do not penetrate deeply into the subsurface. An exception are the pecan trees which have a deep tap root for stability. Since roots can not grow in an absence of oxygen, there may be a potential impact on large mature trees of substantial height. The potential impact would be limited to rendering the trees less stable in severe winds, and would not affect their growth.

SECTION 7.0

7.0 RECOMMENDATIONS FOR IMMEDIATE AND LONG-TERM ACTIONS

The results of the study lead to the formulation of recommendations for immediate and longer term actions to be taken in the area of contamination. Immediate actions are those necessary to protect the health of the residents that may be affected by the hydrocarbons and to begin physical efforts to slow plume migration by product capture. Long-term actions include additional investigation efforts, groundwater modeling of the contaminant movement, and design of product recovery systems for optimum placement of wells.

7.1 RECOMMENDATIONS FOR IMMEDIATE ACTION

Hydrocarbon free product was found at, or in the vicinity of, two wells used for drinking water, and at wells used for irrigation or other nondrinking water use. Although no contamination of drinking water was detected, the following immediate measures are recommended and considered necessary to provide protection to the health of the residents and their property.

1. The drinking water used by persons at the two farm residences should be monitored for dissolved phase hydrocarbons (BTEX) no less than once every two weeks. Monitoring should be by a method capable of detecting contamination. Testing for dissolved phase hydrocarbon should be performed once each month. Connection with an alternate water supply for drinking and domestic uses would alleviate the necessity for frequent testing.
2. Nondrinking water wells used for irrigation or other uses and located inside the plume area should be tested for contamination monthly during the growing season. Testing should also include the Gurley well where toluene was detected in the initial sampling, but not verified in a second sample.
3. Product recovery should be immediately initiated at KWB-4, KWB-6 and in the vicinity of borehole B-91. New, 6-inch recovery wells will be necessary at the latter two locations. Before a decision is made on the type of equipment to be installed for recovery efforts, the wells, including KWB-4, should be bailed free of product and recovery monitored to provide an indication of the type of pump system most efficient at product recovery.
4. Water levels in the monitor wells should be measured monthly to determine whether the pumping of nearby irrigation or domestic wells has an effect on the monitor wells.

7.2 RECOMMENDATIONS FOR LONG-TERM ACTION

Long-term recommendations for action are suggested to provide information for optimum design of product recovery systems and to better determine the fate of the nonrecoverable hydrocarbons.

1. An additional 4-inch monitoring well should be installed 800 ft north of the KWB-3, KWB-3A pair to provide information on possible hydrocarbon movement at the east edge of the pecan grove. Additional downgradient wells should be installed if extensive contamination is present at this location.

2. An additional monitor well should be installed near the location of B-94 to provide information on possible hydrocarbon movement of the southeast finger of the plume.

3. At least three monitor wells should be installed to determine extent and thickness of the lower confining layer beneath the near-surface saturated zone, and to allow sampling and evaluation of the hydrologic and water quality characteristics of the next lower saturated zone. To avoid creating an avenue for possible downward migration of contaminants, deeper monitor wells should be drilled outside the area of the current free-product plume.

4. Systems for hydrocarbon plume control and product recovery from groundwater commonly include one or more of the following types of installations: recovery wells, recovery trenches, and hydraulic barriers. Recovery wells and trenches can either be active with pumps for water drawdown or passive with only oil skimmer equipment installed. Trenches are most effective where the plume exists along a broad front and where the water potentiometric surface does not vary in elevation in the area of the trench.

   Particular emphasis should be given to location of recovery systems near the existing water wells, east of Bolton Road, and south Highway 82 near B-71. These areas are at the leading edge of the major portion of the free product, and recovery will prevent movement of free phase hydrocarbons into uncontaminated sediments. If depth to product is not a constraint to installation, a north-south recovery trench should be located at the west side of the pecan orchard, and another installed perpendicular to the direction of flow in the field southeast of B-71. If artesian conditions exist in these locations, passive skimming of floating product from the trenches will be effective, alleviating the need to pump large volumes of water to recover free product.

5. In locations where capture trenches are not installed, groundwater modeling using existing information, and the information from the baildown tests recommended above, should be performed to determine the optimum system or combination of systems to be used. Groundwater modeling was not performed as part of the first phase investigation.

6. Also important, but of lessor priority, is installation of recovery systems in the vicinity of boreholes B-78 and B-85 to B-87. This area had the largest apparent thickness of product, but is located away from water wells and sensitive agriculture lands. Product capture in this location is desirable because the direction of groundwater movement in that area is toward Bolton Road and the pecan grove, and capture in its current location will avoid additional soil and water contamination as the plume moves toward Bolton Road.

7. Additional work to define the existence and extent of hydrocarbon in the area from boreholes B-84 and B-85 west to the refinery should be conducted. Borehole drilling was not performed in March 1992, because cultivation in these fields had already begun. Additional borings should be made in the fall after harvest of crops has been completed. If borings show extensive free product hydrocarbon, additional recovery systems will be necessary in that area.

8. To better define the hydrologic conditions of the near-surface saturated zone, the status of the current monitor wells on the refinery property should be reviewed and an elevation survey made of selected wells to tie into the land survey established for monitor wells KWB-1 to KWB-9. This will allow better definition of the upgradient source of the water through the preparation of an area-wide potentiometric map.

9. Additional field work should be undertaken to better define the groundwater discharge location of the near-surface saturated zone that is postulated to be found at or near the surface in Sections 11, 13 and 14. The work would consist of borings, and possibly temporary monitor wells, between the existing wells and the possible discharge location to establish lithology, water levels, and water quality parameters.

SECTION 8.0

8.0 REFERENCES

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APPENDIX A

APPENDIX A

Water Well Records

Form WR-23 Orig in S.F. STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well C R Sharp
Street and Number
City Artesia State New Mexico
Well was drilled under Permit No. and is located in the
W½ ¼ NW ¼ NE ¼ of Section 9 Twp. 17 Rge. S26
(B) Drilling Contractor Shrock Sply Co License No. WD 5
Street and Number 1101 Mann Ave
City Artesia State New Mexico
Drilling was commenced Jan. 21 1958
Drilling was completed Feb 8 1958

Elevation at top of casing in feet above sea level Total depth of well 1205
State whether well is shallow or artesian Artesian Depth to water upon completion 16 ft

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
10¾	40½	8			730	Drive		
8	28	8			180	ft 20 ft lap		

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

FILED
FEB 14 1958
OFFICE
GROUND WATER SUPERVISOR
ROSWELL, NEW MEXICO

File No. RA-7 Use Irr. Location No. 12.26.9.214

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	"	4		Soil
4	"	80		gyp + Clay
80	"	84		Sand + gravel
84	"	196		Clay + gyp
196	"	226		Clay + rock Shells
226	"	235		Clay
235	"	245		gyp rock
245	"	290		Clay
290	"	305		Rock (Possibly water)
305	"	377		Sand + Clay
377	"	450		Clay
450	"	580		Clay + rock Shells
580	"	585		rock
585	"	630		Gumbo
630	"	640		rock
640	"	685	Red	Sand
685	"	709	Red	gumbo
709	"	720		Rock
720	"	725		Clay
725	"	755		Rock
755	"	760	Red	Sand
760	"	780		rock
780	"	795		Clay
795	"	810		rock
810	"	851	Red	sand
851	"	923		rock
923	"	1095	white	soft rock
1095	"	1105		hard lime
1105	"	1135		water rock
1135	"	1195		Broken lime
1195	"	1205		hard lime

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

J. E. Shrock
Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well Mrs. E. E. Coll
Street and Number
City Artesia State New Mexico
Well was drilled under Permit No. RA-313 and is located in the
SE ¼ SE ¼ SW ¼ of Section 9 Twp. 17 Rge. 26
(B) Drilling Contractor Myron Bruning License No.
Street and Number Box 881
City Artesia State New Mexic o
Drilling was commenced Oct. 1 19 40
Drilling was completed Oct.311 19 40

Elevation at top of casing in feet above sea level Total depth of well 1157
State whether well is shallow or artesian artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
10	40	8			800	drive		
12½	50	8			104			
the above casing is set in one string								

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				
20 sacks of cement used in setting casing					Halliburton

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. RA-313 Use Location No. 17.26.9.344

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	8			soil
8	18			clay
18	21			fine sand
21	80			clay & gyp stratas
80	195			gyp & clay stratas
195	285			gyp
285	320			red sand
320	685			gyp stratas & red sand
685	720			rock
720	800			red bed
800	860			rock stratas & red bed
870	872			red bed
872	895			rock, soft
895	904			rock, hard
	casing set			
904	931			rock
931	972			rock, streaks of artesian water
972	1020			rock
1020	1035			rock, streaks of artesian water
1035	1070			rock
1070	1085			rock, streaks of artesian water
1085	1157			rock, maybe some water

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

--S-- Myron Bruning
Well Driller

S.F

RA-314

(This form to be executed in triplicate)

WELL RECORD

Date of Receipt.. Permit No. ~~RA-2698~~

Name of permittee, A. B. & Britton Coll

Street or P.O., Artesia, City and State New Mex

1. Well location and description: The artesian (shallow or artesian) well is located in sw ¼, se ¼,

..................¼ of Section 9, Township 17, Range 26; Elevation of top of

casing above sea level, ...feet; diameter of hole, 10 inches; total depth, 1196' feet;

depth to water upon completion, 8 feet; drilling was commenced Dec 8, 1952,

and completed Jan 11, 1953; name of drilling contractor Myron Bruning

..................; Address, Box 881, Artesia, N. M., Driller's License No..................

2. Principal Water-bearing Strata:

	Depth in Feet From	To	Thickness	Description of Water-bearing Formation
No. 1	8	28'		
No. 2		artesian water below surface,		
No. 3		between 960' and 1196' are several water stratas.		
No. 4				
No. 5				

3. Casing Record:

Diameter in Inches	Pounds per ft.	Threads per inch	Depth of Casing or Liner Top	Bottom	Feet of Casing	Type of Shoe	Perforations From	To
22x'								
13 3/8"	54	8	221	joined with swedge nipple				
10 ¾	40	8	680					
			901'	lenght of casing set				

casing cemented, bottom to top, outside, 397 sks cement,
by Denton Cementing Co.
10 casing shoe on bottom of 10" pipe.

4. If above construction replaces old well to be abandoned, give location:..................¼, ...¼, ...¼

of Section.................., Township.................., Range..................; name and address of plugging contractor,

....

....

date of plugging.................., 19..........; describe how well was plugged:

....

....

....

FILED
JAN 25 1953
OFFICE
ARTESIAN WELL SUPERVISOR
ROSWELL, NEW MEXICO

5. Log of Well:

Depth in feet From	To	Thickness in feet	Description of Formation
0'	10'		soil
10	56		clay & gyp stratas
	147		gyp & clay
	171		sand & gyp
	216		gyp
	262		sand
	309		gyp rock
	357		red clay
	377		sand
	418		gyp & sand
	444		red bed
	515		gyp rock
	609		gyp & sand
	657		red sand
	749		red bed & gyp rock
	790		rock
	797		sand
	895		sand stratas & streaks of rock
	901		rock, casing set
	985		rock
	989		red sand
	1196		rock

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Licensed Well Driller

Instructions

This form shall be executed, preferably typewritten, in triplicate and filed with the State Engineer's Office at Roswell, New Mexico, within 10 days after drilling has been completed. Data on water-bearing strata and on all formations encountered should be as complete and accurate as possible.

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well N. E. Carrett
Street and Number
City Las Vegas, State New Mexico
Well was drilled under Permit No. and is located in the
NW ¼ NW ¼ ¼ of Section 9 Twp. 17 Rge. 26
(B) Drilling Contractor G. R. Dublin License No.
Street and Number
City State
Drilling was commenced October 10, 19 09
Drilling was completed December 4, 19 09
Original flow: 576 GPM
Elevation at top of casing in feet above sea level [illegible] Total depth of well 1005 ft.
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				1st flow at 880 ft.
2				2nd flow at 940 ft.
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
6″			0	528				

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. (B-35) RA-602 Use Location No. 17.26.9.116

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	5			Sandy loam 3355
5	8			Clay 3352
8	15			Gyp rock 3345
15	21			Gyp rock 3339
21	29			Clay 3331
29	43			Clay 3317
43	51			Gumbo 3309
51	59			Sand 3301
59	89			Gumbo 3271
89	91			Gyp rock 3269
91	109			Gumbo 3251
109	120			Sand 3240
120	156			Gumbo 3204
156	241			Gyp rock 3119
241	246			Sand 3114
246	391			Gumbo 2767
391	408			Hard shell rock
408	471			Soft shale
471	498			Sand
498	589			Sand
589	602			Shale
602	648			Sand
648	661			Hard lime stone
661	791			Soft rock
791	810			Shale
810	828			Gray lime rock
828	833			Gray lime rock
833	852			Soft shale rock
852	875			Hard lime rock
875	1005			Hard lime rock

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

G. R. Dublin
Well Driller

Form WR-23

STATE ENGINEER OFFICE

FIELD ENGR. LOG

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well J. B. Mulcock
Street and Number
City Artesia State New Mexico
Well was drilled under Permit No. RA 602 and is located in the
SW ¼ NW ¼ NW ¼ of Section 19 Twp. 17 Rge 26
(B) Drilling Contractor Brock Drilling Co. License No. WD 5
Street and Number 1101 Mann Ave.
City Artesia State NM
Drilling was commenced Jan 10 1963
Drilling was completed Feb 5 1963

Elevation at top of casing in feet above sea level Total depth of well 1180
State whether well is shallow or artesian Artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
10 3/4	32	8			859	Guide Shoe		
8 5/8		8			162	ft Ser	Liner set at	998 ft.

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				
					Cemented By Hinton

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received STATE ENGINEER OFFICE 1963 FEB 12 AM 8:31

File No. RA-602 Use Irr. Location No. 17.26.9.113

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	"	3		Soil
3	"	15		Gyp.
15	"	80		Clay
80	"	85		Sand
85	"	115		Clay
115	"	450		Gumbo & Clay
450	"	475		Anhydrite
475	"	595		Clay
595	"	642		Sand & Clay
642	"	690		Rock
690	"	720		Layers of Rock & Clay
730	"	760		Rock
760	"	790	Red	Clay
780	"	825		Clay & Layers of Rock
825	"	835		Hard Rock
835	"	852	Red	Sand & Clay
852	"	858	Grey	Lime
858	"	897		Water lost Circulation
897	"	910		Hard rock
910	"	940		Broken rough rock
940	"	1022	Grey	Lime
1022	"	1030		Broken lime
1030	"	1050		Lime
1050	"	1057		Broken lime
1057	"	1082		Lime
1082	"	1090		Broken Lime
1090	"	1103		Lime
1103	"	1115		Water rock
1115	"	1150		Lime
1150	"	1157		Water rock
1159	"	1180		Hard Lime

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

J. E. Shrock
Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well H. G. Southworth

Street and Number

City Artesia State New Mexico

Well was drilled under Permit No. RA-768 and is located in the

SW ¼ NE ¼ SW ¼ of Section 9 Twp. 17 Rge. 26

(B) Drilling Contractor Myron Bruning License No.

Street and Number Box 881

City Artesia State New Mexico

Drilling was commenced September 20 19 43

Drilling was completed November 5 19 43

Elevation at top of casing in feet above sea level Total depth of well 1714

State whether well is shallow or artesian Artesian Depth to water upon completion

Section 2

PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3

RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
13" O.D.	50	8			80	)	set in one string joined	
10 3/4 O.D	40	8			795	Drive)	with sledge nipple.	
						)	total length 875	

Section 4

RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				
		13 3/4	540		pumped in by plug

Section 5

PLUGGING RECORD

Name of Plugging Contractor License No.

Street and Number City State

Tons of Clay used Tons of Roughage used Type of roughage

Plugging method used Date Plugged 19

Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. RA-768 Use Location No. 17.26.9.323

Section 6

LOG OF WELL

Depth in Feet From	Depth in Feet To	Thickness in Feet	Color	Type of Material Encountered
0	5			soil
5	30			sandy gyp & clay
30	80			sand & gyp
80	290			gyp & sandy clay
290	385			gyp & sandy clay
385	720			red sand & gyp stratas
720	755			rock
775	870			red bed & rock stratas
870	875			lime rock
	casing	set		
875	880			water rock
880	1214			limerock several streaks of water rock
total depth of well is 1214 feet.				

25-40 Bower Sand

275

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

--S-- Myron Bruning
Well Driller

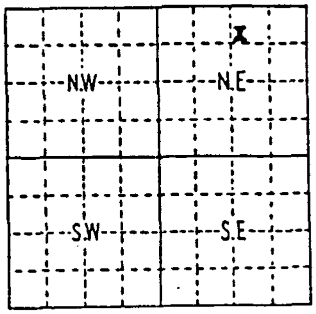
L.B.

WELL RECORD

FILE NO. RA-1440

INSTRUCTIONS: This form should be typewrttten, and filed in the office of the State Engineer, (P.O. Box 1079) Santa Fe, New Mexico, unless the well is situated in the Roswell Artesian Basin, in which case it should be filed in the office of the Artesian Well Supervisor, Roswell, New Mexico. Section 5 should be answered only if an old artesian well has been plugged. All other sections should be answered in full in every case, regardless of whether the well drilled is shallow or artesian in character. This report must be subscribed and sworn to before a Notary Public.

SEC. 1



(Plat of 640 acres)
Locate Well Accurately

Owner of well W. J. Jackson
Street and Number
Post Office Artesia, New Mexico
Well was drilled under Permit No. RA-1440 and
is located in the SW ¼ NW ¼ NE ¼ of Section 9
Township 17S/, Range 26E.
Drilling Contractor Roe L. Newberry and W. P. Black
Street and Number
Post Office

Drilling was commenced February 10 1941 Drilling was completed February 26th 1941

Elevation at top of casing in feet above sea level

State whether well is shallow or artesian Shallow 320'

SEC. 2 PRINCIPAL WATER-BEARING STRATA

No. 1, from to , Thickness in feet , Formation
No. 2, from to , Thickness in feet , Formation
No. 3, from to , Thickness in feet , Formation
No. 4, from to , Thickness in feet , Formation
No. 5, from to , Thickness in feet , Formation

SEC. 3 RECORD OF CASING

DIAMETER IN INCHES	POUNDS PER FOOT	THREADS PER INCH	NAME OF MANUFACTURER	FEET OF CASING	TYPE OF SHOE	PERFORATED		PURPOSE
						FROM	TO	
12½				202				
10				106				
	Pipe slit with torch ,6 slits per circle.							

SEC. 4 RECORD OF MUDDING AND CEMENTING

DIAMETER OF HOLE IN INCHES	NUMBER OF SACKS OF CEMENT	METHODS USED	SPECIFIC GRAVITY OF MUD	TONS OF CLAY USED

SEC. 5 PLUGGING RECORD OF OLD WELL

Well is located in the ¼ ¼ ¼ of Section , Township ,
Range . Name of plugging contractor
Street and Number Post Office
Tons of clay used Tons of roughage used Type of roughage
Was plugging approved by Artesian Well Supervisor

Cement plugs were placed as follows:

No. 1 was placed at feet Number of sacks of cement used
No. 2 was placed at feet Number of sacks of cement used
No. 3 was placed at feet Number of sacks of cement used
No. 4 was placed at feet Number of sacks of cement used
No. 5 was placed at feet Number of sacks of cement used

(OVER)

RA-1440

17.26.9.213
17.26.9.213

SEC. 6

LOG OF WELL

FROM (DEPTH IN	T N IN FEET)	THICKNESS IN FEET	CLASSI N OF FORMATION
35	80	45	Yellow Sandy Clay
80	110	30	Pink Clay
110	130	20	Red Sand - water
130	150	20	Red Sandy Clay
150	170	20	Yellow, sandy clay
170	196	26	Red sand clay, some
196	210	14	Pink Water Sand
210	225	15	White water Sand
225	245	20	Red Sandy Clay
245	260	15	Water Sand
260	285	25	Red Clay
285	320	35	Water Sand, bottomed at red clay.

I, ______________________________ do solemnly swear that, to the best of my knowledge an the foregoing information is a true and correct record of the well for which report is hereby made, insofar as can be determ all available records.

SUBSCRIBED AND SWORN TO BEFORE ME this ________

day of ______________________, A. D., 19 ______

____
Notary Public

My Commission Expires ______________________

Signed W. J. Jackson

Position ______________________

Street and Number ______________________

Post Office ______________________

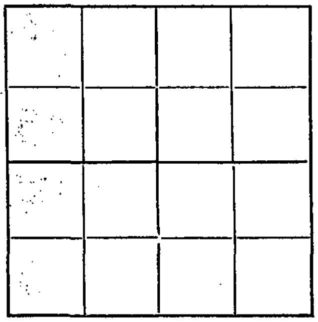
Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1



(Plat of 640 acres)

(A) Owner of well New Mexico Refinery

Street and Number % John Boyd

City Pina Blanca, State New Mexico

Well was drilled under Permit No. RA-1533 and is located in the Blk 2 East Main Addn. ¼ ¼ ¼ of Section 9 Twp. 17 Rge. 26

(B) Drilling Contractor ______ License No. ______

Street and Number ______

City ______ State ______

Drilling was commenced February 2, 19 37

Drilling was completed February 12, 19 37

Elevation at top of casing in feet above sea level ______ Total depth of well 258 ft.

State whether well is shallow or artesian ______ Depth to water upon completion ______

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
8					246			

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor ______ License No. ______

Street and Number ______ City ______ State ______

Tons of Clay used ______ Tons of Roughage used ______ Type of roughage ______

Plugging method used ______ Date Plugged ______ 19 ______

Plugging approved by:

______
Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received ______

File No. RA-1533 Use ______ Location No. 17.26.9.

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	10			Soil
10	20			Sandy clay (some water)
20	180			Yellow clay
180	238			Sand, gravel and clay (possibly some water)
238	258			Water sand and gravel

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

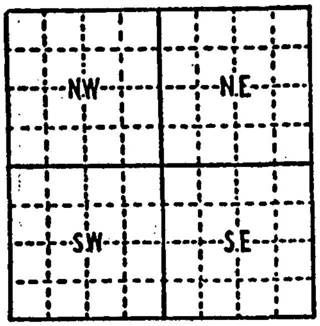
Well Driller

L.B.

WELL RECORD

File No.

INSTRUCTIONS: This form should be typewritten, and filed in the office of the State Engineer, P. O. Box 1079, Santa Fe, New Mexico, or in the office of the Artesian Well Supervisor, Roswell, New Mexico. Section 5 should be answered only if an old artesian well has been plugged. All other sections should be answered in full in every case, regardless of whether the well drilled is shallow or artesian in character. This report must be subscribed and sworn to before a Notary Public.



(Plat of 640 Acres)
Locate Well Accurately

Owner of well Britton Coll
Street and Number Route 1 Box 30
Post Office Artesia, New Mexico
Well was drilled under Permit No. RA 2698 and
is located in the SE ¼ SE ¼ NE ¼ of Section 9
Township 17 S., Range 26 E.
Drilling Contractor Blount & Coll
Street and Number Route 1 Box 30
Post Office Artesia, New Mexico

Drilling was commenced July 28, 1951 Drilling was completed July 31, 1951
Elevation at top of casing in feet above sea level
State whether well is shallow or artesian Shallow, Stock well
Total depth of well 140 feet. Water level upon completion of well 10 feet below land surface.

Sec. 2 PRINCIPAL WATER-BEARING STRATA

No. 1, from 18 to 30, Thickness in feet 12, Formation Gyp
No. 2, from 50 to 80, Thickness in feet 30, Formation Clay & Gravel
No. 3, from 130 to 140, Thickness in feet 10, Formation Gravel
No. 4, from to, Thickness in feet, Formation
No. 5, from to, Thickness in feet, Formation

Sec. 3 RECORD OF CASING

Diameter in Inches	Pounds per Foot	Threads per Inch	Name of Manufacturer	Feet of Casing	Type of Shoe	Perforated		Purpose
						From	To	
8				40				Shut off surface water.
7				23				Meet domestic well requirements.

Sec. 4 RECORD OF MUDDING AND CEMENTING

Diameter of Hole in Inches	Number of Sacks of Cement	Methods Used	Specific Gravity of Mud	Tons of Clay Used

Sec. 5 PLUGGING RECORD OF OLD WELL

Well is located in the ¼ ¼ ¼ of Section, Township,
Range Name of plugging contractor
Street and Number Post Office
Tons of clay used Tons of roughage used Type of roughage
Was plugging approved by Artesian Well Supervisor?

Cement plugs were placed as follows:

No. 1 was placed at feet. Number of sacks of cement used
No. 2 was placed at feet. Number of sacks of cement used
No. 3 was placed at feet. Number of sacks of cement used
No. 4 was placed at feet. Number of sacks of cement used
No. 5 was placed at feet. Number of sacks of cement used

FILED
DEC 12 1951
OFFICE
ARTESIAN WELL SUPERVISOR
ROSWELL, NEW MEXICO

(over)

RA-2698

17 26 9 244

Sec. 6

LOG OF WELL

FROM (Depth in Feet)	TO (Depth in Feet)	THICKNESS IN FEET	CLASSIFICATION OF FORMATION
0	18	18	Topsoil & Clay
18	30	12	Gyp
30	50	20	Clay
50	80	30	Gravel & Clay
80	130	50	Sand rock
130	140	10	Sand & Gravel

I, ..., do solemnly swear that, to the best of my knowledge and belief, the foregoing information is a true and correct record of the well for which report is hereby made, insofar as can be determined from all available records.

SUBSCRIBED AND SWORN TO BEFORE ME this

..................day of.., A.D., 19.......

..
Notary Public

My Commission Expires..

Signed..

Position..

Street and Number...

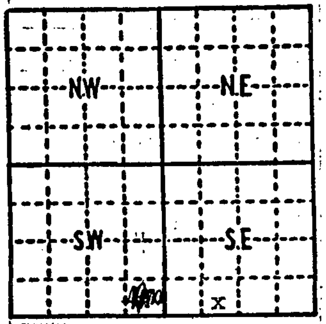
Post Office...

4.B

WELL RECORD

File No.

INSTRUCTIONS: This form should be typewritten, and filed in the office of the State Engineer, P. O. Box 1079, Santa Fe, New Mexico, or in the office of the Artesian Well Supervisor, Roswell, New Mexico. Section 5 should be answered only if an old artesian well has been plugged. All other sections should be answered in full in every case, regardless of whether the well drilled is shallow or artesian in character. This report must be subscribed and sworn to before a Notary Public.



(Plat of 640 Acres)
Locate Well Accurately

Owner of well Britton Coll

Street and Number Rt. 1 Box 30

Post Office Artesia New Mexico

Well was drilled under Permit No. RA-2723 and

is located in the SE ¼ SW ¼ SE ¼ of Section 9

Township 17 South, Range 26 EASt

Drilling Contractor Blount & Coll

Street and Number Rt. 1 Box 30

Post Office Artesia New Mexico

Drilling was commenced July 9, 1951 Drilling was completed July 23 1951, 19

Elevation at top of casing in feet above sea level

State whether well is shallow or artesian Shallow, Domestic

Total depth of well 318 feet. Water level upon completion of well 40 feet below land surface.

Sec. 2 PRINCIPAL WATER-BEARING STRATA

No. 1, from 240 to 318, Thickness in feet 78, Formation Sand rock

No. 2, from to, Thickness in feet, Formation

No. 3, from to, Thickness in feet, Formation

No. 4, from to, Thickness in feet, Formation

No. 5, from to, Thickness in feet, Formation

Sec. 3 RECORD OF CASING

Diameter in Inches	Pounds per Foot	Threads per Inch	Name of Manufacturer	Feet of Casing	Type of Shoe	Perforated		Purpose
						From	To	
7" OD				240				
5" OD	Perforated			85				Liner

Sec. 4 RECORD OF MUDDING AND CEMENTING

Diameter of Hole in Inches	Number of Sacks of Cement	Methods Used	Specific Gravity of Mud	Tons of Clay Used

Sec. 5 PLUGGING RECORD OF OLD WELL

Well is located in the ¼ ¼ ¼ of Section, Township,

Range Name of plugging contractor

Street and Number Post Office

Tons of clay used Tons of roughage used Type of roughage

Was plugging approved by Artesian Well Supervisor?

Cement plugs were placed as follows:

No. 1 was placed at feet. Number of sacks of cement used

No. 2 was placed at feet. Number of sacks of cement used

No. 3 was placed at feet. Number of sacks of cement used

No. 4 was placed at feet. Number of sacks of cement used

No. 5 was placed at feet. Number of sacks of cement used

(over)

RA-2723

17.26.9.434

Sec. 6

LOG OF WELL

From (Depth in Feet)	To (Depth in Feet)	Thickness in Feet	Classification of Formation
0 - 30			Surface & clay
30 - 40			gravel & gyp
40 - 164			clay & gyp
164 - 200			sand rock
200 - 225			loose sand
225 - 260			shells & clay
260 - 274			clay
274 - 318			sandrock & clay

I, ..., do solemnly swear that, to the best of my knowledge and belief, the foregoing information is a true and correct record of the well for which report is hereby made, insofar as can be determined from all available records.

SUBSCRIBED AND SWORN TO BEFORE ME this 7 day of August, A.D., 1951

Gene Dallas

Notary Public

My Commission Expires 10 Aug. 1952

Signed Britton Call

Position Driller

Street and Number Route 1, Box 30

Post Office Artesia, New Mexico

LG

(This form to be executed in triplicate)

WELL RECORD

Date of Receipt ______ Permit No. RA-3225

Name of permittee, J. C. Coleman

Street or P. O. Rt. 1, Box 307 ; City and State Artesia, New Mexico

1. Well location and description: The Shallow (shallow or artesian) well is located in NE ¼, NW ¼, NW ¼ of Section 9, Township 17S, Range 26E; Elevation of top of casing above sea level, [illegible] feet; diameter of hole, 8 inches; total depth, 100 feet; depth to water upon completion, 25 feet; drilling was commenced May 17, 1954 and completed May 19, 1954; name of drilling contractor Willard Beaty 1102 Merchant ; Address, Artesia, New Mexico ; Driller's License No. WD 62

2. Principal Water-bearing Strata:

	Depth in Feet From	To	Thickness	Description of Water-bearing Formation
No. 1	65	70	5	Sand
No. 2	80	94	14	Sand
No. 3				
No. 4				
No. 5				

3. Casing Record:

Diameter in inches	Pounds per ft.	Threads per inch	Depth of Casing or Liner Top	Bottom	Feet of Casing	Type of Shoe	Perforation From	To
6 ID	17	11			100	None	65	94

4. If above construction replaces old well to be abandoned, give location: ______ ¼, ______ ¼, ______ ¼ of Section ______, Township ______, Range ______; name and address of plugging contractor, ______

Date of plugging ______, 19__; describe how well was plugged: ______

FILED
JUN 28 1954
OFFICE
GROUND WATER SUPERVISOR
ROSWELL, NEW MEXICO

RA-3225

17.26.9.112

5. Log of Well:

Depth in Feet From	To	Thickness in feet	Description of Formation
0	3	3	Top Soil 3357
3	10	7	Cleachie 3350
10	26	16	Red Clay 3334
26	42	16	Yellow Clay 3318
42	50	8	Red Clay 3310
50	65	15	Red Bed 3295
65	70	5	Water Sand 3290
70	80	10	Red Clay 3280
80	94	14	Water Sand 3266
94	100	6	Red Clay 3260

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Willard Beaty
Licensed Well Driller

Instructions

This form shall be executed, preferably typewritten, in triplicate and filed with the State Engineer's Office at Roswell, New Mexico, within 10 days after drilling has been completed. Data on water-bearing strata and on all formations encountered should be as complete and accurate as possible.

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well Cecil C. Standard

Street and Number Box 232

City Loco Hills State New Mexico

Well was drilled under Permit No. RA 3282 and is located in the

NE ¼ [illegible] ¼ [illegible] ¼ of Section 9 Twp 17S Rge 26E

(B) Drilling Contractor Willard Beaty License No. [illegible]-62

Street and Number Box 382 1102 Merchant

City Artesia State New Mexico

Drilling was commenced August 28 19 54

Drilling was completed September 2 19 54

Elevation at top of casing in feet above sea level - Total depth of well 125

State whether well is shallow or artesian Shallow Depth to water upon completion 60

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1	89	92	5	Fine Sand
2	105	123	18	Water Sand & Gravel
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
7 [illegible]	17	11	0	125	125	collar	105	125

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.

Street and Number City State

Tons of Clay used Tons of Roughage used Type of roughage

Plugging method used Date Plugged 19

Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

FILED
AUG 31 1955
OFFICE
GROUND WATER SUPERVISOR
ROSWELL, NEW MEXICO

Date Received

File No. RA-3282 Use [illegible] Location No. 17.26.9.112

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered	
From	To				
0	2	2	Brown	Top Soil	3353
2	12	10	White	Cleachie	3343
12	50	38	Red	Clay	3310
50	60	10	Brown	Sand, Showing of Water	3300
60	80	20	Red	Clay	3280
80	92	12	Brown	Water Sand	3263
92	105	13	Red	Clay	3255
105	123	18	Brown	Water, Sand & Gravel	3237
123	125	2	Red	Clay	3235

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Willard Beaty
Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well Mrs. E. E. Coll
Street and Number
City Artesia, State New Mexico
Well was drilled under Permit No. and is located in the
¼ SW ¼ SE ¼ of Section 9 Twp. 17 Rge. 26
(B) Drilling Contractor Sperry & Brunning License No.
Street and Number
City State
Drilling was commenced March 15, 19 23
Drilling was completed May 15, 19 23
Original flow: 1024 GPM
Elevation at top of casing in feet above sea level Total depth of well 1250 ft.
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
8	32				900			

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. Use Location No. 17.26.9.~~440~~ 9.430?

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	905			Soil, clay, water sand and red sand
905	1000			White lime
1000	1100			Several water stratas
1100	1220			White lime
1220	1225			Water rock
1225	1250			White lime

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Sperry & Brunning
Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well V. L. Gates
Street and Number
City Artesia, State New Mexico
Well was drilled under Permit No. RA-307 and is located in the
SW ¼ SW ¼ ¼ of Section 10 Twp. 17S Rge. 26E
(B) Drilling Contractor Pearson Bros. License No.
Street and Number
City Lake Arthur State
Drilling was commenced 5-15-26 19
Drilling was completed 6-28-26 19

Elevation at top of casing in feet above sea level Total depth of well 1263
State whether well is shallow or artesian artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
12½					452			
10					930			

10 inch comes up about 15 feet in 12½ inch casing no seal.

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. RA-307 Use Location No. 17.26.10.33

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	20			soil and gyp
20	45			gravel
45	55			clay
55	60			rock
60	75			white gumbo
75	94			white gumbo
94	118			white gumbo
118	139			white gumbo
139	159			gumbo
159	177			gumbo
177	197			sand
197	217			sand rock
217	239			sand
239	276			sand
276	295			sand shale
295	314			sandy shale
314	334			sand
334	353			rock
353	373			rock
373	393			gumbo and rock caving
393	411			gumbo
411	432			sand
432	452			rock and sand
452	471			rock and sand
471	491			red clay
491	512			sand
512	531			sand
531	552			gumbo
552	572			gumbo
572	586			clay and typ rock
586	645			sand
645	664			clay
664	685			clay
685	705			sand
705	720			sand
720	740			sand rock
740	759			sand rock
759	779			sand rock
779	799			rock
799	818			sand rock
818	837			hard rock
837	852			rock and clay
852	871			rock
871	891			rock and sand
891	908			clay and sand
908	928			hard rock
928	947			hard rock
947	969			sand 4 or rock 17
969	990			hard rock

177	197			sand
197	217		30?	sand rock
217	239			sand
239	276			sand
276	295			sand shale
295	314			sandy shale
314	334			sand
334	353			rock
353	373			rock
373	393			gumbo and rock caving
393	411			gumbo
411	432			sand
432	452			rock and sand
452	471			rock and sand
471	491			red clay
491	512			sand
512	531			sand
531	552			gumbo
552	572			gumbo
572	586			clay and typ rock
586	645			sand T
645	664			clay
664	685			clay
685	705			F sand
705	720			sand
720	740			sand rock
740	759		A	sand rock
759	779			sand rock
779	799			rock
799	818	R		sand rock
818	837		1	hard rock
837	852			rock and clay
D 852	871			rock
871	891			rock and sand
891	908			clay and sand
908	928			hard rock
928	947			hard rock
947	969			sand 4 or rock 17
969	990			hard rock
990	1010			hard rock
1010	1067			hard rock
1067	1086			rough rock
1086	1106			first flow
1106	1124			rock
1124	1143			limerock
1143	1160			limerock
1160	1184			limerock
1184	1202			limerock rough streaks
1202	1222			limerock rough streaks
1222	1242			limerock rough streaks
1242	1263			limerock rough streaks

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Pearson Brothers
Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well Mrs. M. J. Sullivan
Street and Number
City Carlsbad State New Mexico
Well was drilled under Permit No. RA-397 and is located in the
SW ¼ SW ¼ SE ¼ of Section 10 Twp. 17 Rge. 26
(B) Drilling Contractor Pearson Bros. & Shrock License No. W.D.5
Street and Number
City Lake Arthur State New Mexico
Drilling was commenced January 22 19 54
Drilling was completed February 16 19 54

Elevation at top of casing in feet above sea level Total depth of well 1095
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
13 3/8					198' 8"			
10					607'10"			
8					235' 6"	per liner		

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received February 7, 1955

File No. RA-397 Use Location No. 17.26.10.433

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	10			gravel
10	260			sand & gravel
260	328			clay
328	340			sand
340	380			clay
380	485			gumbo & rock
485	515			sand
515	540			clay
540	560			sand
560	580			soft rock
580	599			clay lost circulation
599	640			gumbo
640	725			sand
725	757			gumbo
757	760			rock
760	780			gumbo
780	785			rock
785	798			gumbo
798	815			rock
815	830			water rock
830	846			rock
846	850			red sand
850	883			rock
883	905			soft rock
905	940			rock
940	965			red sand
965	975			hard rock
975	990			rough rock
990	1000			hard rock
1000	1019			rough rock
1019	1040			hard rock
1040	1095			broken lime water rock

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

--S-- J. E. Shrock
Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(A) Owner of well D.D. Sullivan ~~Dan~~
Street and Number
City State
Well was drilled under Permit No. and is located in the
¼ SW ¼ SE ¼ of Section 10 Twp. 17S Rge. 26E
(B) Drilling Contractor Gesler & Slacumb License No.
Street and Number
City State
Drilling was commenced July 27, 19 09
Drilling was completed 19

(Plat of 640 acres)

ORIGINAL FLOW 900 GPM

Elevation at top of casing in feet above sea level Total depth of well 1007'
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
8			0	783	783			
4			0	244	244			

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. RA-3195, -397 Use Location No. 17.26.10.430

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	10			soil
10	22			gyp rock
22	34			sand
34	44			boulders
44	78			rock
78	120			sand
120	302			shale
302	320			gumbo
320	340			clay
340	420			shale
420	480			rock
480	757			shale
757	764			rock
764	789			rock
789	837			rock
837	856			shale
856	865			water rock
865	891			rock
891	956			shale
956	968			rock
968	988			shale
988	1007			rock

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

NSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the arest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and curately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging cord, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well D. D. Sullivan

Street and Number

City Artesia, State New Mexico

Well was drilled under Permit No. RA-1300 and is located in the

SW ¼ SE ¼ ¼ of Section 10 Twp. 17 Rge. 26

(B) Drilling Contractor R & R Drilling Co. License No.

Street and Number

City State

Drilling was commenced March 24, 19 37

Drilling was completed April 2, 19 37

Elevation at top of casing in feet above sea level Total depth of well 210 ft.

State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1		18'	1st flow	
2		36 to 40	2nd flow	
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.

Street and Number City State

Tons of Clay used Tons of Roughage used Type of roughage

Plugging method used Date Plugged 19

Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. RA-1300 Use Location No. 17.26.10.430

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	23		3217	Gypsum rock
23	25		3215	Water sand
25	36		3204	Sand and gravel
36	40		3250	Gravel (water)
40	43		3297	Water sand
43	48		3272	White clay
48	55		3254	White clay
55	70		3270	Water sand
70	76		3264	White clay
76	80		3210	Sand
80	90		3250	White clay
90	125		3215	White clay
125	132		3205	Sand rock
132	145		3195	White clay
145	150		3190	Sand
150	157		3133	Sand rock
157	175		3165	Water sand
175	195		3145	White clay
195	206		3131	Sand rock
206	210		3130	Water sand

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

R & R Drilling Co.
Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(A) Owner of well V. L. Gates
Street and Number
City Artesia, State New Mexico
Well was drilled under Permit No. RA-1331 and is located in the
SW ¼ SW ¼ SW ¼ of Section 10 Twp. 17 Rge. 26
(B) Drilling Contractor D. N. Gray License No.
Street and Number
City State
Drilling was commenced December 1938
Drilling was completed January 1939

(Plat of 640 acres)

Elevation at top of casing in feet above sea level Total depth of well 278 ft.
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
					278			

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. RA-1331 Use Location No. 17.26.10.333

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	20			Clay
20	27			Gravel
27	178			Clay
178	186			Sand
186	205			Clay
205	222			Sand
222	242			Clay
242	276			Sand
276	278			Clay

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

D. N. Gray
Well Driller

Form WR-23 FIELD F R. LOG

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(A) Owner of well Bruce Harris

Street and Number Box 842

City Artesia State New Mexico

Well was drilled under Permit No. RA-4196 and is located in the SW ¼ SW ¼ SW ¼ of Section 10 Twp. 17-S Rge. 26E

(B) Drilling Contractor Willard Beaty License No. WD-62

Street and Number 1102 Merchant

City Artesia State New Mexico

Drilling was commenced April 26 19 60

Drilling was completed May 12 19 60

(Plat of 640 acres)

Elevation at top of casing in feet above sea level [illegible] Total depth of well 294

State whether well is shallow or artesian Shallow Depth to water upon completion 80

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1	280	292	12	Sand & Gravel
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
7"OD	20	8 Round		294	294	Steel	275	294

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				
		8"			

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.

Street and Number City State

Tons of Clay used Tons of Roughage used Type of roughage

Plugging method used Date Plugged 19

Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

STATE ENGINEER OFFICE
DISTRICT II
ARTESIA, N. MEX.
'60 JUN -8 AM 8 19

File No. RA-4196 Use Dom Location No. 17.26.10.333

4196

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered 3350 ft
From	To			
0	2	2	Brown	Top Soil 3348
2	25	23	Red	Clay 3325
25	30	5	Gray	Gravel 3320
30	40	10	Red	Clay 3310
40	70	30	Red	Sandy Clay 3280
70	140	70	Red	Clay 3210
140	160	20	Brown	Sand 3190
160	200	40	Red	Clay 3150
200	240	40	Brown	Sand 3110
240	250	10	Red	Clay 3100
250	270	20	Brown	Sand 3080
270	280	10	Red	Clay 3070
280	292	12	Brown	Sand & Gravel 3058
292	294	2	Red	Clay 3056

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Well Driller

Form WR-23 **STATE ENGINEER OFFICE**

FIELD ENGR. LOG

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well A. B. Harris
Street and Number Box 842
City Artesia State N.M.
Well was drilled under Permit No. RA 4798 and is located in the
SW ¼ SW ¼ ¼ of Section 10 Twp. 17 Rge 26 N.M.P.M.
(B) Drilling Contractor C. J. Smith License No. WD 28
Street and Number 306 W Chisum
City Artesia State
Drilling was commenced May 23 1963
Drilling was completed " 26 1963

Elevation at top of casing in feet above sea level Total depth of well 850'
State whether well is shallow or artesian domestic purpose Depth to water upon completion 120'

Section 2 **PRINCIPAL WATER-BEARING STRATA**

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				Perforated from 840' to 850'
2				
3				originally drilled for oil well
4				test
5				

Section 3 **RECORD OF CASING**

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
7"								

Section 4 **RECORD OF MUDDING AND CEMENTING**

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 **PLUGGING RECORD**

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received STATE ENGINEER OFFICE 1963 JUN -6 AM 8:21 ✓

File No. RA-4798 Use Dom. Location No. 17.26.10.330

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

A. F. Smith

Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well Western Ventures, Inc. A. B. Harris
Street and Number
City State
Well was drilled under Permit No. RA-3559 and is located in the
¼ SW ¼ SW ¼ of Section 10 Twp. 17S Rge. 26E
(B) Drilling Contractor Donnelly Drlg. Co. License No.
Street and Number Carper Bldg.
City Artesia State New Mexico
Drilling was commenced May 4 1956
Drilling was completed May 19, 1956

Elevation at top of casing in feet above sea level 3346-3354 DF Total depth of well 1839
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1	Not known, drilled w/rotary.			
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
9 5/8	--				965	Guide	water shut-off	
7	20				1839	Guide	Production string	

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				
		12 1/4		700	pump & plug
		8 3/4		250	Pump and plug

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received August 17, 1956

File No. RA-3559 Use OWD Location No. 17S.26E.10.+1330

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	40	40		surface sand & gravel
40	615	575		sand & xxxx clay
615	795	180		lime & anhydrite
795	875	80		stks. anhr. w/lm. & clay
875	995	122		Stringers sand & caly lime & anhydrite
995	1035	40		lime
1035	1123	78		anhydrite w/lm. stks.
1123	1165	42		lime
1165	TD			
1165	1180	lm. w/sdy. lm. stks.		
1180	1320	140		lm. & anhr.
1320	1341	21		lime
1341	1347	6		lime
1347	1363	16		black lm. & sdy. lm. gray lm.
1363	1430	67		lime
1430	1464	34		gray lm. hd. sdy. stks.
1464	1434	20		brown lm.
1484	1513	29		lime
1513	1576	63		brown lm. & sdy. lm.
1576	1618	42		
1618	1681	63		lime & sdy. stks.
1681	1732	51		lime
1732	1783	51		
1753	1838	87	55:104	TD lime
1839				TD

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well Western Ventures, Inc. A. B. Harris No. 1
Street and Number Box 1021
City Santa Fe State New Mexico
Well was drilled under Permit No. RA-3559 and is located in the
¼ SW ¼ SW ¼ of Section 10 Twp. 17S Rge. 26E
(B) Drilling Contractor License No.
Street and Number
City State
Drilling was commenced 19
Drilling was completed 19

Elevation at top of casing in feet above sea level Total depth of well
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor Denton Oil Well Cementing Co. License No.
Street and Number City Artesia State New Mexico
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged August 13 1956
Plugging approved by: HL

James

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	
1	1475	1560	20
2	1325	1300	5
3	1150	1125	5
4	1010	970	8
5	675	625	5

FOR USE OF STATE ENGINEER ONLY

Date Received 8/14/56

File No. RA-3559 Use Oil Location No. 17.26.10.330

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Well Driller

Form WR-23

FIELD ENGR. LOG

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well R. J. Heard
Street and Number Box 416
City Loco Hills State N. Mex
Well was drilled under Permit No. RA 4922 and is located in the
NW ¼ NW ¼ ¼ of Section 10, Twp. 17S Rge. 26E
(B) Drilling Contractor A. F. Smith License No. WD 28
Street and Number Box 1202
City Artesia State N. M.
Drilling was commenced Dec. 1963
Drilling was completed Dec. 1963

Elevation at top of casing in feet above sea level Total depth of well 218'
State whether well is shallow or artesian domestic Depth to water upon completion 25'

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1	25	35	10	sand
2	96	139	43	sand
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
7"					139	None	118	139

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received STATE ENGINEER OFFICE
DISTRICT II
1963 DEC 24 AM 8:26 ✓

File No. RA 4922 Use Dom Location No. 17.26.10.110

Dom - ok.

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	25	25		red Clay
25	35	10		Sand
35	96	61		red Clay
96	139	43		sand
139	218	79		red Clay

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

A. F. Smith
Well Driller

Phone
746 359

Revised June 1972

STATE ENGINEER OFFICE
WELL RECORD

FIELD ENGR. LOG

Section 1. GENERAL INFORMATION

Owner of well Lee Dilbeck Owner's Well No. RA 6550
Street or Post Office Address 210 Centre
City and State Artesia, New Mexico 88210

Well was drilled under Permit No. RA-6550 and is located in the:

a. SW ¼ NE ¼ ~~NE~~ NW ¼ ____ ¼ of Section 10 Township 17S Range 26E N.M.P.M.

b. Tract No. ____ of Map No. ____ of the ____

c. Lot No. ____ of Block No. ____ of the ____
Subdivision, recorded in ____ County.

d. X= ____ feet, Y= ____ feet, N.M. Coordinate System ____ Zone in
the ____ Grant.

(B) Drilling Contractor H & W Enterprises License No. WD675

Address P.O. Box 437 Artesia NM 88210 E. of Artesia 746-4516

Drilling Began 8-1-79 Completed 8-10-79 Type tools Cable Size of hole 7" in.

Elevation of land surface or ____ at well is 3335 ft. Total depth of well 125 ft.

Completed well is ☒ shallow ☐ artesian. Depth to water upon completion of well 50 ft.

Section 2. PRINCIPAL WATER-BEARING STRATA

Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation	Estimated Yield (gallons per minute)
From	To			
95	120	25	Water Sand	10

Section 3. RECORD OF CASING

Diameter (inches)	Pounds per foot	Threads per in.	Depth in Feet		Length (feet)	Type of Shoe	Perforations	
			Top	Bottom			From	To
7"	29 Lb	P/E	1	125	126	P/E	90	120

Section 4. RECORD OF MUDDING AND CEMENTING

Depth in Feet		Hole Diameter	Sacks of Mud	Cubic Feet of Cement	Method of Placement
From	To				

Section 5. PLUGGING RECORD

Plugging Contractor ____
Address ____
Plugging Method ____
Date Well Plugged ____
Plugging approved by:
____
State Engineer Representative

No.	Depth in Feet		Cubic Feet of Cement
	Top	Bottom	
1			
2			
3			
4			

FOR USE OF STATE ENGINEER ONLY

Date Received 8/16/79

Quad ____ FWL ____ FSL ____

File No. RA-6550 Use D-S Location No. 17.26.10.123.23

.70 From E Line
.20 S From N Line

Section 6. LOG OF HOLE

Depth in Feet		Thickness in Feet	Color and Type of Material Encountered
From	To		
0	20	20	Top Soil
20	60	40	Calicher- Clay
60	85	25	Fine Brown Sand
85	95	10	Coarse Sand
95	120	25	Water & Sand
120	125	5	Red Bed TD

Section 7. REMARKS AND ADDITIONAL INFORMATION

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described hole.

Tony Hall
Driller

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the appropriate district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1(a) and Section 5 need be completed.

Revised June 1972

STATE ENGINEER OFFICE
WELL RECORD

[illegible]

Section 1. GENERAL INFORMATION

(A) Owner of well Bob Smith Owner's Well No. RA-7180
Street or Post Office Address C/o Ray Stephens
City and State Box 91 Hagerman, NM

Well was drilled under Permit No. RA-7180 and is located in the:

a. Ne ¼ NW ¼ ____ ¼ ____ ¼ of Section 10 Township 17S Range 26E N.M.P.M.

b. Tract No. ____ of Map No. ____ of the ____

c. Lot No. ____ of Block No. ____ of the ____
Subdivision, recorded in Eddy County.

d. X= ____ feet, Y= ____ feet, N.M. Coordinate System ____ Zone in the ____ Grant.

(B) Drilling Contractor Ray Stephens License No. WD-784

Address Box 91 Hagerman, NM 88232

Drilling Began 8-2-83 Completed 8-10-83 Type tools Rotary Size of hole 10 in.

Elevation of land surface or ____ at well is ____ ft. Total depth of well 220 ft.

Completed well is ☒ shallow ☐ artesian. Depth to water upon completion of well 80 ft.

Section 2. PRINCIPAL WATER-BEARING STRATA

Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation	Estimated Yield (gallons per minute)
From	To			
100	210	110	Fine Sand	20

Section 3. RECORD OF CASING

Diameter (inches)	Pounds per foot	Threads per in.	Depth in Feet		Length (feet)	Type of Shoe	Perforations	
			Top	Bottom			From	To
6 5/8	17	0	0	220	220	None	180	220

Section 4. RECORD OF MUDDING AND CEMENTING

Depth in Feet		Hole Diameter	Sacks of Mud	Cubic Feet of Cement	Method of Placement
From	To				

Section 5. PLUGGING RECORD

Plugging Contractor ____
Address ____
Plugging Method ____
Date Well Plugged ____
Plugging approved by:

____
State Engineer Representative

No.	Depth in Feet		Cubic Feet of Cement
	Top	Bottom	
1			
2			
3			
4			

FOR USE OF STATE ENGINEER ONLY

Date Received August 12, 1983

Quad ____ FWL ____ FSL ____

File No. RA-7180 Use Domestic Location No. 17.26.10.12323
Off SE Corner

Section 6. LOG OF HOLE

Depth in Feet		Thickness in Feet	Color and Type of Material Encountered
From	To		
0	5	5	Top Soil
5	40	35	Coliche
40	65	25	Brown & Blue clay
65	90	25	Fine Sand
90	100	10	Brown clay
100	210	10	Fine Sand
210	220	110	Brown Clay

Section 7. REMARKS AND ADDITIONAL INFORMATION

Set packer at 100 ft.

Mud off top water

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described hole.

Driller

INSTRUCTIONS: This form ... uld be executed in triplicate, preferably typewritten, and submitted ... appropriate district office of the State Engineer. All ... ns, except Section 5, shall be answered as completely and accura ... possible when any well is drilled, repaired or deepened. ... en this form is used as a plugging record, only Section 1(a) and Section ... need be completed.

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well J. M. Vogel
Street and Number
City Artesia, State New Mexico
Well was drilled under Permit No. RA-1183 and is located in the NW ¼ NE ¼ ¼ of Section 15 Twp. 17 Rge. 26
(B) Drilling Contractor Gray Bros. License No.
Street and Number
City State
Drilling was commenced July 30, 19 34
Drilling was completed August 7, 19 34

Elevation at top of casing in feet above sea level Total depth of well 225 ft.
State whether well is shallow or artesian Depth to water upon completion

Section 2

PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3

RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
10					220			

Section 4

RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5

PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. RA-1183 Use Location No. 17.26.15.120

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	18			Gravel
18	20			Sand
20	25			Water gravel
25	30			Red bed
30	90			White clay
90	115			Red clay
115	122			Gyp
122	135			Sandy clay
135	145			Sand rock
145 q	155			Fine sand
155	225			Water gravel

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Gray Bros.
Well Driller

Form WR-23 Orig in S.F. STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well Charles L. Allison
Street and Number
City Roswell. State New Mexico
Well was drilled under Permit No. RA-1227 RAS-5 and is located in the
NW ¼ NW ¼ NW ¼ of Section 15 Twp. 17S. Rge. 26E.
(B) Drilling Contractor E.C & D.N.Gray License No.
Street and Number
City State
Drilling was commenced December 30, 1935 19
Drilling was completed January 13, 1936 19

Elevation at top of casing in feet above sea level Total depth of well 240'
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
10	194							
8	52							

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received October 20, 1958

File No. RA-1227 Use Location No. 17.26.15.111

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	10	10		soil
10	15	5		white clay and water
15	58	43		white clay
58	61	3		shell rock
61	75	14		clay
75	110~~38~~	35		clay and shell rock
110	115	5		shell rock
115	138	23		clay
138	175	37		sandy clay
175	240	65		water sand
				set 194' of 10" casing. Set 52' of 8" perforated casing in bottom.

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Well Driller

WELL RECORD

FILE No. 5-13 RA-1503

INSTRUCTIONS: This form should be typewrttten, and filed in the office of the State Engineer, (P.O. Box 1079) Santa Fe, New Mexico, unless the well is situated in the Roswell Artesian Basin, in which case it should be filed in the office of the Artesian Well Supervisor, Roswell, New Mexico. Section 5 should be answered only if an old artesian well has been plugged. All other sections should be answered in full in every case, regardless of whether the well drilled is shallow or artesian in character. This report must be subscribed and sworn to before a Notary Public.

SEC. 1

NW NE SW SE

(Plat of 640 acres)
Locate Well Accurately

M. C. Parrish Jr.

Owner of well Bee Jackson

Street and Number "

Post Office

Well was drilled under Permit No. RA [illegible] and

is located in the SW ¼ SW ¼ NW ¼ of Section 15

Township 12, Range 26.

Drilling Contractor W. P. Black

Street and Number

Post Office Box 743 Artesia

Drilling was commenced Oct 2 19 44 Drilling was completed Oct 11 19 44

Elevation at top of casing in feet above sea level

State whether well is shallow or artesian Shallow

SEC. 2 PRINCIPAL WATER-BEARING STRATA

No. 1, from 0 to 10, Thickness in feet 10, Formation Surface.

No. 2, from 10 to 15, Thickness in feet 05, Formation Sand - Water

No. 3, from 15 to 73, Thickness in feet 58, Formation Clay

No. 4, from 73 to 83, Thickness in feet 10, Formation Sand - Water

No. 5, from 83 to 95, Thickness in feet 12, Formation Sand

SEC. 3 RECORD OF CASING

DIAMETER IN INCHES	POUNDS PER FOOT	THREADS PER INCH	NAME OF MANUFACTURER	FEET OF CASING	TYPE OF SHOE	PERFORATED FROM	PERFORATED TO	PURPOSE
14		8		180	Welded Collar	1	180	Irrigating
10		8		78	Collar	1	78	Irrigating

SEC. 4 RECORD OF MUDDING AND CEMENTING

DIAMETER OF HOLE IN INCHES	NUMBER OF SACKS OF CEMENT	METHODS USED	SPECIFIC GRAVITY OF MUD	TONS OF CLAY USED

SEC. 5 PLUGGING RECORD OF OLD WELL

Well is located in the ____ ¼ ____ ¼ ____ ¼ of Section ____, Township ____,

Range ____. Name of plugging contractor ____

Street and Number ____ Post Office ____

Tons of clay used ____ Tons of roughage used ____ Type of roughage ____

____ Was plugging approved by Artesian Well Supervisor ____

Cement plugs were placed as follows:

No. 1 was placed at ____ feet Number of sacks of cement used ____

No. 2 was placed at ____ feet Number of sacks of cement used ____

No. 3 was placed at ____ feet Number of sacks of cement used ____

No. 4 was placed at ____ feet Number of sacks of cement used ____

No. 5 was placed at ____ feet Number of sacks of cement used ____

(OVER)

RA-1503

12.26.15.133

SEC. 6

LOG OF WELL

FROM (DEPTH	TO IN FEET)	THICKNESS IN FEET	CLAS ON OF FORMATION
95	125	30	Sand-Clay
125	140	15	Sand
140	180	40	Sand-Gravel
180	190	10	Clay
190	210	20	Sand-Gravel
210	237	27	Sand
237	240	3	Clay

I, W. F. Black do solemnly swear that, to the best of my knowledge and belief, the foregoing information is a true and correct record of the well for which report is hereby made, insofar as can be determined from all available records.

SUBSCRIBED AND SWORN TO BEFORE ME this 2 day of March, A. D., 1945

[illegible] Hudson
Notary Public

My Commission Expires 4/3/48
In + for Eddy County, N.M.

Signed W P Black
Position Driller
Street and Number Box 743
Post Office [illegible], N.M.

L.B.

Form WR-23 STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well W.M. Jackson & D.B Fernandez
Street and Number
City Artesia State New Mexico
Well was drilled under Permit No. RA-2050 & RA-2871 Comb and is located in the
SW ¼ SW ¼ NW ¼ of Section 15 Twp. 17 Rge. 26
(B) Drilling Contractor Shock Drilling Co. License No. WD 5
Street and Number
City Lake Arthur State New Mexico
Drilling was commenced Apr. 7 1955
Drilling was completed Apr. 30 1955

Elevation at top of casing in feet above sea level Total depth of well 1231 ft.
State whether well is shallow or artesian Artesian Depth to water upon completion 42 ft.

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
13 3/8	54	8			207.6	Baker Float		
10 3/4	40½	8			586.1			
8 3/8	32	8			232	Drive Shoe on Per. Liner Pipe to 1012 ft		

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

MAY 4 1955
OFFICE
GROUND WATER SUPERVISOR
ROSWELL, NEW MEXICO

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. RA-2050 + RA-2871 Comb. Use Irrig Location No. 17.26.15.133

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	..	3		Soil
3	..	70		Gyp & Clay
70	..	82		Gravel
82	..	110		Clay & Gravel
110	..	209		Sand & Gravel
209	..	219		Soft Rock
219	..	300		Sand & Clay
300	..	306		Gyp Rock
306	..	380		Clay & rock Shells
380	..	495		Gumbo
495	..	580		Gumbo & rock
580	..	590		Rock
590	..	635		Gumbo & rock shells
635	..	692		Sand
692	..	698		Gumbo
698	..	702		Rock, 968 ft. To 974 ft. Rough Rock
702	..	720		Sand, rock 974 .. .. 992 .. Rock
720	..	740		Sand, 992 .. .. 1016 .. Rough Rock
740	..	775		Hard rock, 1016 .. .. 1030 Water rock
775	..	788		Sand 1030 .. 1035 Hard rock
788	..	820		Rock 1035 .. 1231 Broken lime
820	..	829		Sand
829	..	834		rock
834	..	856		Clay
856	..	865		Rock
865	..	869		Sand
869	..	895		Rock
895	..	915		Rough rock
915	..	923		Sand
923	..	968		Hard rock

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

J. E. Shcock
Well Driller

(This form to be executed in triplicate)

WELL RECORD

Date of Receipt .... Permit No. RA-3353

Name of permittee, Y. D. Joy

Street or P. O. .... City and State Artesia, N. M.

1. Well location and description: The shallow (shallow or artesian) well is located in NW ¼, NE ¼, NW ¼ of Section 15, Township 17S, Range 26E; Elevation of top of casing above sea level, 33-15 feet; diameter of hole, 7"OD inches; total depth, 295 feet; depth to water upon completion, ... feet; drilling was commenced Dec. 14 19 51 and completed Jan. 8 19 52 name of drilling contractor D. E. Gray ....; Address, Artesia, New Mex.; Driller's License No. WD.-19

2. Principal Water-bearing Strata:

	Depth in Feet From	To	Thickness	Description of Water-bearing Formation
No. 1	260	295	35	Sand & Clay streaks
No. 2				
No. 3				
No. 4				
No. 5				

3. Casing Record:

Diameter in Inches	Pounds per ft.	Threads per inch	Depth of Casing or Liner Top	Bottom	Feet of Casing	Type of Shoe	Perforation From	To
8" ~~16212"~~					167'8"			
7"OD					257'9"			
5"ID					62'9"		232 to 295	

4. If above construction replaces old well to be abandoned, give location: .... ¼, ... ¼, ... ¼ of Section ...., Township ...., Range ....; name and address of plugging contractor, ...

date of plugging .... 19....; describe how well was plugged: ....

FILED
DEC 3 1954
OFFICE OF GROUND WATER SUPERVISOR
ROSWELL, NEW MEXICO

RA-3353

RA-3353

17.26.15.121

3353

5. Log of Well:

Depth in feet From	Depth in feet To	Thickness in feet	Description of Formation 3345 Gr
0	35	35	Clay 3310
35	40	5	Rock & Gravel 3305
40	100	60	Clay & Rock streaks 3245
100	120	20	Sand & Gravel 3225
120	125	5	Clay 3220
125	131	6	Sand 3214
131	134	3	Clay 3211
134	155	21	Sand 3190
155	164	9	Clay 3181
164	200	36	Sand 3145
200	208	8	Clay 3137
208	236	28	Sand 3109
236	237	1	Clay 3108
237	258	21	Sand 3087
258	260	2	Clay 3085
260	295	35	Sand & Clay streaks 3050

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

D N Gray
Licensed Well Driller

Instructions

This form shall be executed, preferably typewritten, in triplicate and filed with the State Engineer's Office at Roswell, New Mexico, within 10 days after drilling has been completed. Data on water-bearing strata and on all formations encountered should be as complete and accurate as possible.

Form WR-23

STATE ENGINEER OFFICE

FIELD ENGR. LOG

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well Walter Nugent
Street and Number 305 W Chisum
City Artesia State N.M.
Well was drilled under Permit No. RA-4684 and is located in the
SW ¼ SW ¼ NW ¼ of Section .... Twp. .... Rge. ....
(B) Drilling Contractor A. F. Smith License No. WD-28
Street and Number 306 W Chisum
City Artesia State N.M.
Drilling was commenced Aug 25 1962
Drilling was completed Aug 28 1962

Elevation at top of casing in feet above sea level .... Total depth of well 220'
State whether well is shallow or artesian domestic Depth to water upon completion 50'

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1	25'	30'	5	Sand
2	185'	200'	15	Sand + gravel
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
7"					220'	none	185'	220'

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor .... License No. ....
Street and Number .... City .... State ....
Tons of Clay used .... Tons of Roughage used .... Type of roughage ....
Plugging method used .... Date Plugged .... 19....
Plugging approved by:

....
Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received [illegible]

File No. RA-4689 Use D[illegible] Location No. 12.26.15.133

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	5	5		soil
5	25	20		Clay
25	30	5		sand
30	185'	155		Clay
185'	200	15		sand & gravel
200	220	20		red Clay

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

C. F. Smith
Well Driller

Form WR-23

STATE ENGINEER OFFICE

FIELD ENGR. LOG

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

N/2

(Plat of 640 acres)

(A) Owner of well Benny Mason
Street and Number 205 W Main
City Artesia State N. M.
Well was drilled under Permit No. RA-4765 and is located in the S/2 ¼ SE ¼ NW ¼ of Section 15 Twp. 17S Rge. 26E
(B) Drilling Contractor A. G. Smith License No. WD 28
Street and Number 306 W Chisum
City Artesia State N. M.
Drilling was commenced Feb 14 1963
Drilling was completed " 16 1963

Elevation at top of casing in feet above sea level Total depth of well 185'
State whether well is shallow or artesian domestic Depth to water upon completion 70'

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1	20	50	30	sand
2	150	185	35	sand
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
7"					185'	none	155'	185'

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received ✓

STATE ENGINEER OFFICE
DISTRICT II
1963 FEB 26 AM 8:15

File No. RA-4765 Use Dom. Location No. 17.26.15.140

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	5	5		Soil
5	20	15		Gyp
20	50	30		Sand
50	150	100		Red Clay
150	185	35		Sand

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

A. F. Smith
Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(A) Owner of well E. D. Hillyer
Street and Number
City Artesia State New Mexico
Well was drilled under Permit No. P-3 and is located in the ¼ SW ¼ NW ¼ of Section 15 Twp. 17S Rge. 26E
(B) Drilling Contractor License No.
Street and Number
City State
Drilling was commenced January 27, 19 08
Drilling was completed June 6, 19 08

(Plat of 640 acres)

ORIGINAL FLOW 1076 GPM

Elevation at top of casing in feet above sea level Total depth of well 1285
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
8			0	752	752			
6			0	225	225			

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. P-3 Use Location No. 17.26.15.130

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	20			soil
20	45			clay
45	60			shale
60	70			gumbo
70	80			clay
80	90			gumbo
90	95			sand
95	100			soft rock
100	130			shale
130	150			gumbo
150	155			clay
155	185			shale and sand
180	191			soft rock
191	200			gumbo
200	235			shale
235	265			gumbo
265	290			soft rock
290	305			clay
305	330			gravel and sand
330	346			rock
346	354			gumbo
354	364			shale
364	372			sand
372	384			rock
384	395			sand
395	402			shale
402	412			sand
412	421			rock
421	446			clay and gumbo
446	455			rock
455	464			gravel
464	484			XXXX sand
484	499			rock
499	504			sand
504	544			rock
544	566			gumbo
566	576			rock
576	584			shale
584	601			sand
601	622			soft and hard rock
622	626			fine gravel
626	656			gumbo
656	667			rock
667	687			shale
687	692			hard rock
692	695			hard rock
695	729			shale
729	731			hard rock (set casing)
731	738			hard rock
738	750			shale
750	781			rock, soft and hard
781	798			shale
798	808			soft rock
808	821			shale
821	828			hard rock some water
828	843			shale
843	873			clay and rock (soft)
873	882			soft rock
882	916			shale
916	971			rock, soft and hard
971	1046			hard rock
1046	1050			porous hard rock water
1046	1050			porous hard rock water
1050	1110			lime rock hard
1110	1124			white sand rock
1124	1202			white lime rock (water)
1202	1285			whitelime rock shell every 10 to 12' with wat under each shell.

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Well Driller

(This form is to be executed in triplicate)

WELL RECORD

Date of Receipt .... Permit No. RA_?

Name of permitee, Clyde Dungan

Street or P. O. Box 1324, City and State Artesia, N.M.

1. Well location and description: The Shallow (shallow or artesian) well is located in ~~SW~~ N½ N½ ¼, SW ~~SW~~ ¼, ~~SW~~ NW ¼ of Section 15, Township 17 S, Range 26E; Elevation of top of casing above sea level, ... feet; diameter of hole, 4" inches; total depth, 182 feet; depth to water upon completion, 128 feet; drilling was commenced Nov.28, 1953, and completed Nov.28, 1953; name of drilling contractor A.F.Smith 306 W. Chisum; Address, Artesia, N.M.; Driller's License No. WD_28

2. Principal Water-bearing Strata:

	Depth in Feet From	To	Thickness	Description of Water-bearing Formation
No. 1		No log on well .		
No. 2		Run 182 ft.4" pipe in old well, with collar on bottom of pipe.		
No. 3		Perforated bottom joint and gravel packed casing.		
No. 4				
No. 5				

3. Casing Record:

Diameter in inches	Pounds per ft.	Threads per inch	Depth of Casing or Liner Top	Bottom	Feet of Casing	Type of Shoe	Perforation From	To

4. If above construction replaces old well to be abandoned, give location: ....¼, ...¼, ...¼ of Section ...., Township ...., Range............; name and address of plugging contractor, ...

date of plugging ...., 19......; describe how well was plugged: ....

Copy to S7
1-11-56

[illegible]
NOV 30 1953
GROUND [illegible]

NO LOG

5. Log of Well:

Depth in Feet		Thickness in feet	Description of Formation
From	To		

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

A. F. Smith
Licensed Well Driller

Instructions

This form shall be executed, preferably typewritten, in triplicate and filed with the State Engineer's Office at Roswell, New Mexico, within 10 days after drilling has been completed. Data on water-bearing strata and on all formations encountered should be as complete and accurate as possible.

Form WR-23 **FIELD ENGR. LOG** STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well [illegible]
Street and Number Box 873
City [illegible] State New Mexico
Well was drilled under Permit No. RA 1977 and is located in the
NE ¼ NW ¼ SW ¼ of Section 16 Twp. 12 S Rge. 26 E
(B) Drilling Contractor [illegible] License No. WD-5
Street and Number [illegible]
City [illegible] State New Mexico
Drilling was commenced March 23 1960
Drilling was completed April 12 1960

Elevation at top of casing in feet above sea level Total depth of well 1225 ft
State whether well is shallow or artesian Artesian Depth to water upon completion 98 ft

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
13 3/8	48	8			772	Float		
10 3/4	40	~~8~~	From Surface to	1199		Plain	Set to 819	ft.

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				
					Cemented to top by Halliburton

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received STATE ENGINEER OFFICE 1960 APR 18 AM 8:12

File No. RA-1044 Use Irr. Location No. 12.26.16.311

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	"	5		Soil
5	"	15		Gyp
15	"	30		Boulders
30	"	60		Clay & gyp
60	"	85		Sand & gravel
85	"	120		Clay
120	"	340		Sand & gravel
340	"	360		Hard rock
360	"	600		Clay
600	"	685		Clay & rock
685	"	760		rock
760	"	780	Red	Sand & clay
780	"	790		Rock
790	"	800		Sand & rock layers
800	"	818		Rock
818	"	830		Soft sandy rock
830	"	870	Red	soft sand
870	"	950		Hard lime
950	"	980		Broken lime
980	"	985		Soft lime
985	"	996		Rough rock
996	"	1052		Broken lime
1052	"	1095		Hard lime
1095	"	1105		White rock
1105	"	1140		Hard lime
1140	"	1160		Soft lime
1160	"	1173		Hard lime
1173	"	1220		Soft lime
1230	"	1225		Hard lime

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

J E Shrock
Well Driller

Form WR-23 FIELD ENGR. LOG STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well [illegible]

Street and Number Box 873

City [illegible] State [illegible]

Well was drilled under Permit No. [illegible] and is located in the NW ¼ NW ¼ SW ¼ of Section 16 Twp. 12 Rge. [illegible]

(B) Drilling Contractor [illegible] License No. [illegible]

Street and Number 1101 Main [illegible]

City [illegible] State [illegible]

Drilling was commenced March 23 19[illegible]

Drilling was completed April 12 19[illegible]

Elevation at top of casing in feet above sea level Total depth of well 1325 ft

State whether well is shallow or artesian Artesian Depth to water upon completion [illegible]

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
13 3/8	48	8			743	Float		
10 3/4	40	8	Welded	liner	179 ft	Plain	[illegible]	[illegible] ft.

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				
					Cemented to top [illegible]

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.

Street and Number City State

Tons of Clay used Tons of Roughage used Type of roughage

Plugging method used Date Plugged 19

Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received 1960 APR 18 AM 8:12

File No. RA-1044 Use Irr. Location No. 12.26.16.311

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	"	5		Sand
5	"	15		Gyp
15	"	30		Boulders
30	"	60		Clay & gyp
60	"	85		Sand & gravel
85	"	130		Clay
130	"	340		Sand & gravel
340	"	360		Hard rock
360	"	600		Clay
600	"	685		Clay & rock
685	"	760		Rock
760	"	780	Red	Sand & clay
780	"	790		Rock
790	"	800		Sand & rock layers
800	"	818		Rock
818	"	830		Soft sand & rock
830	"	870	Red	Soft shale
870	"	950		Hard lime
950	"	980		Broken lime
980	"	985		Soft lime
985	"	996		Rough rock
996	"	1052		Broken lime
1052	"	1095		Hard lime
1095	"	1105		Water rock
1105	"	1140		Hard lime
1140	"	1160		Soft lime
1160	"	1173		Hard lime
1173	"	1220		Soft lime
1220	"	1225		Hard lime

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

F. E. Shrock
Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well Albert F. Woods,
Street and Number
City Artesia State New Mexico
Well was drilled under Permit No. and is located in the
¼ NW ¼ NW ¼ of Section 16 Twp. 17S Rge. 26E
(B) Drilling Contractor M.S.Bruning License No.
Street and Number
City State
Drilling was commenced April 15, 1930
Drilling was completed June 1, 1930

Elevation at top of casing in feet above sea level Total depth of well 1233'
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
12½	50		0	1233	1233			

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. RA-1090 Use Location No. 17.26.16.110

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	15			soil
15	30			gyp
15	30			gyp
30	35			sand
35	450			gyp and clay
450	460			gyp rock
460	490			sandy shale and gyp stratas
490	690			sandy sahle and gyp stratas
690	710			rock
710	740			red sand
740	770			rock
770	820			red sand
820	840			rock lime
840	876			shale
876	912			lime rock
912	913			water rock
913	958			lime rock
958	960			water rock
960	996			lime rock
996	1000			water rock
1000	1027			lime rock
1027	1032			water rock
1032	1058			lime rock
1058	1060			water rock
1060	1118			lime rock
1118	1132			water rock
1132	1218			lime rock
1218	1220			water rock
1220	1232			lime rock

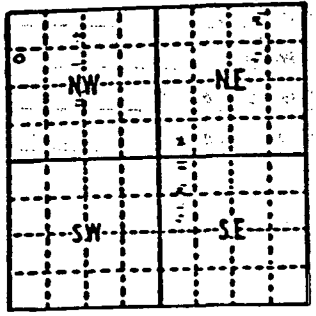
The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Well Driller

WELL RECORD

File No. RA-2568

INSTRUCTIONS: This form should be typewritten, and filed in the office of the State Engineer, P. O. Box 1079, Santa Fe, New Mexico, or in the office of the Artesian Well Supervisor, Roswell, New Mexico. Section 5 should be answered only if an old artesian well has been plugged. All other sections should be answered in full in every case, regardless of whether the well drilled is shallow or artesian in character. This report must be subscribed and sworn to before a Notary Public.



(Plat of 640 Acres)
Locate Well Accurately

Owner of well C. C. Armstrong & Son ~~Armstrong and Armstrong~~
Street and Number P. O. Box 873, Roswell, New Mexico
Post Office Roswell, New Mexico
Well was drilled under Permit No. RA-2568 and
is located in the SW ¼ NW ¼ NE ¼ of Section 16
Township 17S, Range 26E
Drilling Contractor Keyes Drilling Co.
Street and Number 1012 South Fern. Ave.
Post Office Roswell, New Mexico

Drilling was commenced January 21, 1950 Drilling was completed January 26, 1950
Elevation at top of casing in feet above sea level [illegible]
State whether well is shallow or artesian Shallow
Total depth of well 232 feet. Water level upon completion of well 42 feet below land surface.

Sec. 2

PRINCIPAL WATER-BEARING STRATA

No. 1, from 216 to 220, Thickness in feet 4, Formation Water Sand
No. 2, from ______ to ______, Thickness in feet ______, Formation ______
No. 3, from ______ to ______, Thickness in feet ______, Formation ______
No. 4, from ______ to ______, Thickness in feet ______, Formation ______
No. 5, from ______ to ______, Thickness in feet ______, Formation ______

Sec. 3

RECORD OF CASING

Diameter in Inches	Pounds per Foot	Threads per Inch	Name of Manufacturer	Feet of Casing	Type of Shoe	Perforated From	Perforated To	Purpose
7"	24	8	Used	216'	Texas	None		Surface
5 3/16	18	8	used	30'	none	all		Liner

Sec. 4

RECORD OF MUDDING AND CEMENTING

Diameter of Hole in Inches	Number of Sacks of Cement	Methods Used	Specific Gravity of Mud	Tons of Clay Used

Sec. 5

PLUGGING RECORD OF OLD WELL

Well is located in the ______ ¼ ______ ¼ ______ ¼ of Section ______, Township ______
Range ______ Name of plugging contractor ______
Street and Number ______ Post Office ______
Tons of clay used ______ Tons of roughage used ______ Type of roughage ______
______ Was plugging approved by Artesian Well Supervisor? ______

Cement plugs were placed as follows:

No. 1 was placed at ______ feet. Number of sacks of cement used ______
No. 2 was placed at ______ feet. Number of sacks of cement used ______
No. 3 was placed at ______ feet. Number of sacks of cement used ______
No. 4 was placed at ______ feet. Number of sacks of cement used ______
No. 5 was placed at ______ feet. Number of sacks of cement used ______

(over)

RA 2568.

17.26.16.113

Sec. 6

LOG OF WELL

FROM (Depth in Feet)	TO (Depth in Feet)	THICKNESS IN FEET	CLASSIFICATION OF FORMATION
0	4 3376	4	Top Soil
4	18 3362	14	Sandstone
18	40 3340	22	Sandy clay
40	56 3324	16	Sand and clay
56	60 3320	4	Gravel
60	118 3262	58	Sand
118	140 3240	22	Sandy clay
140	148 3232	8	Red clay
148	170 3210	22	Sand and Gravel
170	172 3208	2	Red clay
172	190 3190	18	Conglomerate
190	200 3190	10	Sand and clay
200	216 3164	16	Sandstone
216	220 3160	4	Water sand
220	232 3149	12	Conglomerate

I, Conrad G. Keyes, do solemnly swear that, to the best of my knowledge and belief, the foregoing information is a true and correct record of the well for which report is hereby made, insofar as can be determined from all available records.

SUBSCRIBED AND SWORN TO BEFORE ME this ______ day of ______, A.D., 19__

______ Notary Public

My Commission Expires ______

Signed ______

Position Driller

Street and Number 1012 So. Penn. Ave.

Post Office ______

Form WR-23 STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well S. A. Lanning
Street and Number
City Artesia, State New Mexico
Well was drilled under Permit No. and is located in the
¼ NE ¼ NW ¼ of Section 16 Twp. 17 Rge. 26
(B) Drilling Contractor S. A. Buttler License No.
Street and Number
City State
Drilling was commenced August 19 08
Drilling was completed August 19 08
Original flow: 1114 gpm
Elevation at top of casing in feet above sea level Total depth of well 935 ft.
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				1st flow at 715 ft.
2				2nd flow at 920 ft.
3				3rd flow at 935 ft.
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
6					703			

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. Use Location No. 17.26.16.120

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	10			Soil
10	50			Gyp, dirt and rock
50	60			Sand
60	100			Gumbo
100	120			Sand
120	150			Soft white rock
150	200			Gumbo
200	235			White sand
235	350			Gumbo
350	390			Rock
390	475			Gumbo
475	490			Soft rock
490	550			Gumbo
550	600			Soft red sand rock
600	650			Sand
650	660			Hard rough rock
660	680			Shale
680	700			Red sand
700	750			Gumbo
750	855			Hard rough rock
855	870			Sand red and soft
870	890			Hard and rough
890	920			Hard smooth rock
920	935			Good hard water rock

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

S. A. Buttler
Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well R. L. Raimey ?
Street and Number
City Artesia State N.M.
Well was drilled under Permit No. and is located in the
¼ NE ¼ NW ¼ of Section 16 Twp. 17 Rge. 26
(B) Drilling Contractor S.A. Butler License No.
Street and Number
City State
Drilling was commenced 19
Drilling was completed 19
Well deepened
Elevation at top of casing in feet above sea level Total depth of well 932
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

from driller's log 12-10-62

File No. Use Location No. 17.26.16.120

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
840	860			rough rock
860	900			shale & sand
900	920			hard slick rock
920	932			water rock
				Remarks: Well had several joints of pipe
				lost and I made a new hole from
				840 to 900 feet and set a 5 inch
				liner and drilled a 4 3/4 hole to
				the bottum which is 932 feet deep/

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Well Driller

Form WR-23

STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well S. A. Lanning
Street and Number
City Artesia, State New Mexico
Well was drilled under Permit No. and is located in the
¼ NW ¼ NW ¼ of Section 16 Twp. 17 Rge. 26
(B) Drilling Contractor License No.
Street and Number
City State
Drilling was commenced May 19 17
Drilling was completed June 19 17

Elevation at top of casing in feet above sea level Total depth of well 1182 ft.
State whether well is shallow or artesian Depth to water upon completion

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation
	From	To		
1				1st flow at 1025 ft.
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth		Feet	Type Shoe	Perforations	
			Top	Bottom			From	To
8					724		724	
6					205			

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet		Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
From	To				

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug		No. of Sacks Used
	From	To	

FOR USE OF STATE ENGINEER ONLY

Date Received

File No. Use Location No. 17.26.16.110

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	910			Sand and clay and the usual aluvial formation
720	750			Rock set casine at 724
750	910			Red sand with rock stratas
910	1182			Lime rock

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Well Driller

APPENDIX B

APPENDIX B

Landowner Interviews

Non irrigation wells in study area.

Owner	Formation	Depth, ft	State Engineer Number	Drilled	Miscellaneous	Type of Use	User
G. G. Armstrong (Gary Anderson)	Valley fill	232	RA-2568	1950	Report of hydrocarbon "diesel or gas" in winter 1972. Clear spring 1973	House, drinking, yard	Owner
Bearing Service & Supply (Loy Fletcher)	—	—	—	—	On city water supply-septic tank on property	—	—
Mack Chase	Artesian	850	RA-4798	1963	Converted from oil exploration well	House, drinking, yard	Farm workers
	Valley fill	294	RA-4196	1960		Yard	
Britton Coll (Robert Horner)	Valley fill	318	RA-2723	1951		House, drinking, livestock	Farm workers
	Valley fill	140	RA-2698	1951	Well plugged with debris	Stock well	Unused
Sherrel Gurley	Valley fill	—	RA-3156	—	Well on property prior to purchase in 1964. No log on file with SEO	Yard irrigation	Owner
Truman Joy	Valley fill	295	RA-3353	1951		House, yard	Owner

Notes:

1. Landowner information supplemented by SEO information.
2. Names in parentheses are farm or business managers.

Irrigation wells and crop information in study area.

Owner	Formation	Depth, ft	State Engineer Number	Drilled	Miscellaneous	Crop	Cropping	Federal Programs	Irrigation
G. G. Armstrong (Gary Anderson)	Artesian	1232	RA-1090	1930		Cotton Alfalfa Chile	Early spring to October	Yes	Pipe/ditch
Mack Chase	Artesian	1263	RA-307	1926		Pecan Ryegrass Alfalfa Sheep	Year round	—	Pipe/ditch
	Valley fill	278	RA-1331	1939					
Britton Coll (Robert Horner)	Artesian	1157	RA-313	1940	SEO report of oil in well 12/91, possibly a leaking pump seal	Alfalfa Chile	Early spring to October	—	Pipe/ditch (36 in/acre)
	Artesian	1196	RA-314	1952					
	n/a	n/a	n/a	n/a	Unused, converted from oil exploration use, covered in field				
	Artesian	1250	n/a	1923	No SEO # or exact location information availible. Log on file with SEO				
Truman Joy	Valley fill	240	RA-1227	1936		Alfalfa Cotton	Early spring to October	Yes 4 yrs cotton 4 yrs alfalfa	Pipe/sprinkle 42-48 in/ acre hay

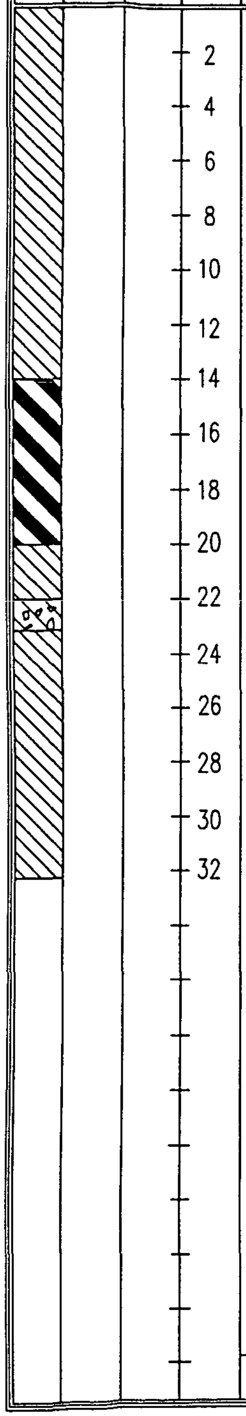
Notes:
1. Landowner information supplemented by SEO information.
2. Names in parentheses are farm or business managers.

APPENDIX C

APPENDIX C

Well Completion Logs

Sym | Samp Loc | PID (ppm) | Depth (Feet)



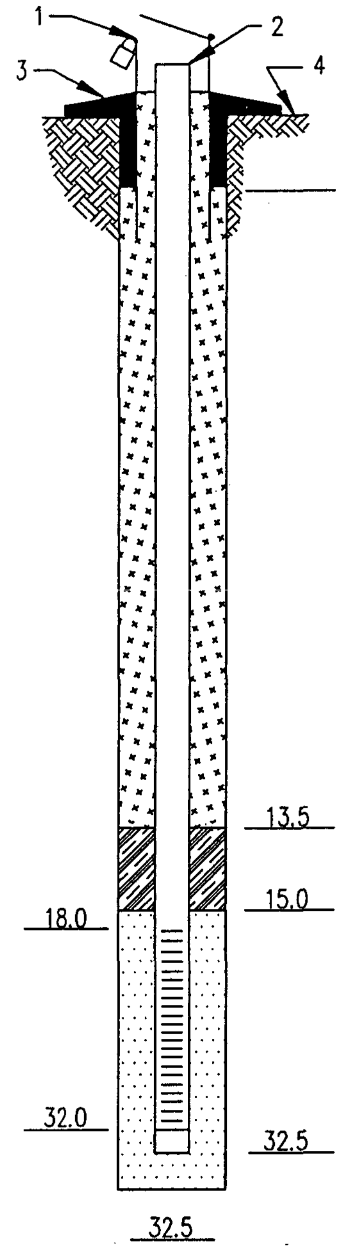
Geologic Description

0-2'	SANDY CLAY, dark brown, with roots.
2-14'	SANDY CLAY, brown, dry to moist, lighter in color with increasing depth, white caliche pebbles showing up at 9-10 feet, occasional pockets of fine white sand.
14-20'	CLAY, reddish brown, moist, some caliche pebbles and sand pockets.
20-22'	SANDY CLAY, brown and white, saturated increasing pebble content.
22-23'	GRAVEL, 1 to 2" rocks, saturated.
23-32.5'	SANDY CLAY, brown and white, moist dry, pebble content decreasing with depth.
	TD = 32.5'

NOTE: 5 foot core barrel recovery system used as sampling technique

ST=Shelby Tube | SS=Split Spoon | C=Cuttings

Monitoring Well ☒
Piezometer



Depths in Feet from Ground Surface (Not to Scale)

Design Specifications

Elevations: 1 3351.07 2 3350.87
(feet MSL) 3 3349.10 4 3348.7
Coordinates: X 5171.71 Y 5193.86
Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐
Casing Diameter: ☒ 2" ☐ 3" ☐ 4" ☐ 6" ☐
Screen Slot: ☐ 0.008 ☒ 0.010 ☐
Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐
Sand Pack: CSSI 16-40
Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐
Grout Type: Portland Weight:
Bore Hole Diameter: 8"
Drill Rig: ☒ Hollow Stem ☐ Rotary ☐
Drilled By: PRECISION ENGINEERING
Logged By: PHILIP CADARETTE
Completion Date: FEBRUARY 11, 1992

Date	D-T-W	MSL	Date	Field pH	Field EC
2/19/92	14.7	3336.4			
3/10/92	14.5	3336.2			

Comments: Concrete with 5% bentonite used to grout from seal to surface.

KWBES

Navajo

KWB1A

Project: 622092001-237 (1A)
Location: ARTESIA, NEW MEXICO

Geologic Description

Sym	Samp Loc	PID (ppm)	Depth (Feet)

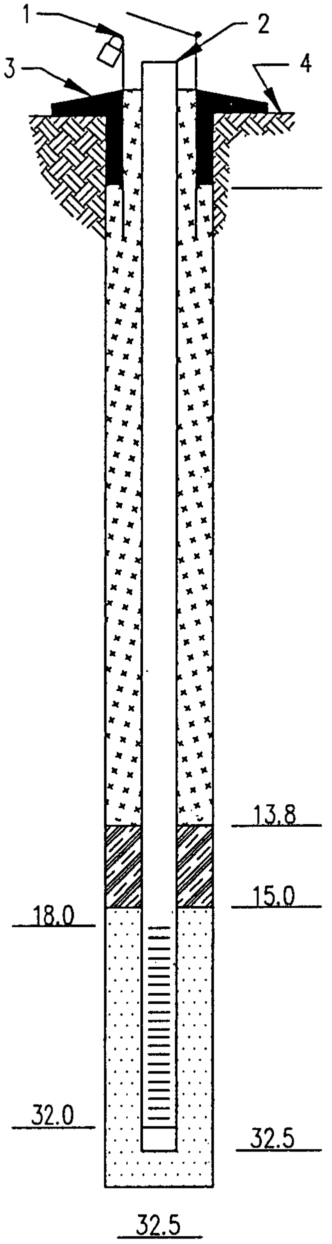
0–2'	SANDY CLAY, dark brown, with roots.
2–14'	SANDY CLAY, brown, dry to moist, lighter in color with increasing depth, white caliche pebbles showing up at 9–10 feet, occasional pockets of fine white sand.
14–20'	CLAY, reddish brown, moist, some caliche pebbles and sand pockets.
20–22'	SANDY CLAY, brown and white, saturated, increasing pebble content.
22–23'	GRAVEL, 1 to 2" rocks, saturated.
23–32.5'	SANDY CLAY, brown and white, moist to dry, pebble content decreasing with depth.

TD = 32.5'

☐ ST=Shelby Tube ☐ SS=Split Spoon ☒ C=Cuttings

Monitoring Well ☒

Piezometer ☐



Depths in Feet from Ground Surface (Not to Scale)

Design Specifications

Elevations: 1 3351.06 2 3350.83
(feet MSL) 3 3349.18 4 3348.8

Coordinates: X 5172.42 Y 5181.92

Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐

Casing Diameter: ☐ 2" ☐ 3" ☒ 4" ☐ 6" ☐

Screen Slot: ☐ 0.008 ☒ 0.010 ☐

Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐

Sand Pack: CSSI 16–40

Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐

Grout Type: Portland Weight:

Bore Hole Diameter: 12"

Drill Rig: ☒ Hollow Stem ☐ Rotary ☐

Drilled By: PRECISION ENGINEERING

Logged By: PHILIP CADARETTE

Completion Date: FEBRUARY 15, 1992

Date	D–T–W	MSL	Date	Field pH	Field EC
2/19/92	14.4	3336.4			
3/10/92	14.5	3336.3			

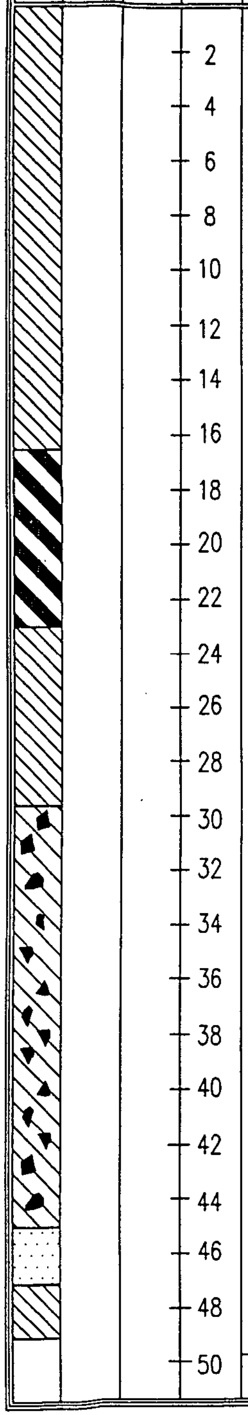
Comments: Concrete with 5% bentonite used to grout from seal to surface.

KWBES

KWB1B

Project: 622092001–237 (1B)
Location: ARTESIA, NEW MEXICO

Sym | Samp Loc | PID (ppm) | Depth (Feet)



Geologic Description

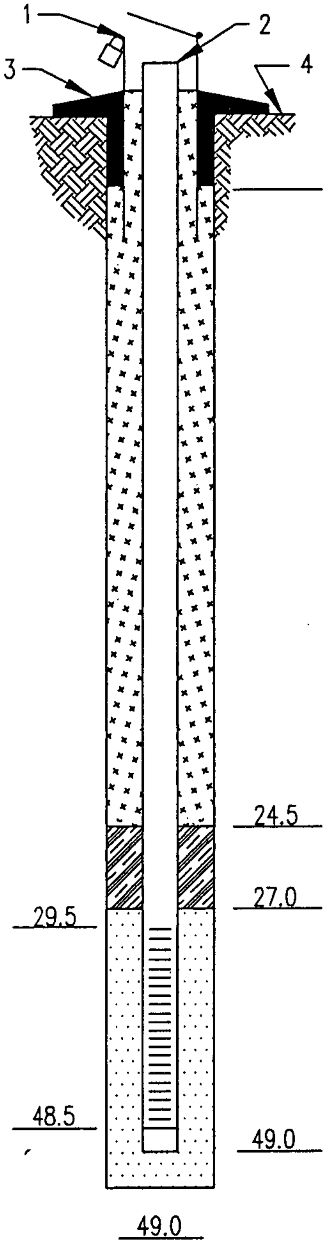
0-16.5'	SANDY CLAY, brown, moist to dry, becoming lighter in color with decreasing moisture, pockets of fine white caliche appearing at 14'.
16.5-23'	CLAY, brown, moist, stiff to plastic, some black stippling.
23-29.5'	SANDY CLAY, brown, moist, reaching saturation near 29'.
29.5-45'	CLAYEY GRAVEL, saturated, fine sand, pebbles, rocks to 3" in diameter, gravel sand-clay mix.
45-47.5'	SAND, fine grained, brown, saturated.
47.5-49'	SANDY CLAY, brown, moist to dry.

TD = 49.0'

NOTE: 5 foot core barrel recovery system used as sampling technique

ST=Shelby Tube | SS=Split Spoon | C=Cuttings

Monitoring Well ☒
Piezometer ☐



Depths in Feet
from Ground Surface
(Not to Scale)

Design Specifications

Elevations: 1 3366.18 2 3366.04
(feet MSL) 3 3364.03 4 3363.8

Coordinates: X 1659.24 Y 3905.78

Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐

Casing Diameter: ☒ 2" ☐ 3" ☐ 4" ☐ 6" ☐

Screen Slot: ☐ 0.008 ☒ 0.010 ☐

Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐

Sand Pack: CSSI 16-40

Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐

Grout Type: Portland Weight:

Bore Hole Diameter: 8"

Drill Rig: ☒ Hollow Stem ☐ Rotary ☐

Drilled By: PRECISION ENGINEERING

Logged By: PHILIP CADARETTE

Completion Date: FEBRUARY 14, 1992

Date	D-T-W	MSL	Date	Field pH	Field EC
2/19/92	29.0	3337.0			
3/10/92	29.3	3336.7			

Comments: Concrete with 5% bentonite used to grout from seal to surface.

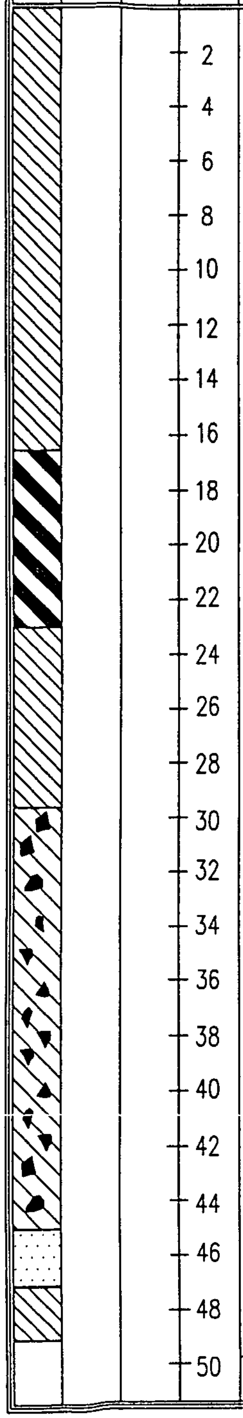
KWBES

Navajo

KWB2A

Project: 622092001-237 (2A)
Location: ARTESIA, NEW MEXICO

Sym	Samp Loc	PID (ppm)	Depth (Feet)



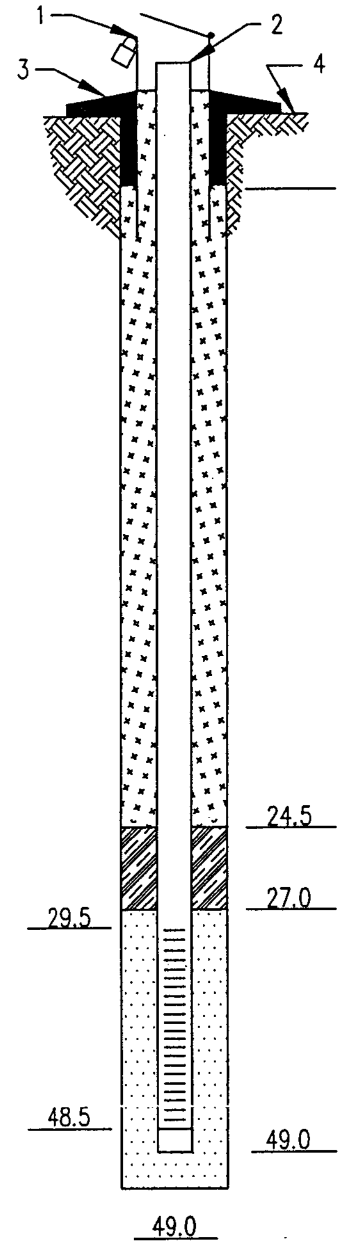
Geologic Description

0-16.5'	SANDY CLAY, brown, moist to dry, becoming lighter in color with decreasing moisture, pockets of fine white caliche (appearing at 14').
16.5-23'	CLAY, brown, moist, stiff to plastic, some black stippling.
23-29.5'	SANDY CLAY, brown, moist, reaching saturation near 29'.
29.5-45'	CLAYEY GRAVEL, saturated, fine sand, pebbles, rocks to 3" in diameter, gravel sand-clay mix.
45-47.5'	SAND, fine grained, brown, saturated.
47.5-49'	SANDY CLAY, brown, moist to dry.

TD = 49.0'

☐ ST=Shelby Tube ☐ SS=Split Spoon ☒ C=Cuttings

Monitoring Well ☒
Piezometer ☐



Depths in Feet
from Ground Surface
(Not to Scale)

Design Specifications

Elevations: 1 3366.40 2 3366.26
(feet MSL) 3 3364.12 4 3363.9
Coordinates: X 1646.63 Y 3905.71
Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐
Casing Diameter: ☐ 2" ☐ 3" ☒ 4" ☐ 6" ☐
Screen Slot: ☐ 0.008 ☒ 0.010 ☐
Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐
Sand Pack: CSSI 16-40
Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐
Grout Type: Portland Weight:
Bore Hole Diameter: 12"
Drill Rig: ☒ Hollow Stem ☐ Rotary ☐
Drilled By: PRECISION ENGINEERING
Logged By: PHILIP CADARETTE
Completion Date: FEBRUARY 18, 1992

Date	D-T-W	MSL	Date	Field pH	Field EC
2/19/92	28.9	3337.4			
3/10/92	29.2	3337.1			

Comments: Concrete with 5% bentonite used to grout from seal to surface.

KWBES

Navajo

KWB2B

Project: 622092001-237 (2B)
Location: ARTESIA, NEW MEXICO

Sym	Samp Loc	PID (ppm)	Depth (Feet)
			2
			4
			6
			8
			10
			12
			14
			16
			18
			20
			22
			24
			26
			28
			30
			32
			34
			36
			38
			40
			42
			44
			46
			48
			50

Geologic Description

0–24'	SANDY CLAY, brown, moist, becoming lighter in color with depth to @ 5' – dryer with depth – large pockets of white caliche starting around 8'. – small seam of pebbles @ 17.5' – intermittent thin seams – small seam of pebbles @ 17.5' – intermittent thin seams of fine sand from 17.5 to 20', moist – occasional small pebbles
24–25'	CLAY, brown, stiff, moist.
25–29'	SANDY CLAY, brown, interspersed with 6" seams of gravel, saturated.
29–30'	CLAYEY GRAVEL, saturated.
30–35'	CLAYEY SAND, brown, saturated with pebbles and rock.
35–39.5'	CLAY, brown, dry to moist, increasing sand and moisture with depth – gravel, dry at 39'.

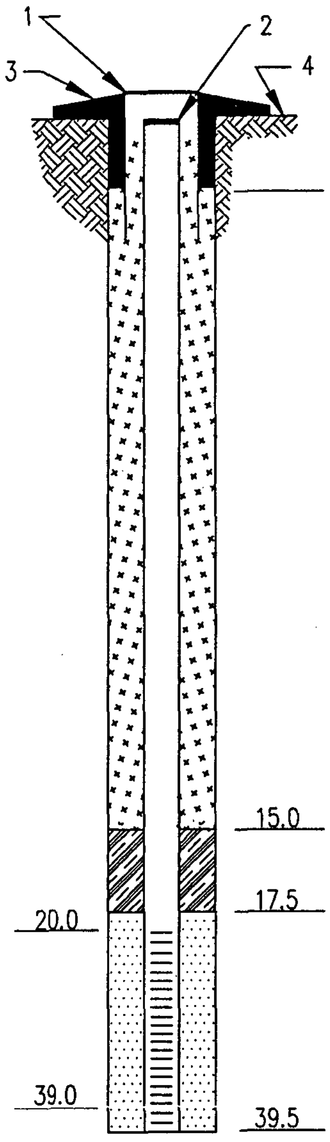
TD = 39.5'

NOTE: 5 foot core recovery system used as sampling technique.

ST=Shelby Tube | SS=Split Spoon | C=Cuttings

Monitoring Well ☒

Piezometer ☐



Depths in Feet
from Ground Surface
(Not to Scale)

Design Specifications

Elevations: (feet MSL) 1 3345.49 2 3345.31
3 3345.49 4 3345.3

Coordinates: X 2183.45 Y 7907.17

Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐

Casing Diameter: ☒ 2" ☐ 3" ☐ 4" ☐ 6" ☐

Screen Slot: ☐ 0.008 ☒ 0.010 ☐

Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐

Sand Pack: 20/40 Colorado

Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐

Grout Type: Type I Portland Weight:

Bore Hole Diameter: 8"

Drill Rig: ☒ Hollow Stem ☐ Rotary ☐

Drilled By: PRECISION ENGINEERING

Logged By: PHILLIP CADARETTE

Completion Date: FEBRUARY 14, 1992

Date	D-T-W	MSL	Date	Field pH	Field EC
2/19/92	20.7	3324.6			
3/10/92	21.0	3324.3			

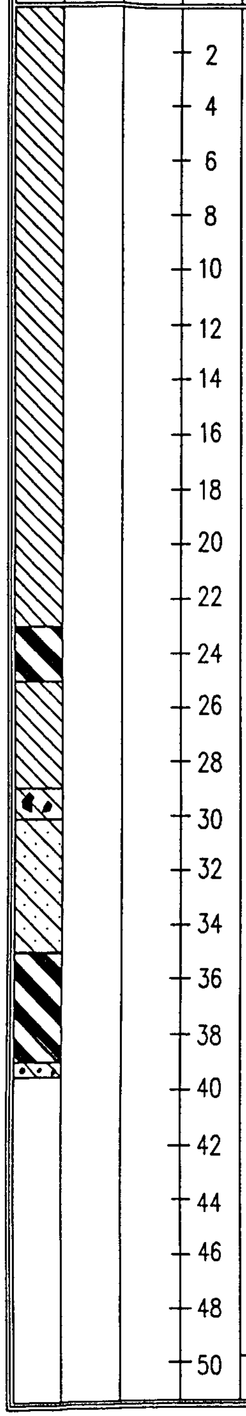
Comments: Concrete with 5% bentonite used to grout from seal to surface.

KWBES

KWB3A

Project: 622092001-237 (3A)
Location: ARTESIA, NEW MEXICO

Sym	Samp Loc	PID (ppm)	Depth (Feet)



Geologic Description

0-24' SANDY CLAY, brown, moist, becoming lighter in color with depth to @ 5'
- dryer with depth
- large pockets of white caliche starting around 8'.
- small seam of pebbles @ 17.5'
- intermittent thin seams
- small seam of pebbles @ 17.5'
- intermittent thin seams of fine sand from 17.5 to 20', moist
- occasional small pebbles

24-25' CLAY, brown, stiff, moist.

25-29' SANDY CLAY, brown, interspersed with 6" seams of gravel, saturated.

29-30' CLAYEY GRAVEL, saturated.

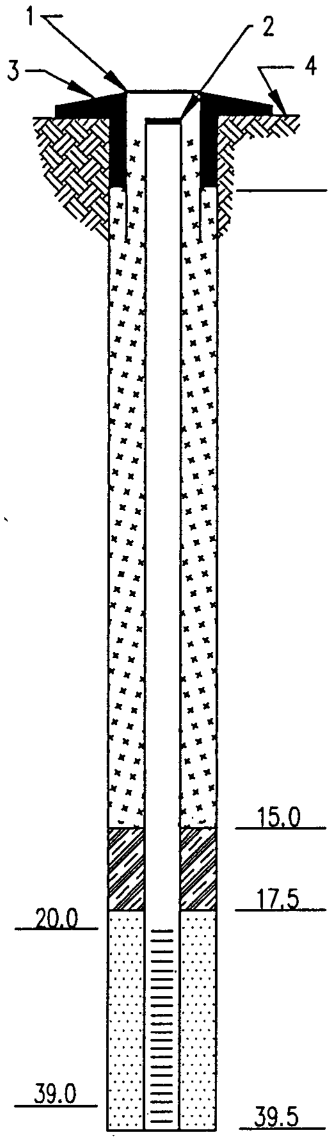
30-35' CLAYEY SAND, brown, saturated with pebbles and rock.

35-39.5' CLAY, brown, dry to moist, increasing sand and moisture with depth - gravel, dry at 39'.

TD = 39.5'

ST=Shelby Tube | SS=Split Spoon | C=Cuttings

Monitoring Well ☒
Piezometer



Depths in Feet from Ground Surface (Not to Scale)

Design Specifications

Elevations: 1 3345.52 2 3345.10
(feet MSL) 3 3345.52 4 3345.3

Coordinates: X 2193.17 Y 7905.71

Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐

Casing Diameter: ☒ 2" ☐ 3" ☐ 4" ☐ 6" ☐

Screen Slot: ☐ 0.008 ☒ 0.010 ☐

Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐

Sand Pack: 20/40 Colorado

Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐

Grout Type: Type I Portland Weight:

Bore Hole Diameter: 12"

Drill Rig: ☒ Hollow Stem ☐ Rotary ☐

Drilled By: PRECISION ENGINEERING

Logged By: PHILLIP CADARETTE

Completion Date: FEBRUARY 15, 1992

Date	D-T-W	MSL	Date	Field pH	Field EC
2/19/92	21.0	3324.1			
3/10/92	21.2	3323.9			

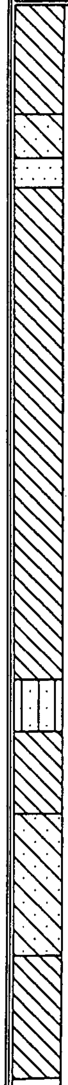
Comments: Concrete with 5% bentonite used to grout from seal to surface.

KWBES

KWB3B

Project: 622092001-237 (3B)
Location: ARTESIA, NEW MEXICO

Sym	Samp Loc	PID (ppm)	Depth (Feet)
			2
			4
			6
			8
			10
			12
			14
			16
			18
			20
			22
			24
			26
			28
			30
			32
			34
			36
			38
			40
			42
			44
			46
			48
			50



Geologic Description

0–4.5'	SANDY CLAY, brown, moist to dry, becoming lighter in color with decreasing moisture.
4.5–6'	CLAYEY SAND, brown, moist.
6–7'	SAND, fine grained, brown, moist.
7–25'	SANDY CLAY, brown, moist, gray hydrocarbon staining appearing at 8', dark gray to black staining from 8–11', strong odor, staining and odor disappear from 15–16', brown color, gray stain and odor return at 16', thin pebble bed near 18', black, saturated, increasing rock content from 18–25'.
25–27'	SILTY SAND, brown, odor.
27–30'	SANDY CLAY, gray to brown, moist.
30–35'	CLAYEY SAND, dark gray, grossly contaminated, no structure, saturated.
35–39.5'	SANDY CLAY, brown, moist to dry.

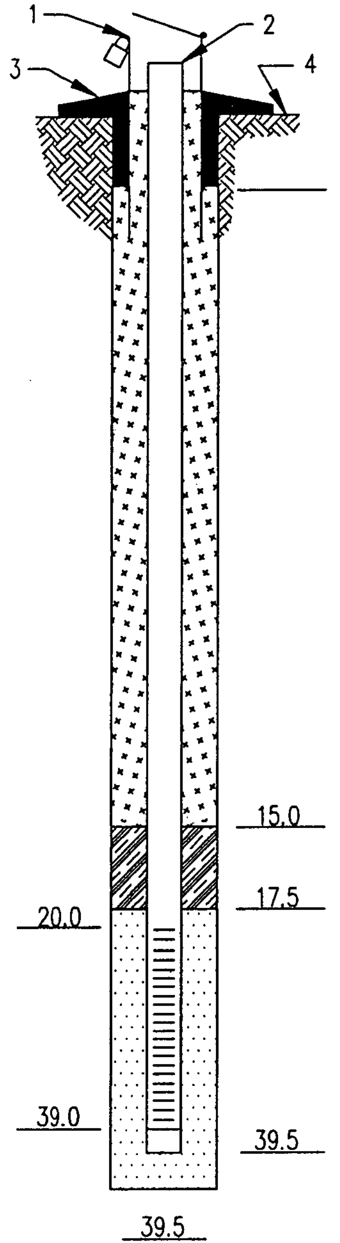
TD = 39.5'

NOTE: 5 foot core barrel recovery system used as sampling technique

ST=Shelby Tube | SS=Split Spoon | C=Cuttings

Monitoring Well ☒

Piezometer



Depths in Feet
from Ground Surface
(Not to Scale)

Design Specifications

Elevations: 1 3368.33 2 3368.12
(feet MSL) 3 3365.81 4 3365.4

Coordinates: X 2811.44 Y 3574.80

Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐

Casing Diameter: ☐ 2" ☐ 3" ☒ 4" ☐ 6" ☐

Screen Slot: ☐ 0.008 ☒ 0.010 ☐

Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐

Sand Pack: CSSI 16–40

Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐

Grout Type: Portland Weight:

Bore Hole Diameter: 12"

Drill Rig: ☒ Hollow Stem ☐ Rotary ☐

Drilled By: PRECISION ENGINEERING

Logged By: PHILIP CADARETTE

Completion Date: FEBRUARY 17. 1992

Date	D-T-P	MSL	D-T-W	Field pH	Field EC
2/19/92			24.2		
3/10/92	24.0	3344.1	26.1		

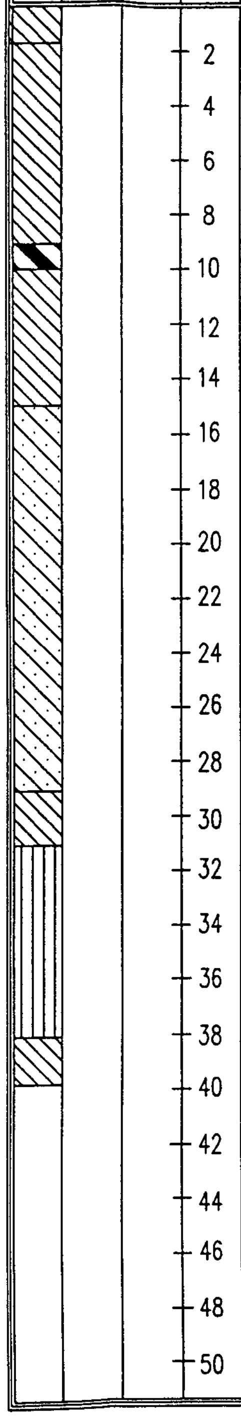
Comments: Concrete with 5% bentonite used to grout from seal to surface.

KWBES

KWB4

Project: 622092001-237 (KWB4)
Location: ARTESIA, NEW MEXICO

Sym | Samp Loc | PID (ppm) | Depth (Feet)



Geologic Description

0–9'	SANDY CLAY, brown, moist to dry, becoming lighter in color with decreasing moisture.
9–10'	CLAY, brown, moist.
10–15'	SANDY CLAY, brown, dry to moist, gray hydrocarbon staining starting at 14'.
15–29'	CLAYEY SAND, gray staining with strong hydrocarbon smell, dry to moist.
29–31'	SANDY CLAY, gray staining, strong odor, moist.
31–38'	SATURATED SILT, brown, strong odor, sheen.
38–39.5'	CLAY, brown, stiff, dry.

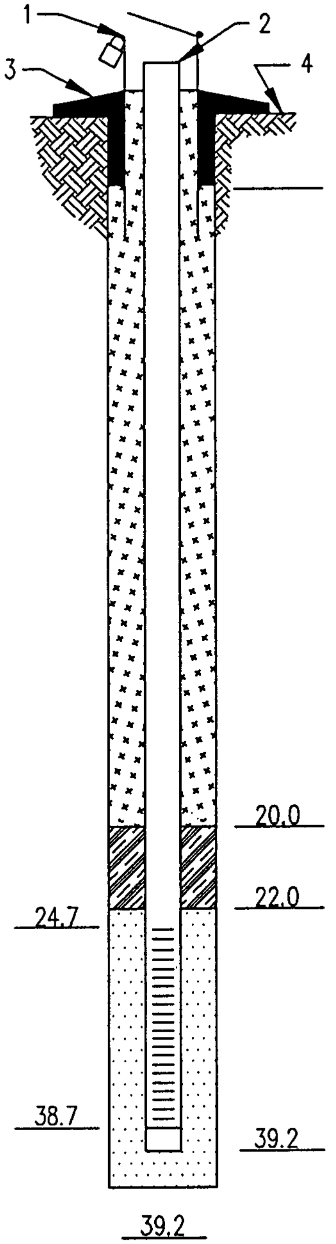
TD = 39.2'

NOTE: 5 foot core barrel recovery system used as sampling technique

ST=Shelby Tube | SS=Split Spoon | C=Cuttings

Monitoring Well ☒

Piezometer ☐



Depths in Feet from Ground Surface (Not to Scale)

Design Specifications

Elevations: (feet MSL) 1 3363.02 2 3362.87 3 3360.92 4 3360.6

Coordinates: X 2928.10 Y 4245.94

Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐

Casing Diameter: ☒ 2" ☐ 3" ☐ 4" ☐ 6" ☐

Screen Slot: ☐ 0.008 ☒ 0.010 ☐

Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐

Sand Pack: CSSI 16-40

Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐

Grout Type: Portland Weight:

Bore Hole Diameter: 8"

Drill Rig: ☒ Hollow Stem ☐ Rotary ☐

Drilled By: PRECISION ENGINEERING

Logged By: PHILIP CADARETTE

Completion Date: FEBRUARY 11, 1992

Date	D-T-P	MSL	D-T-W	Field pH	Field EC
2/19/92			23.1		
3/10/92	23.3	3339.6	23.4		

Comments: Concrete with 5% bentonite used to grout from seal to ground surface.

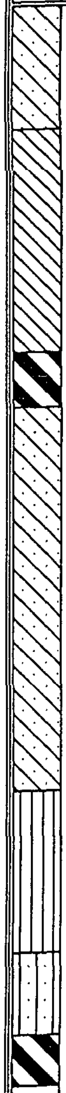
KWBES

Navajo

KWB5

Project: 622092001-237 (KWB5)
Location: ARTESIA, NEW MEXICO

Sym	Samp Loc	PID (ppm)	Depth (Feet)
			2
			4
			6
			8
			10
			12
			14
			16
			18
			20
			22
			24
			26
			28
			30
			32
			34
			36
			38
			40
			42
			44
			46
			48
			50



Geologic Description

0–5'	SANDY CLAY, brown, moist to dry, becoming lighter in color with decreasing moisture.
5–13'	SANDY CLAY, light brown, dry to moist, showing white streaks of caliche at 10'.
13–15'	CLAY, dark brown, dry to moist.
15–29'	CLAYEY SAND, brown, moist, slight gray discoloration starting at 16.5', black and gray hydrocarbon staining from 17–20', thin gravel layers at 18', discoloration lessening with depth, brown clayey sand alternating with thin bands of gravel starting at 20'.
29–35'	CLAYEY SILT, brown to tan, saturated.
35–38'	SAND with GRAVEL, tan, saturated.
38–39.5'	CLAY, brown, stiff, dry.

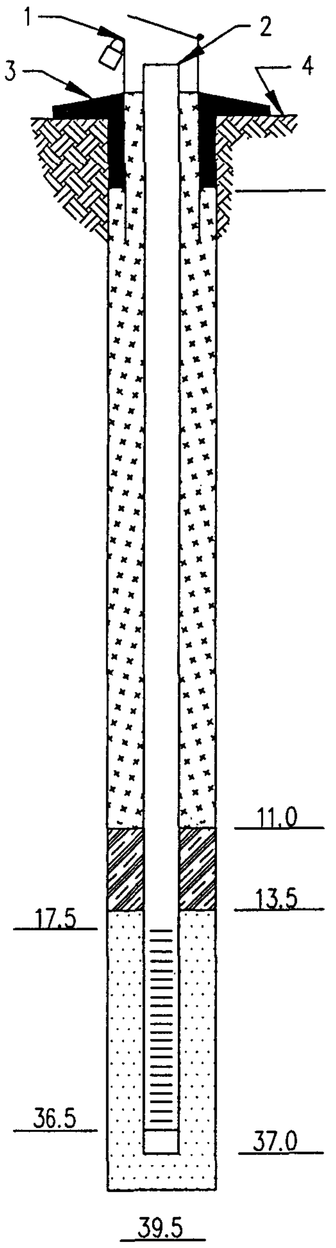
TD = 39.5'

NOTE: 5 foot core barrel recovery system used as sampling technique

ST=Shelby Tube | SS=Split Spoon | C=Cuttings

Monitoring Well ☒

Piezometer ☐



Depths in Feet from Ground Surface (Not to Scale)

Design Specifications

Elevations: 1 3358.71 2 3358.55
(feet MSL) 3 3356.41 4 3356.1

Coordinates: X 2652.58 Y 5161.82

Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐

Casing Diameter: ☒ 2" ☐ 3" ☐ 4" ☐ 6" ☐

Screen Slot: ☐ 0.008 ☒ 0.010 ☐

Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐

Sand Pack: CSSI 16–40

Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐

Grout Type: Portland Weight:

Bore Hole Diameter: 8"

Drill Rig: ☒ Hollow Stem ☐ Rotary ☐

Drilled By: PRECISION ENGINEERING

Logged By: PHILIP CADARETTE

Completion Date: FEBRUARY 12, 1992

Date	D-T-P	MSL	D-T-W	Field pH	Field EC
2/19/92	21.6	3337.0	24.8		
3/10/92	21.8	3336.8	25.1		

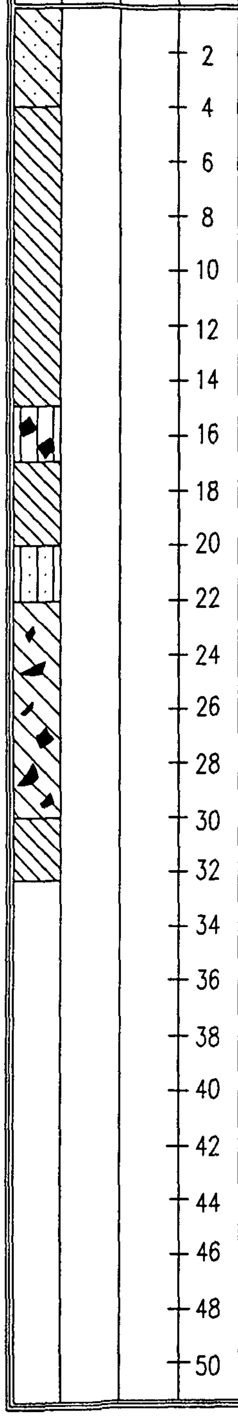
Comments: Concrete with 5% bentonite used to grout from seal to ground surface.

KWBES

KWB6

Project: 622092001-237 (KWB6)
Location: ARTESIA, NEW MEXICO

Sym	Samp Loc	PID (ppm)	Depth (Feet)



Geologic Description

0-4'	CLAYEY SAND, brown, moist, becoming lighter colored with depth.
4-15'	SANDY CLAY, brown, moist to dry, occasional small pebbles of caliche, white bands of fine grain caliche increasing in frequency to 10', gravel content increasing with depth, 2" diameter rocks encountered at 14.5'.
15-17'	GRAVEL, silty, moist.
17-20'	CLAYEY SAND, brown, saturated.
20-22'	SILTY SAND, brown, saturated, some gravel.
22-30'	CLAYEY GRAVEL, saturated, increasing clay content with depth.
30-32.5'	CLAY, brown, stiff, moist to dry.

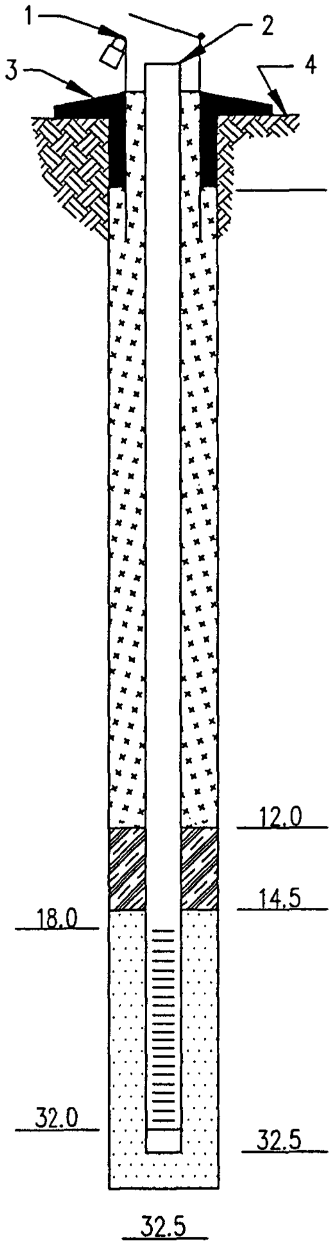
TD = 32.5'

NOTE: 5 foot core barrel recovery system used as sampling technique

☐ ST=Shelby Tube ☐ SS=Split Spoon ☐ C=Cuttings

Monitoring Well ☒

Piezometer ☐



Depths in Feet from Ground Surface (Not to Scale)

Design Specifications

Elevations: 1 3344.14 2 3344.00

(feet MSL) 3 3341.80 4 3341.6

Coordinates: X 3484.17 Y 8055.72

Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐

Casing Diameter: ☒ 2" ☐ 3" ☐ 4" ☐ 6" ☐

Screen Slot: ☐ 0.008 ☒ 0.010 ☐

Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐

Sand Pack: CSSI 16-40

Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐

Grout Type: Portland Weight:

Bore Hole Diameter: 8"

Drill Rig: ☒ Hollow Stem ☐ Rotary ☐

Drilled By: PRECISION ENGINEERING

Logged By: PHILIP CADARETTE

Completion Date: FEBRUARY 13, 1992

Date	D-T-W	MSL	Date	Field pH	Field EC
2/19/92	19.5	3324.5			
3/10/92	20.8	3323.2			

Comments: Concrete with 5% bentonite used to grout from seal to ground surface.

KWBES

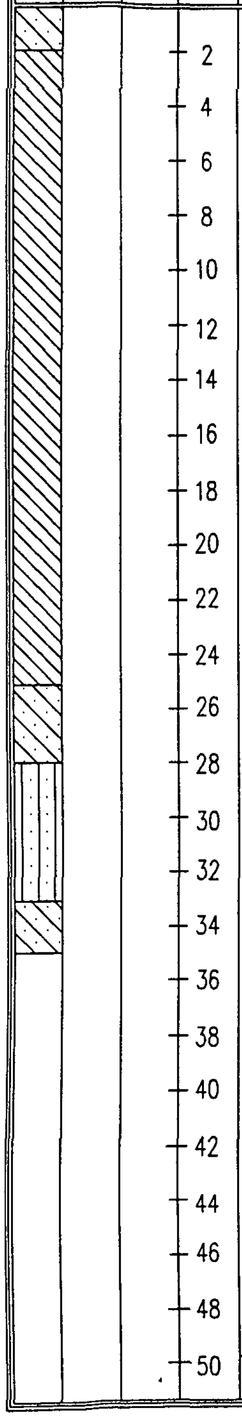
Navajo

KWB7

Project: 622092001-237 (KWB7)

Location: ARTESIA, NEW MEXICO

Sym	Samp Loc	PID (ppm)	Depth (Feet)



Geologic Description

0-2' CLAYEY SAND, brown, moist, becoming lighter colored with depth.

2-25' SANDY CLAY, brown, moist to dry, becoming lighter in color with depth to 5', thin banding of caliche nodules noted at various depths, banding becoming thicker with depth, slight gray hydrocarbon staining evident at 15', darker gray hydrocarbon staining with depth, odor increasing, 2" gravel seam, saturated at 23'.

25-28' CLAYEY SAND, dark gray, from 23-26', strong hydrocarbon odor, saturated.

28-33' SILTY SAND, brown, saturated, slight staining, decreased odor.

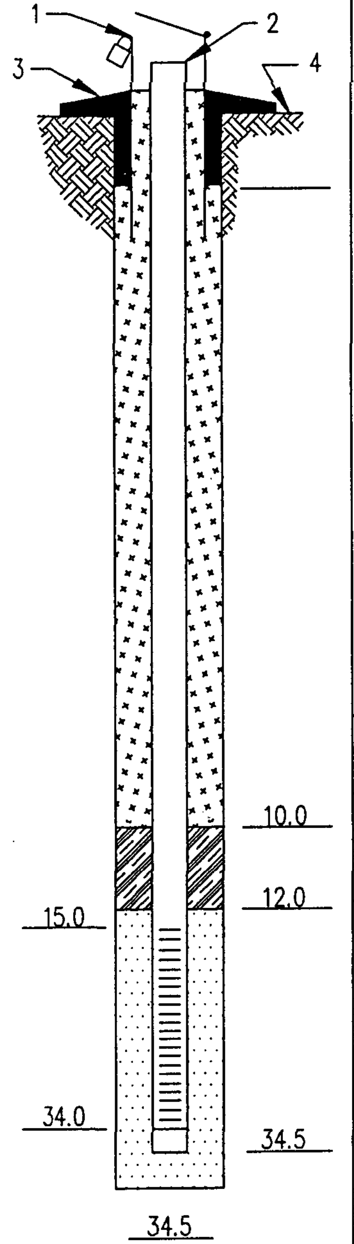
33-35' CLAYEY SAND, brown, moist.

TD = 34.5'

NOTE: 5 foot core barrel recovery system used as sampling technique

ST=Shelby Tube ☐ SS=Split Spoon ☐ C=Cuttings

Monitoring Well ☒
Piezometer



Depths in Feet from Ground Surface (Not to Scale)

Design Specifications

Elevations: 1 3353.17 2 3352.97
(feet MSL) 3 3350.80 4 3350.4

Coordinates: X 3211.93 Y 6875.69

Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐

Casing Diameter: ☒ 2" ☐ 3" ☐ 4" ☐ 6" ☐

Screen Slot: ☐ 0.008 ☒ 0.010 ☐

Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐

Sand Pack: CSSI 16-40

Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐

Grout Type: Portland Weight:

Bore Hole Diameter: 8"

Drill Rig: ☒ Hollow Stem ☐ Rotary ☐

Drilled By: PRECISION ENGINEERING

Logged By: PHILIP CADARETTE

Completion Date: FEBRUARY 12, 1992

Date	D-T-W	MSL	Date	Field pH	Field EC
2/19/92	20.6	3332.4			
3/10/92	21.0	3332.0			

Comments: Concrete with 5% bentonite used to grout from seal to ground surface.

KWBES

Navajo

KWB8

Project: 622092001-237 (KWB8)
Location: ARTESIA, NEW MEXICO

Sym | Samp Loc | PID (ppm) | Depth (Feet)

Geologic Description

0–22.5' SANDY CLAY, brown, dry, caliche nodules throughout, color lighter with depth, increasing sand content and caliche inclusions with depth white caliche banding starting at 10', thin gravel seam at 13', sandy clay exhibiting increasing moisture near 15'.

22.5–23' CLAYEY GRAVEL, saturated.

23–25' SILTY SAND, brown, saturated.

25–34.5' SANDY CLAY, brown, saturated to 26' then moist, dry near 34'.

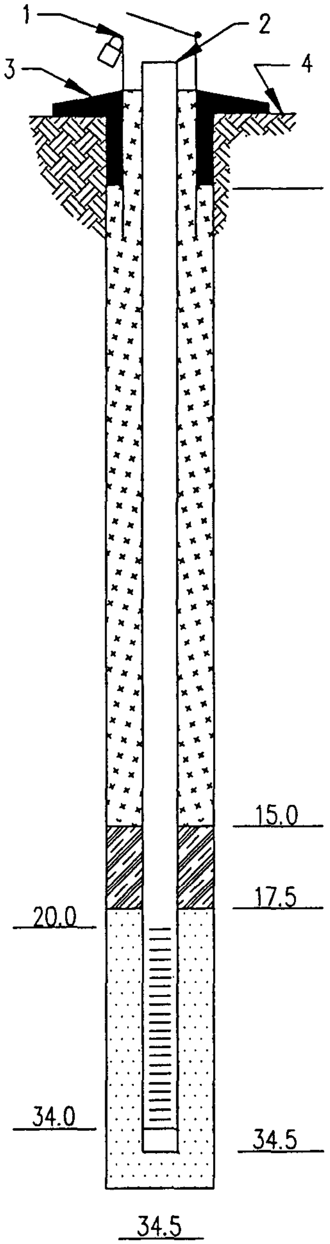
TD = 34.5'

NOTE: 5 foot core barrel recovery system used as sampling technique

Depth (Feet): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50

ST=Shelby Tube ☐ SS=Split Spoon ☐ C=Cuttings

☒ Monitoring Well
☐ Piezometer



Depths in Feet from Ground Surface (Not to Scale)

Design Specifications

Elevations: 1 3352.67 2 3352.53
(feet MSL) 3 3349.90 4 3349.8

Coordinates: X 1838.15 Y 6600.55

Type of Casing: ☒ PVC Sched. 40 Flush Thread ☐ Stainless Steel ☐

Casing Diameter: ☒ 2" ☐ 3" ☐ 4" ☐ 6" ☐

Screen Slot: ☐ 0.008 ☒ 0.010 ☐

Screen Style: ☒ Machine Slot ☐ Wire Wrap ☐

Sand Pack: CSSI 16–40

Bentonite Seal: ☐ 1/2" Pellets ☐ Hole Plug ☐ Slurry ☒ 1/4" Pellets ☐

Grout Type: Portland Weight:

Bore Hole Diameter: 8"

Drill Rig: ☒ Hollow Stem ☐ Rotary ☐

Drilled By: PRECISION ENGINEERING

Logged By: PHILIP CADARETTE

Completion Date: FEBRUARY 13, 1992

Date	D–T–W	MSL	Date	Field pH	Field EC
2/19/92	24.9	3327.6			
3/10/92	25.2	3327.3			

Comments: Concrete with 5% bentonite used to grout from seal to ground surface.

KWBES

Navajo

KWB9

Project: 622092001–237 (KWB9)
Location: ARTESIA, NEW MEXICO

APPENDIX D

APPENDIX D

Laboratory Results

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

Mr. David Boyer
KW Brown Environmental Services
500 Graham Road
College Station, Texas 77845

25 February, 1992

Dear David, UMR

On 3 ~~January~~ February, 1992, eleven water samples and one pump oil sample were received by Inter-Mountain Laboratories - College Station. The samples were received cooled and in good condition. The samples were identified by Project Name "Navajo Refining" and Project Number 622092001. Analyses for Benzene-Toluene-Ethylbenzene-Xylenes (BETX) and Inorganic parameters were performed according to the accompanying chain of custody forms. Total Recoverable Petroleum Hydrocarbons (TPH) will be completed this week. No trip blank accompanied the shipment.

It is the policy of this laboratory to employ, whenever possible, preparatory and analytical methods which have been approved by regulatory agencies. The methods used in the analysis of samples reported herein are found in "Test Methods for Evaluating Solid Waste", SW-846, USEPA, 1986 and "Chemical Analysis of Water and Waste", USEPA, 1978. All reports in this package reference methods utilized.

Quality Control reports have been included for your information and use. These reports appear at the end of the analytical package and may be identified by title. I apologize for the incomplete package and for not having it to you yesterday. If you have any questions regarding the information in this package, please feel free to call at your convenience.

Sincerely,

Ulonda M Rogers

Ulonda M. Rogers
Project Manager

KWBE0166

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 6201007
Sample ID: ~~RA 4196~~ RA-1331 WRB 5/92
Sample Number: C92166
Sample Matrix: Water
Preservative: HCl, Cool
Condition: Intact

Report Date: 02/10/92
Date Sampled: 01/31/92
Date Received: 02/03/92
Date Analyzed: 02/04/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	100%	88-110%
4-Bromofluorobenzene	99%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrove
Analyst

Wanda M Rog
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 6201007
Sample ID: RA 307
Sample Number: C92167
Sample Matrix: Water
Preservative: HCl, Cool
Condition: Intact

Report Date: 02/10/92
Date Sampled: 01/31/92
Date Received: 02/03/92
Date Analyzed: 02/04/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	102%	88-110%
4-Bromofluorobenzene	100%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovee
Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**K. W. BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refining		
Project Number:	622092001	Report Date:	02/10/92
Login Number:	6201007	Date Sampled:	01/31/92
Sample ID:	Chase Bolton North - Domestic House	Date Received:	02/03/92
Sample Number:	C92168	Date Analyzed:	02/04/92
Sample Matrix:	Water		
Preservative:	HCl, Cool		
Condition:	Intact		

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	96%	88-110%
	4-Bromofluorobenzene	93%	86-115%

Reference: Method 5030, Purge and Trap.
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrree
Analyst

Wanda M Kogan
Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K.W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Sample ID: Pump Oil
Sample Number: C92170
Sample Matrix: Oil
Preservative: HCl, Cool
Condition: Intact

Report Date: 02/10/92
Date Sampled: 01/31/92
Date Received: 02/03/92
Date Extracted: 02/06/92
Date Analyzed: 02/06/92

Analyte	Concentration (ug/Kg)	Detection Limit (ug/Kg)
Benzene	ND	7000
Toluene	18000	7000
Ethylbenzene	ND	7000
p,m-Xylene	18000	7000
o-Xylene	9000	7000

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	104%	88-110%
4-Bromofluorobenzene	105%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX DUPLICATE - VOLATILE AROMATIC HYDROCARBONS

Sample Number:	C92170 Duplicate	Date Sampled:	01/31/92
Sample Matrix:	Soil	Date Received:	02/03/92
Preservative:	Cool	Date Extracted:	02/17/92
Condition:	Intact	Date Analyzed:	02/17/92

Analyte	Sample Result (ug/Kg)	Duplicate Result (ug/Kg)	Percent Difference
Benzene	ND	ND	NA
Toluene	18000	16000	12%
Ethylbenzene	ND	ND	NA
p,m-Xylene	18000	20000	11%
o-Xylene	9000	10000	11%

ND - Analyte not detected at stated detection limit.
NA - Value not calculated or applicable

Quality Control: Duplicate acceptance limit set at 30% difference.

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	109%	88-110%
4-Bromofluorobenzene	107%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovec
Analyst

Wanda M Rog
Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 6201007
Sample ID: Armstrong Domestic
Sample Number: C92171
Sample Matrix: Water
Preservative: HCl, Cool
Condition: Intact

Report Date: 02/10/92
Date Sampled: 01/30/92
Date Received: 02/03/92
Date Analyzed: 02/04/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	96%	88-110%
4-Bromofluorobenzene	91%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovec
Analyst

Wanda M Logan
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX SPIKE - VOLATILE AROMATIC HYDROCARBONS

Sample Number:	C92171 Spike	Report Date:	02/10/92
Sample Matrix:	Water	Date Sampled:	01/30/92
Preservative:	HCl, Cool	Date Received:	02/03/92
Condition:	Intact	Date Analyzed:	02/04/92

Analyte	Spike Added (ug/L)	Sample Result (ug/L)	Spike Result (ug/L)	Percent Recovery	Acceptance Limit
Benzene	10.0	ND	9.2	92%	39-150%
Toluene	10.0	ND	9.2	92%	46-148%
Ethylbenzene	10.0	ND	11.3	113%	32-160%
p,m-Xylene	20.0	ND	22.2	111%	NE
o-Xylene	10.0	ND	10.6	106%	NE

ND - Analyte not detected at stated detection limit.
NE - Acceptance limit not established

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	95%	88-110%
4-Bromofluorobenzene	93%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Jessica Vandrover
Analyst

Wanda M
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX SPIKE DUPLICATE - VOLATILE AROMATIC HYDROCARBONS

Sample Number: C92171 Spike Duplicate
Sample Matrix: Water
Preservative: HCl, Cool
Condition: Intact

Report Date: 02/10/92
Date Sampled: 01/30/92
Date Received: 02/03/92
Date Analyzed: 02/04/92

Analyte	Spike Result (%)	Duplicate Result (%)	Percent Difference
Benzene	92.5%	90.5%	2.1%
Toluene	92.1%	90.7%	1.5%
Ethylbenzene	113%	111%	1.2%
p,m-Xylene	111%	110%	1.1%
0-Xylene	106%	105%	0.7%

ND - Analyte not detected at stated detection limit.

Quality Control: Duplicate acceptance limit set at 20% difference.

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	95%	88-110%
4-Bromofluorobenzene	96%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Jessica Vandrovec
Analyst

Wanda M Rog
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 6201007
Sample ID: RA 313
Sample Number: C92172
Sample Matrix: Water
Preservative: HCl, Cool
Condition: Intact

Report Date: 02/10/92
Date Sampled: 01/30/92
Date Received: 02/03/92
Date Analyzed: 02/05/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	1.7	0.2
Toluene	0.8	0.2
Ethylbenzene	2.1	0.2
p,m-Xylene	1.4	0.2
o-Xylene	2.4	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	95%	88-110%
4-Bromofluorobenzene	94%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovec
Analyst

Wanda M Log
Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**K. W. BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refining		
Project Number:	622092001	Report Date:	02/10/92
Login Number:	6201007	Date Sampled:	01/30/92
Sample ID:	Coll - Horner Domestic	Date Received:	02/03/92
Sample Number:	C92173	Date Analyzed:	02/05/92
Sample Matrix:	Water		
Preservative:	HCl, Cool		
Condition:	Intact		

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	94%	88-110%
	4-Bromofluorobenzene	97%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica L. Vandrovec
Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**K. W. BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refining		
Project Number:	622092001	Report Date:	02/10/92
Login Number:	6201007	Date Sampled:	01/30/92
Sample ID:	T. Joy Domestic	Date Received:	02/03/92
Sample Number:	C92174	Date Analyzed:	02/05/92
Sample Matrix:	Water		
Preservative:	HCl, Cool		
Condition:	Intact		

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	94%	88-110%
4-Bromofluorobenzene	96%	86-115%

Reference:

Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrover
Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 6201007
Sample ID: Gurley Domestic
Sample Number: C92175
Sample Matrix: Water
Preservative: HCl, Cool
Condition: Intact

Report Date: 02/10/92
Date Sampled: 01/30/92
Date Received: 02/03/92
Date Analyzed: 02/05/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	0.6	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	97%	88-110%
4-Bromofluorobenzene	96%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrover
Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 6201007
Sample ID: Richard Chase Home Well
Sample Number: C92176
Sample Matrix: Water
Preservative: HCl, Cool
Condition: Intact

Report Date: 02/10/92
Date Sampled: 01/30/92
Date Received: 02/03/92
Date Analyzed: 02/05/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	0.7	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	0.5	0.2
o-Xylene	0.2	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	98%	88-110%
4-Bromofluorobenzene	97%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovec
Analyst

Wanda M Rogers
Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX SPIKE - VOLATILE AROMATIC HYDROCARBONS

Sample Number: C92176 Spike
Sample Matrix: Water
Preservative: HCl, Cool
Condition: Intact

Report Date: 02/10/92
Date Sampled: 01/30/92
Date Received: 02/03/92
Date Analyzed: 02/05/92

Analyte	Spike Added (ug/L)	Sample Result (ug/L)	Spike Result (ug/L)	Percent Recovery	Acceptance Limit
Benzene	10.0	ND	10.3	103%	39-150%
Toluene	10.0	0.7	10.6	98%	46-148%
Ethylbenzene	10.0	ND	9.9	98%	32-160%
p,m-Xylene	20.0	0.5	21.0	102%	NE
o-Xylene	10.0	0.2	9.4	92%	NE

ND - Analyte not detected at stated detection limit.
NE - Acceptance limit not established

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	95%	88-110%
4-Bromofluorobenzene	95%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**K. W. BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refining		
Project Number:	622092001	Report Date:	02/10/92
Login Number:	6201007	Date Sampled:	01/30/92
Sample ID:	Duplicate 1	Date Received:	02/03/92
Sample Number:	C92177	Date Analyzed:	02/05/92
Sample Matrix:	Water		
Preservative:	HCl, Cool		
Condition:	Intact		

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	1.1	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	96%	88-110%
	4-Bromofluorobenzene	97%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovec
Analyst

Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX DUPLICATE - VOLATILE AROMATIC HYDROCARBONS

Sample Number: C92177 Duplicate
Sample Matrix: Water
Preservative: HCl, Cool
Condition: Intact

Date Sampled: 01/30/92
Date Received: 02/03/92
Date Analyzed: 02/05/92

Analyte	Sample Result (ug/L)	Duplicate Result (ug/L)	Percent Difference
Benzene	ND	ND	NA
Toluene	1.1	0.8	33.0%
Ethylbenzene	ND	ND	NA
p,m-Xylene	ND	ND	NA
o-Xylene	ND	ND	NA

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	103%	88-110%
4-Bromofluorobenzene	101%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrover
Analyst

Wenda M Roger
Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**K. W. BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refining		
Project Number:	622092001	Report Date:	02/10/92
Login Number:	6201007	Date Sampled:	01/30/92
Sample ID:	Field Blank	Date Received:	02/03/92
Sample Number:	C92178	Date Analyzed:	02/05/92
Sample Matrix:	Water		
Preservative:	HCl, Cool		
Condition:	Intact		

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	95%	88-110%
	4-Bromofluorobenzene	95%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrover
Analyst

Wanda M Rogers
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
METHOD BLANK - VOLATILE AROMATIC HYDROCARBONS

Sample Number: MB020492V1   Date Analyzed: 02/04/92
Sample Matrix: Water

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	97%	88-110%
	4-Bromofluorobenzene	100%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Jessica Vandrovec
Analyst

Wendi M Log
Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
METHOD BLANK - VOLATILE AROMATIC HYDROCARBONS

Sample Number: MB020592V1
Sample Matrix: Water
Date Analyzed: 02/05/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	100%	88-110%
4-Bromofluorobenzene	100%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Jessica Vandrovec
Analyst

Wendi M Rog
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
METHOD BLANK - VOLATILE AROMATIC HYDROCARBONS

Sample Number: MB020592V2
Sample Matrix: Water
Date Analyzed: 02/05/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	91%	88-110%
4-Bromofluorobenzene	95%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Analyst

Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
METHOD BLANK - VOLATILE AROMATIC HYDROCARBONS

Sample Number: MB021792V2
Sample Matrix: Solid

Date Extracted: 02/17/92
Date Analyzed: 02/17/92

Analyte	Concentration (ug/Kg)	Detection Limit (ug/Kg)
Benzene	ND	100
Toluene	ND	100
Ethylbenzene	ND	100
p,m-Xylene	ND	100
o-Xylene	ND	100

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	105%	88-110%
4-Bromofluorobenzene	104%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Jessica Vandrovec
Analyst

Review

iml
Inter-Mountain
Laboratories, Inc.

11183 SH 30
College Station, Texas 77845
Phone (409) 776-8945

Client: K. W. BROWN ENVIRONMENTAL SERVICES
500 Graham Road
College Station, TX 77845

2/21/92

Re: Navajo Refinery
P.O. #42989
Progect No. 622092001
Login No. 6201007

IML Lab No.		C92166/12761	C92167/12762	C92168/12763	C92171/12764	C92172/12765
Sample Id.		RA~~4106~~ 1331 ARB 5/92	RA307	Chase Bolton North House - Domestic	Armstrong Domestic	RA 313
Date Sampled		01/31/92	01/31/92	01/31/92	01/30/92	01/30/92
Date Received		02/03/92	02/03/92	02/03/92	02/03/92	02/03/92
Alkalinity	mg/L	166.	170.	188.	158.	73.
Calcium	mg/L	317.	343.	408.	184.	132.
Bicarbonate	mg/L	203.	207.	229.	193.	88.
Carbonate	mg/L	0.	0.	0.	0.	0.
Chloride	mg/L	225.	573.	103.	32.	21.
Conductivity	umhos/cm	2400.	3770.	2750.	1270.	976.
Magnesium	mg/L	98.	128.	135.	59.	43.
pH	s.u.	7.4	7.4	7.7	7.3	7.3
Potassium	mg/L	1.8	2.0	2.0	1.2	1.1
Sodium	mg/L	106.	348.	92.	24.	16.
Sulfate	mg/L	913.	1130.	1370.	516.	428.
TDS	mg/L	1830.	2710.	2110.	952.	698.

iml
Inter-Mountain
Laboratories, Inc.

11183 SH 30
College Station, Texas 77845
Phone (409) 776-8945

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
500 Graham Road
College Station, TX 77845

2/21/92

Re: Navajo Refinery
P.O. #42989
Progect No. 622092001
Login No. 6201007

IML Lab No.		C92173/12766	C92174/12767	C92175/12768	C92176/12769
Sample Id.		Coll-Horner Domestic	T. Joy Domestic	Gurley Domestic	Richard Chase Home Well
Date Sampled		01/30/92	01/30/92	01/30/92	01/30/92
Date Received		02/03/92	02/03/92	02/03/92	02/03/92
Alkalinity	mg/L	145.	181.	175.	166.
Calcium	mg/L	194.	366.	465.	530.
Bicarbonate	mg/L	178.	221.	213.	203.
Carbonate	mg/L	0.	0.	0.	0.
Chloride	mg/L	18.	151.	232.	1420.
Conductivity	umhos/cm	1290.	2880.	3680.	8080.
Magnesium	mg/L	58.	115.	155.	198.
pH	s.u.	7.5	7.4	7.2	7.3
Potassium	mg/L	1.2	2.0	2.7	2.8
Sodium	mg/L	22.	108.	150.	861.
Sulfate	mg/L	583.	1210.	1580.	1770.
TDS	mg/L	992.	2160.	2820.	5170.

Inter-Mountain Laboratories, Inc.

11183 SH 30
College Station, Texas 77845
Phone (409) 776-8945

Client: K. W. BROWN ENVIRONMENTAL SERVICES
500 Graham Road
College Station, TX 77845

Re: Navajo Refinery
P.O. #42989
Progect No. 622092001
Login No. 6201007

IML Lab No.		C92177/12770	C92178/12771	C92166/12772
Sample Id.		Duplicate 1	Field Blank	RA~~4196~~ RA-1331 IML-DUP
Date Sampled				01/31/92
Date Received		02/03/92	02/03/92	02/03/92
Alkalinity	mg/L	162.	1.	166.
Calcium	mg/L	186.	1.	312.
Bicarbonate	mg/L	197.	1.	203.
Carbonate	mg/L	0.	0.	0.
Chloride	mg/L	34.	<1.	225.
Conductivity	umhos/cm	1290.	2.2	2420.
Magnesium	mg/L	59.	0.5	97.
pH	s.u.	7.5	5.0	7.4
Potassium	mg/L	1.2	<0.1	1.8
Sodium	mg/L	24.	<1.	106.
Sulfate	mg/L	521.	2.	912.
TDS	mg/L	960.	<1.	1830.

Reviewed by: Mitch Swan
Mitch Swan--Water Laboratory Supervisor

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

Rcvd 3/11/92

Mr. David Boyer
K.W. Brown Environmental Services
500 Graham Road
College Station, Texas 77845

March 6, 1992

Dear David,

On February 3, 1992 a sample set was received by Inter-Mountain Laboratories - College Station. Included in the set was a sample of pump oil to be analyzed for Total Recoverable Petroleum Hydrocarbons (TRPH), as indicated on the enclosed chain of custody. It was received cooled and in good condition, with no additional preservative. The Project Name was Navajo Refining, and the Project Number was 622092001.

Early analysis of the sample, which was performed on a gas chromatograph with a Flame Ionization Detector, showed the presence of a hydrocarbon envelope that did not match the profiles of either gasoline or diesel. Using a standard hydrocarbon mixture of C18 to C44 as comparison, it was determined that the sample contained hydrocarbons in the range of C18 to C30. Both gasoline and diesel are made up of lighter components, with gasoline being considerably less than C18 and diesel containing nothing heavier than C24.

It is the policy of this laboratory to employ, whenever possible, preparatory and analytical methods which have been approved by regulatory agencies. The methods used in the analyses of samples reported here are found in "Test Methods for Evaluating Solid Waste", SW-846, USEPA, 1986, All reports in this package reference methods utilized.

If there are any questions regarding the information presented in this package, please feel free to call at your convenience.

Sincerely,

Mary Higginbotham

Mary Higginbotham
Project Manager

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

TOTAL RECOVERABLE PETROLEUM HYDROCARBONS
TRPH

Client:	**K.W. Brown Environmental Services**		
Project ID:	Navajo Refining	Report Date:	03/03/92
Sample ID:	Pump Oil	Date Sampled:	01/31/92
Laboratory ID:	C92169	Date Received:	02/03/92
Sample Matrix:	Oil	Date Extracted:	02/12/92
Preservative:	Cool	Date Analyzed:	02/14/92
Condition:	Intact		

Analyte	Concentration (mg/L)	Detection Limit (mg/L)
Diesel	ND	50
Gasoline	ND	50

ND - Analyte not detected at stated detection limit

References:

Method 8015 (Modified): Nonhalogenated Volatile Organics
- Test Methods for Evaluating Solid Waste, SW - 846, Vol. IB, United States Environmental Protection Agency, September, 1986.

Mary Higginbotham
Analyst

Review

CHAIN OF CUSTODY RECORD

Project No. 622092001	Project Name Navajo Refining	M. DGB	Login No. ~~6210~~ 6201007	P.O. No. 42989

FILE COPY

Sample Identification	Date	Time	Sample Container (Size/Material)	Sample Type (Liquid, Soil, etc.)	Preservative	Analyses Requested						Comments
						A	B	C	D	E	F	
Armstrong Domestic	1/30/92	11:18	1 liter Poly 2 40ml VOA	liquid	None HCl	X	X					C92171
RA 313	1/30/92	13:55				X	X					C92172
Coll-Horner Domestic	1/30/92	14:35				X	X					C92173
T. Joy Domestic	1/30/92	15:47				X	X					C92174
Gurley Domestic	1/30/92	1452				X	X					C92175
Richard Chase Home Well	1/30/92	17:07				X	X					C92176
Duplicate 1						X	X					C92177
Field Blank						X	X					C92178

Relinquished By (Signature)	Date	Time	Received By (Signature)
	2-3-92	0930	Lance Cooper

Analyses:

A BTEX

B EC, pH, NA, K, Ca, Mg, Cl, $SO_4^=$, $CO_3^=$, HCO_3^-

[illegible] TDS

D

E

F

CHAIN OF CUSTODY RECORD

FILE COPY

Project No. 622092001
Project Name NAVAjo Refining
M. DGB
Login No. 6201007
P.O. No. 42989

Sample Identification	Date	Time	Sample Container (Size/Material)	Sample Type (Liquid, Soil, etc.)	Preservative	A	B	C	D	E	F	Comments
RA 4196	1/31/92	9:15	1000 ml 2 40ml VOA	liquid	NA HCl	X	X					C92166
RA 307	1/31/92	930	1000 ml 2 40ml VOA		NA HCl	X	X					C92167
ChaseBolton North - Domestic House	1/31/92	9:45	1000 ml 2 40ml VOA		NA HCl	X	X					C92168
Pump oil	1/31/92	8:45	2 40ml VOA		None				X			Please PAy C92169
Pump oil	1/31/92	8:45	2 40ml VOA		HCl	X						Special Attention C92170 to this

Relinquished By (Signature)	Date	Time	Received By (Signature)
	2-3-92	0930	Lance Hooper

Analyses:
A BTEX
B EC, pH, NA, K, CA, Mg, Cl, SO_4, $CO_3^=$, HCO_3^-
TDS
D TPH by GC
E
F

Inter·Mountain
Laboratories, Inc.

3304 Longmire
College Station, Texas 77845
Phone (409) 774-4999

Mr. David Boyer
KW Brown Environmental Services
500 Graham Road
College Station, Texas 77845

16 March, 1992

Dear Mr. Boyer,

On 20 February, 1992, eleven water samples were received by Inter-Mountain Laboratories - College Station. The samples were received cool and in good condition. The samples were identified by Project Name "Navajo Refinery" and Project Number 622092001. Analyses for Benzene-Toluene-Ethylbenzene-Xylenes (BETX), Major Cations and Anions, Conductivity (EC), and pH were performed according to the accompanying chain of custody forms. A trip blank accompanied the shipment.

It is the policy of this laboratory to employ, whenever possible, preparatory and analytical methods which have been approved by regulatory agencies. The methods used in the analysis of samples reported herein are found in "Test Methods for Evaluating Solid Waste", SW-846, USEPA, 1986. All reports in this package reference methods utilized.

A Hewlett-Packard 5890 Series II Gas Chromatograph and a Tekmar Purge and Trap were utilized for sample analysis. Volatile analysis was performed in accordance with EPA Method 8020: Aromatic Volatile Organics. Samples KWB - 4, KWB - 5, KWB - 6, and KWB - 8 had significant amounts of the BTEX analytes. The remainder of the samples had very low levels of BTEX analytes or none at all.

Quality Control reports have been included for your information and use. These reports appear at the end of the analytical package and may be identified by title. If you have any questions regarding the information in this package, please feel free to call at your convenience.

Sincerely,

Jessica Vandrovec

Jessica Vandrovec
Project Manager

KWBE328

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 9202009
Sample ID: KWB - 1A
Sample Number: C92328
Sample Matrix: Water
Preservative: Cool
Condition: Intact

Report Date: 02/25/92
Date Sampled: 02/17/92
Date Received: 02/20/92
Date Analyzed: 02/24/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	98%	88-110%
4-Bromofluorobenzene	97%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovec
Analyst

Wanda M Rogers
Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: K. W. BROWN ENVIRONMENTAL SERVICES
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 9202009
Sample ID: KWB - 2A
Sample Number: C92329
Sample Matrix: Water
Preservative: Cool
Condition: Intact

Report Date: 02/25/92
Date Sampled: 02/19/92
Date Received: 02/20/92
Date Analyzed: 02/24/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	0.9	0.2
Toluene	0.4	0.2
Ethylbenzene	0.3	0.2
p,m-Xylene	0.5	0.2
o-Xylene	0.2	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	96%	88-110%
4-Bromofluorobenzene	99%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrover
Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX DUPLICATE - VOLATILE AROMATIC HYDROCARBONS

Sample Number: C92329 Duplicate
Sample Matrix: Water
Preservative: Cool
Condition: Intact

Date Sampled: 02/19/92
Date Received: 02/20/92
Date Analyzed: 02/24/92

Analyte	Sample Result (ug/L)	Duplicate Result (ug/L)	Percent Difference
Benzene	0.9	0.9	4.1%
Toluene	0.4	0.4	0.5%
Ethylbenzene	0.3	0.3	20.1%
p,m-Xylene	0.6	0.6	3.7%
o-Xylene	0.3	0.3	19.7%

ND - Analyte not detected at stated detection limit.

Quality Control: Duplicate acceptance limit set at 20% difference.

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	97%	88-110%
4-Bromofluorobenzene	101%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Review

Inter-Mountain Laboratories, Inc.

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College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 9202009
Sample ID: KWB - 3A
Sample Number: C92330
Sample Matrix: Water
Preservative: Cool
Condition: Intact

Report Date: 02/25/92
Date Sampled: 02/18/92
Date Received: 02/20/92
Date Analyzed: 02/24/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	0.2	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	97%	88-110%
4-Bromofluorobenzene	99%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovec
Analyst

Wanda M Rogers
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX SPIKE - VOLATILE AROMATIC HYDROCARBONS

Sample Number:	C92330 Spike	Report Date:	03/01/92
Sample Matrix:	Water	Date Sampled:	02/18/92
Preservative:	Cool	Date Received:	02/20/92
Condition:	Intact	Date Analyzed:	02/24/92

Analyte	Spike Added (ug/L)	Sample Result (ug/L)	Spike Result (ug/L)	Percent Recovery	Acceptance Limit
Benzene	10.0	0.2	11.4	112%	39-150%
Toluene	10.0	ND	9.5	94.8%	46-148%
Ethylbenzene	10.0	ND	10.9	109%	32-160%
p,m-Xylene	20.0	ND	21.4	106%	NE
o-Xylene	10.0	ND	10.2	101%	NE

ND - Analyte not detected at stated detection limit.
NE - Acceptance limit not established

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	96%	88-110%
4-Bromofluorobenzene	98%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**K. W. BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refining		
Project Number:	622092001	Report Date:	03/01/92
Login Number:	9202009	Date Sampled:	02/18/92
Sample ID:	KWB - 4	Date Received:	02/20/92
Sample Number:	C92331	Date Analyzed:	02/25/92
Sample Matrix:	Water		
Preservative:	Cool		
Condition:	Intact		

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	1400	200
Toluene	2300	200
Ethylbenzene	900	200
p,m-Xylene	1600	200
o-Xylene	700	200

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	104%	88-110%
	4-Bromofluorobenzene	106%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovec
Analyst

Wanda M Rog
Review

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3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 9202009
Sample ID: KWB - 5
Sample Number: C92332
Sample Matrix: Water
Preservative: Cool
Condition: Intact

Report Date: 03/01/92
Date Sampled: 02/19/92
Date Received: 02/20/92
Date Analyzed: 02/25/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	11200	200
Toluene	4000	200
Ethylbenzene	3000	200
p,m-Xylene	2300	200
o-Xylene	900	200

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	110%	88-110%
4-Bromofluorobenzene	113%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovec
Analyst

Review

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BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name:	Navajo Refining
Project Number:	622092001
Login Number:	9202009
Sample ID:	KWB - 6
Sample Number:	C92333
Sample Matrix:	Water
Preservative:	Cool
Condition:	Intact

Report Date:	03/01/92
Date Sampled:	02/19/91
Date Received:	02/20/92
Date Analyzed:	02/24/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	33100	200
Toluene	8300	200
Ethylbenzene	3100	200
p,m-Xylene	5300	200
o-Xylene	1800	200

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	100%	88-110%
4-Bromofluorobenzene	104%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Review

Inter·Mountain Laboratories, Inc.

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BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 9202009
Sample ID: KWB - 7
Sample Number: C92334
Sample Matrix: Water
Preservative: Cool
Condition: Intact

Report Date: 03/01/92
Date Sampled: 02/17/92
Date Received: 02/20/92
Date Analyzed: 02/25/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	1.5	0.2
Toluene	2.0	0.2
Ethylbenzene	1.2	0.2
p,m-Xylene	1.2	0.2
o-Xylene	1.0	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	106%	88-110%
4-Bromofluorobenzene	100%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX SPIKE - VOLATILE AROMATIC HYDROCARBONS

Sample Number: C92334 Spike
Sample Matrix: Water
Preservative: Cool
Condition: Intact

Report Date: 03/01/92
Date Sampled: 02/17/92
Date Received: 02/20/92
Date Analyzed: 02/25/92

Analyte	Spike Added (ug/L)	Sample Result (ug/L)	Spike Result (ug/L)	Percent Recovery	Acceptance Limit
Benzene	10.0	1.5	12.8	112%	39-150%
Toluene	10.0	2.0	11.6	96.4%	46-148%
Ethylbenzene	10.0	1.2	11.9	107%	32-160%
p,m-Xylene	20.0	1.2	22.1	104%	NE
o-Xylene	10.0	1.0	10.9	98.8%	NE

ND - Analyte not detected at stated detection limit.
NE - Acceptance limit not established

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	104%	88-110%
4-Bromofluorobenzene	101%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Analyst

Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX SPIKE DUPLICATE - VOLATILE AROMATIC HYDROCARBONS

Sample Number: C92334 Spike Duplicate
Sample Matrix: Water
Preservative: Cool
Condition: Intact

Date Sampled: 02/17/92
Date Received: 02/20/92
Date Analyzed: 02/25/92

Analyte	Spike Result (%)	Duplicate Result (%)	Percent Difference
Benzene	112%	109%	3.3%
Toluene	96.4%	94.0%	2.5%
Ethylbenzene	107%	105%	1.9%
p,m-Xylene	104%	103%	1.7%
0-Xylene	98.8%	98.3%	0.5%

ND - Analyte not detected at stated detection limit.

Quality Control: Duplicate acceptance limit set at 20% difference.

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	105%	88-110%
4-Bromofluorobenzene	103%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Jessica Vandrover
Analyst

Ulonda M Logan
Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**K. W. BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refining		
Project Number:	622092001	Report Date:	03/01/92
Login Number:	9202009	Date Sampled:	02/18/92
Sample ID:	KWB - 8	Date Received:	02/20/92
Sample Number:	C92335	Date Analyzed:	02/25/92
Sample Matrix:	Water		
Preservative:	Cool		
Condition:	Intact		

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	1500	100
Toluene	1000	100
Ethylbenzene	1100	100
p,m-Xylene	800	100
o-Xylene	300	100

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	102%	88-110%
	4-Bromofluorobenzene	102%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovec
Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 9202009
Sample ID: KWB - 9
Sample Number: C92336
Sample Matrix: Water
Preservative: Cool
Condition: Intact

Report Date: 03/01/92
Date Sampled: 02/19/92
Date Received: 02/20/92
Date Analyzed: 02/25/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	1.0	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	0.2	0.2
o-Xylene	0.3	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	110%	88-110%
4-Bromofluorobenzene	106%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Jessica Vandrovec
Analyst

Wanda M Kogan
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refining
Project Number: 622092001
Login Number: 9202009
Sample ID: KWB - Dup
Sample Number: C92337
Sample Matrix: Water
Preservative: Cool
Condition: Intact

Report Date: 03/01/92
Date Sampled: 02/19/92
Date Received: 02/20/92
Date Analyzed: 02/25/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	0.7	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	0.3	0.2
o-Xylene	0.2	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	106%	88-110%
4-Bromofluorobenzene	104%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**K. W. BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refining		
Project Number:	622092001	Report Date:	03/01/92
Login Number:	9202009	Date Sampled:	02/19/92
Sample ID:	Domestic Well-Shallow (Chase)	Date Received:	02/20/92
Sample Number:	C92338	Date Analyzed:	02/25/92
Sample Matrix:	Water		
Preservative:	Cool		
Condition:	Intact		

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	100%	88-110%
	4-Bromofluorobenzene	103%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments: pH=3

Jessica Vandrover
Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**K. W. BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refining		
Project Number:	622092001	Report Date:	03/01/92
Login Number:	9202009	Date Sampled:	NA
Sample ID:	Travel Blank	Date Received:	02/20/92
Sample Number:	C92339TB	Date Analyzed:	02/26/92
Sample Matrix:	Water		
Preservative:	HCl, Cool		
Condition:	Intact		

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	104%	88-110%
	4-Bromofluorobenzene	104%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments: pH=2

Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
METHOD BLANK - VOLATILE AROMATIC HYDROCARBONS

Sample Number: MB022492V1 Date Analyzed: 2/24/92
Sample Matrix: Water

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	100%	88-110%
4-Bromofluorobenzene	100%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Jessica Vandrovec
Analyst

Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
METHOD BLANK - VOLATILE AROMATIC HYDROCARBONS

Sample Number: MB022592V2
Sample Matrix: Water
Date Analyzed: 2/25/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	110%	88-110%
4-Bromofluorobenzene	112%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Analyst

Review

iml
Inter-Mountain
Laboratories, Inc.

11183 SH 30
College Station, Texas 77845
Phone (409) 776-8945

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
500 Graham Road
College Station, TX 77845

2/26/92

Re: Navajo Refinery
P.O. #
Project No. 622092001
Login No.

IML Lab No.	C92328/13028	C92329/13029	C92330/13030
Sample Id.	KWB-1A	KWB-2A	KWB-3A
Date Sampled	02/17/92	02/19/92	02/18/92
Date Received	02/24/92	02/24/92	02/24/92
pH s.u.	7.1	7.4	7.1
Conductivity umhos/cm	5741.	4116.	6460.
Calcium mg/L	577.	447.	688.
Magnesium mg/L	379.	231.	258.
Potassium mg/L	5.0	4.0	8.5
Sodium mg/L	285.	144.	400.
Alkalinity mg/L	373.	282.	347.
Chloride mg/L	275.	155.	412.
Sulfate mg/L	2661.	1804.	2547.

Reviewed by: Mitch Swan
Mitch Swan--Water Laboratory Supervisor

iml
Inter-Mountain
Laboratories, Inc.

11183 SH 30
College Station, Texas 77845
Phone (409) 776-8945

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
500 GRAHAM ROAD
COLLEGE STATION, TEXAS 77845

3/16/92

PROJECT #622092001

PROJECT NAME: NAVAJO REFINERY

IML Lab No.		C92331/13031	C92332/13032	C92333/13033
Sample ID.		KWB-4	KWB-5	KWB-6
Date Sampled		2/18/92	2/19/92	2/19/92
Date Received		2/24/92	2/24/92	2/24/92
pH	s.u.	6.7	7.2	7.1
CONDUCTIVITY	umhos/cm	3730.	2310.	2540.
CALCIUM	mg/L	260.	191.	210.
MAGNESIUM	mg/L	162.	116.	124.
POTASSIUM	mg/L	1.2	1.0	1.2
SODIUM	mg/L	279.	104.	138.
TOTAL ALKALINITY	mg/L	566.	757.	736.
CHLORIDE	mg/L	629.	248.	275.
SULFATE	mg/L	432.	65.	179.

Reviewed by: Mitch Swan
Mitch Swan, Supervisor--Water Operations

iml
Inter-Mountain
Laboratories, Inc.

11183 SH 30
College Station, TX 77845
Phone (409) 776-8945
FAX (409) 774-4705

Client: **K. W. BROWN ENVIRONMENTAL SERVICES**
500 Graham Road
College Station, TX 77845

5/18/92

Re: Navajo Refinery
Project No. 622092001
Revised Report

IML Lab No.	C92334/13034	C92335/13035	C92336/13036
Sample Id.	KWB-7	KWB-8	KWB-9
Date Sampled	02/17/92	02/18/92	02/19/92
Date Received	02/24/92	02/24/92	02/24/92
pH s.u.	7.2	7.3	7.1
Conductivity umhos/cm	3410.	3530.	3390.
Calcium mg/L	291.	471.	276.
Magnesium mg/L	185.	204.	186.
Potassium mg/L	0.8	0.9	0.6
Sodium mg/L	203.	148.	219.
Alkalinity mg/L	459.	388.	624.
Chloride mg/L	279.	124.	330.
Sulfate mg/L	1090.	1750.	787.

Reviewed by: Mitch Swan
Mitch Swan--Water Laboratory Supervisor

iml
Inter-Mountain Laboratories, Inc.

11183 SH 30
College Station, Texas 77845
Phone (409) 776-8945

Client: K. W. BROWN ENVIRONMENTAL SERVICES
500 GRAHAM ROAD
COLLEGE STATION, TEXAS 77845

3/16/92

PROJECT #622092001

PROJECT NAME: NAVAJO REFINERY

IML Lab No.		C92337/13037	C92338/13038	C92339/13039
Sample ID.		KWB-DUP	Domestic well-Shallow	KWB-5 (DUP)
Date Sampled		2/19/92	2/19/92	2/19/92
Date Received		2/24/92	2/24/92	2/24/92
pH	s.u.	7.2	7.5	7.2
CONDUCTIVITY	umhos/cm	5710.	3740.	2310.
CALCIUM	mg/L	652.	340.	180.
MAGNESIUM	mg/L	261.	126.	117.
POTASSIUM	mg/L	3.0	2.1	1.0
SODIUM	mg/L	435.	357.	112.
TOTAL ALKALINITY	mg/L	236.	171.	754.
CHLORIDE	mg/L	428.	536.	244.
SULFATE	mg/L	2690.	1130.	66.

Reviewed by: Mitch Swan

Mitch Swan, Supervisor--Water Operations

CHAIN OF CUSTODY RECORD

Project No. 622092001	Project Name Navajo Refinery	P.M. DB	Login No.	P.O. No.

FILE COPY

Sample Identification	Date	Time	Sample Container (Size/Material)	Sample Type (Liquid, Soil, etc.)	Preser-vative	Analyses Requested A	B	C	D	E	F	Comments
KWB - 1A	2/17	1645	2 VOAS/Glass 1 Liter/Plastic	Liquid	HCL No	X	X	X	X			C92328
KWB - 2A	2/19	1230				X	X	X	X			C92329
KWB - 3A	2/18	1230				X	X	X	X			C92330
KWB - 4	2/18	1750				X	X	X	X			C92331
KWB - 5	2/19	0915				X	X	X	X			C92332
KWB - 6	2/19	1030				X	X	X	X			C92333
KWB - 7	2/17	1630				X	X	X	X			C92334
KWB - 8	2/18	1450				X	X	X	X			C92335
KWB - 9	2/19	0920				X	X	X	X			C92336
KWB - Dup	2/19	—				X	X	X	X			C92337
Domestic Well - Shallow (Chase)	2/19	1700				X	X	X	X			C92338
Trip Blank												C92339

Relinquished By (Signature)	Date	Time	Received By (Signature)
	2/20/92	0930	

Analyses:

A BETX
B Major Cations / Anions
C pH
D EC
E
F

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

Mr. David Boyer
KW Brown Environmental Services
500 Graham Road
College Station, Texas 77845

25 March 1992

Dear Mr. Boyer,

On 10 March 1992, six soil samples and one water sample were received by Inter-Mountain Laboratories - College Station. The samples were received cool and in good condition. The samples were identified by Project Name "Navajo Refinery" and Project Number 622092001. Analysis for Benzene-Toluene-Ethylbenzene-Xylenes (BETX) was performed according to the accompanying chain of custody forms. No trip blank accompanied the shipment.

It is the policy of this laboratory to employ, whenever possible, preparatory and analytical methods which have been approved by regulatory agencies. The methods used in the analysis of samples reported herein are found in "Test Methods for Evaluating Solid Waste", SW-846, USEPA, 1986. All reports in this package reference methods utilized.

A Hewlett-Packard 5890 Series II Gas Chromatograph and a Tekmar Purge and Trap were utilized for sample analysis. Volatile analysis was performed in accordance with EPA Method 8020: Aromatic Volatile Organics. No BTEX was detected in Samples COLL / EW - 1 and Gurley Domestic Well at stated detection limits. All other samples had significant amounts of the BTEX analytes and are reported in mg/KG (ppm).

Quality Control reports have been included for your information and use. These reports appear at the end of the analytical package and may be identified by title. If you have any questions regarding the information in this package, please feel free to call at your convenience.

Sincerely,

Ulonda M Rogers

Ulonda M. Rogers
Project Manager

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**KW BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refinery	Report Date:	03/18/92
Project Number:	622092001	Date Sampled:	03/04/92
Login Number:	9203003	Date Received:	03/10/92
Sample ID:	COLL / ALF - 1	Date Extracted:	03/18/92
Sample Number:	C92617	Date Analyzed:	03/18/92
Sample Matrix:	Soil		
Preservative:	Cool		
Condition:	Intact		

Analyte	Concentration (mg/Kg)	Detection Limit (mg/Kg)
Benzene	133	4
Toluene	227	4
Ethylbenzene	236	4
p,m-Xylene	417	4
o-Xylene	145	4

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	107%	88-110%
	4-Bromofluorobenzene	109%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Lance Looper
Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**KW BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refinery	Report Date:	03/20/92
Project Number:	622092001	Date Sampled:	03/03/92
Login Number:	9203003	Date Received:	03/10/92
Sample ID:	ANDERSON - 5	Date Extracted:	03/17/92
Sample Number:	C92618	Date Analyzed:	03/17/92
Sample Matrix:	Soil		
Preservative:	Cool		
Condition:	Intact		

Analyte	Concentration (mg/Kg)	Detection Limit (mg/Kg)
Benzene	50	2
Toluene	95	2
Ethylbenzene	79	2
p,m-Xylene	130	2
o-Xylene	45	2

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	99%	88-110%
	4-Bromofluorobenzene	99%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Lance Looper
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **KW BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refinery
Project Number: 622092001
Login Number: 9203003
Sample ID: COLL / NS - 4
Sample Number: C92619
Sample Matrix: Soil
Preservative: Cool
Condition: Intact

Report Date: 03/20/92
Date Sampled: 03/06/92
Date Received: 03/10/92
Date Extracted: 03/18/92
Date Analyzed: 03/18/92

Analyte	Concentration (mg/Kg)	Detection Limit (mg/Kg)
Benzene	34	5
Toluene	93	5
Ethylbenzene	92	5
p,m-Xylene	1539	5
o-Xylene	52	5

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	104%	88-110%
4-Bromofluorobenzene	101%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Lance Looper
Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client:	**KW BROWN ENVIRONMENTAL SERVICES**		
Project Name:	Navajo Refinery	Report Date:	03/20/92
Project Number:	622092001	Date Sampled:	03/06/92
Login Number:	9203003	Date Received:	03/10/92
Sample ID:	COLL / EW - 1	Date Extracted:	03/18/92
Sample Number:	C92620	Date Analyzed:	03/18/92
Sample Matrix:	Soil		
Preservative:	Cool		
Condition:	Intact		

Analyte	Concentration (mg/Kg)	Detection Limit (mg/Kg)
Benzene	ND	0.1
Toluene	ND	0.1
Ethylbenzene	ND	0.1
p,m-Xylene	ND	0.1
o-Xylene	ND	0.1

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	90%	88-110%
4-Bromofluorobenzene	89%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Lance Looper
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **KW BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refinery
Project Number: 622092001
Login Number: 9203003
Sample ID: COLL / HOUSE - 1
Sample Number: C92621
Sample Matrix: Soil
Preservative: Cool
Condition: Intact

Report Date: 03/20/92
Date Sampled: 03/07/92
Date Received: 03/10/92
Date Extracted: 03/18/92
Date Analyzed: 03/18/92

Analyte	Concentration (mg/Kg)	Detection Limit (mg/Kg)
Benzene	20	2
Toluene	74	2
Ethylbenzene	44	2
p,m-Xylene	73	2
o-Xylene	27	2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	111%	88-110%
4-Bromofluorobenzene	109%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Lance Cooper
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **KW BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refinery
Project Number: 622092001
Login Number: 9203003
Sample ID: CHASE - 3
Sample Number: C92622
Sample Matrix: Soil
Preservative: Cool
Condition: Intact

Report Date: 03/20/92
Date Sampled: 03/09/92
Date Received: 03/10/92
Date Extracted: 03/18/92
Date Analyzed: 03/18/92

Analyte	Concentration (mg/Kg)	Detection Limit (mg/Kg)
Benzene	29	2
Toluene	69	2
Ethylbenzene	89	2
p,m-Xylene	106	2
o-Xylene	41	2

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	117%	88-110%
	4-Bromofluorobenzene	116%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Wenda M Rog
Analyst

Lance Looper
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
METHOD BLANK - VOLATILE AROMATIC HYDROCARBONS

Sample Number: MB031892V1
Sample Matrix: Solid
Date Extracted: 03/18/92
Date Analyzed: 03/18/92

Analyte	Concentration (ug/Kg)	Detection Limit (ug/Kg)
Benzene	ND	100
Toluene	ND	100
Ethylbenzene	ND	100
p,m-Xylene	ND	100
o-Xylene	ND	100

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	100%	88-110%
4-Bromofluorobenzene	100%	86-115%

Reference:
Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Analyst

Lance Cooper
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
METHOD BLANK - VOLATILE AROMATIC HYDROCARBONS

Sample Number: MB031892V2
Sample Matrix: Solid

Date Extracted: 03/18/92
Date Analyzed: 03/18/92

Analyte	Concentration (ug/Kg)	Detection Limit (ug/Kg)
Benzene	ND	100
Toluene	ND	100
Ethylbenzene	ND	100
p,m-Xylene	ND	100
o-Xylene	ND	100

ND - Analyte not detected at stated detection limit.

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	100%	88-110%
	4-Bromofluorobenzene	101%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Wanda M Koger
Analyst

Lance Looper
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
METHOD BLANK - VOLATILE AROMATIC HYDROCARBONS

Sample Number: MB031892V1
Sample Matrix: Water

Date Analyzed: 3/18/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	0.5	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	100%	88-110%
4-Bromofluorobenzene	100%	86-115%

Reference:

Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Analyst

Lance Looper
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

BTEX
VOLATILE AROMATIC HYDROCARBONS

Client: **KW BROWN ENVIRONMENTAL SERVICES**
Project Name: Navajo Refinery
Project Number: 622092001
Login Number: 9203003
Sample ID: Gurley Domestic Well
Sample Number: C92623
Sample Matrix: Water
Preservative: HCl, Cool
Condition: Intact

Report Date: 03/20/92
Date Sampled: 03/09/92
Date Received: 03/10/92
Date Analyzed: 03/18/92

Analyte	Concentration (ug/L)	Detection Limit (ug/L)
Benzene	ND	0.2
Toluene	ND	0.2
Ethylbenzene	ND	0.2
p,m-Xylene	ND	0.2
o-Xylene	ND	0.2

ND - Analyte not detected at stated detection limit.

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	89%	88-110%
4-Bromofluorobenzene	90%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Lance Looper
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX SPIKE - VOLATILE AROMATIC HYDROCARBONS

Sample Number:	C92623 SPK	Report Date:	03/20/92
Sample Matrix:	Water	Date Sampled:	03/09/92
Preservative:	HCl, Cool	Date Received:	03/10/92
Condition:	Intact	Date Analyzed:	03/18/92

Analyte	Spike Added (ug/L)	Sample Result (ug/L)	Spike Result (ug/L)	Percent Recovery	Acceptance Limit
Benzene	10.0	ND	11.5	115%	39-150%
Toluene	10.0	ND	9.6	96%	46-148%
Ethylbenzene	10.0	ND	10.3	103%	32-160%
p,m-Xylene	20.0	ND	20.1	101%	NE
o-Xylene	10.0	ND	9.9	99%	NE

ND - Analyte not detected at stated detection limit.
NE - Acceptance limit not established

Quality Control:

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	94%	88-110%
4-Bromofluorobenzene	101%	86-115%

Reference:

Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Analyst

Lance Cooper
Review

Inter-Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX SPIKE - VOLATILE AROMATIC HYDROCARBONS

Sample Number:	C92620 SPIKE	Date Sampled:	03/06/92
Sample Matrix:	Soil	Date Received:	03/10/92
Preservative:	Cool	Date Extracted:	03/18/92
Condition:	Intact	Date Analyzed:	03/18/92

Analyte	Spike Added (ug/Kg)	Sample Result (ug/Kg)	Spike Result (ug/Kg)	Percent Recovery	Acceptance Limit
Benzene	1340	ND	1210	90.4%	39-150%
Toluene	1340	ND	1210	90.4%	46-148%
Ethylbenzene	1340	ND	1260	94.4%	32-160%
p,m-Xylene	2670	ND	2400	89.9%	NE
o-Xylene	1340	ND	1200	89.8%	NE

ND - Analyte not detected at stated detection limit
NE - Acceptance limit not established

Quality Control:	Surrogate	Percent Recovery	Acceptance Limits
	Toluene-d8	105%	88-110%
	4-Bromofluorobenzene	103%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, November 1986.

Comments:

Analyst

Lance Lopez
Review

Inter·Mountain Laboratories, Inc.

3304 Longmire
College Station, Texas 77845

QUALITY CONTROL REPORT
MATRIX DUPLICATE - VOLATILE AROMATIC HYDROCARBONS

Sample Number:	C92617 DUP	Date Sampled:	03/04/92
Sample Matrix:	Soil	Date Received:	03/10/92
Preservative:	Cool	Date Extracted:	03/18/92
Condition:	Intact	Date Analyzed:	03/18/92

Analyte	Sample Result (mg/Kg)	Duplicate Result (mg/Kg)	Percent Difference
Benzene	133	143	6.7%
Toluene	227	261	14.1%
Ethylbenzene	236	285	18.7%
p,m-Xylene	417	522	22.3%
o-Xylene	145	185	24.0%

ND - Analyte not detected at stated detection limit.

Quality Control: Duplicate acceptance limit set at 30% difference.

Surrogate	Percent Recovery	Acceptance Limits
Toluene-d8	110%	88-110%
4-Bromofluorobenzene	113%	86-115%

Reference: Method 5030, Purge and Trap
Method 8020, Aromatic Volatile Organics
SW-846, Test Methods for Evaluating Solid Wastes, United States Environmental Protection Agency, September 1986.

Comments:

Analyst

Lance Cooper
Review

CHAIN OF CUSTODY RECORD

Project No. 6R2092001 | Project Name NAVAJO REFINERY | .M. D. BOYER | Login No. 9203003 | P.O. No. 43138

FILE COPY

Sample Identification	Date	Time	Sample Container (Size/Material)	Sample Type (Liquid, Soil, etc.)	Preservative	Analyses Requested A	B	C	D	E	F	Comments
COLL/ALF-1	3/4/92	0850	2 40ml Glass Jars	Soil		X						C92617
ANDERSON-5	3/3/92	0835	" "	" "		X						C92618
COLL/NS-4	3/6/92	1145	" "	" "		X						C92619
COLL/EW-1	3/6/92	1510	" "	" "		X						C92620
COLL/HOUSE-1	3/7/92	1115	" "	" "		X						C92621
CHASE-3	3/9/92	1010	" "	" "		X						C92622
GURLEY DOMESTIC WELL	3/9/92	1300	2 20ml Glass Jars	Liquid	HCL	X						C92623

Relinquished By (Signature)	Date	Time	Received By (Signature)
Philip Colwell	3/9/92	1600	Lance Cooper

Analyses:

A BETX

B

C

D

E

F

NAVAJO REFINING COMPANY

ARTESIA, NEW MEXICO

PLEASE DELIVER 2 PAGES INCLUDING THIS COVER PAGE

TO: Dave Boyer

WITH: K.W. Brown

FROM: Dave Griffin

FAX # (409) 690-7310

IF YOU DO NOT RECEIVE ALL PAGES PLEASE CALL (505)748-3311 EXT. [redacted] 270

NOTE: Plume Product Analyses

Aromatic = 27.8 Vol %
; OLEFIN = 3.3 Vol %

DISTILLATION RECORD

PLANT
Date 3/4/92
Tank No. REC WELL - K.W.B.
Tank Car No.

Gravity 52.7
I.B.P. 110
5%
10% 162
20% 189
30% 214
40% 238
50% 264
60% 296
70% 334
75% ~~[illegible]~~
80% 382
85%
90% 456
95%
D.P. 490
E.P. 600
RON
MON
R+M
2

Kind Test Well Sample
Flash (O.C.)
" (T.C.C.)
" (Foster)
" (P.M.)
Cetane
Vis. @
C.T.
Color
Doctor
Sulfur 0.23
B.S. & W. %
C.R.
Stability
W. Cloud
M. Cloud
Pour Point
Reid V.P.

0% MTBE

% Rec. % Res. % Loss

(Signed)
Bryan Printers & Stationers, Inc. Form No. 155

Sg ≅ 0.768

DISTILLATION RECORD

PLANT
Date 10-2-91
Tank No. PTE. OF 402 TK
Tank Car No.

Gravity 43.2
I.B.P. 184
5%
10% 234
20% 270
30% 304
40% 338
50% 364
60% 406
70% 439
75%
80% 480
85%
90% 582
95%
D.P.
E.P. 600 +
RON
MON
R+M
2

Kind Test Well Sample
Flash (O.C.)
" (T.C.C.)
" (Foster)
" (P.M.)
Cetane
Vis. @
C.T.
Color Distillate
Doctor Pass
Sulfur 0.54/0.40
B.S. & W. %
C.R.
Stability
W. Cloud
M. Cloud
Pour Point
Reid V.P.

.106 Grams lead per U.S. GAL

% Rec. 96.0 % Res. % Loss

(Signed)
Bryan Printers & Stationers, Inc. Form No. 155

DISTILLATION RECORD

PLANT
Date 11/12/91
Tank No.
Tank Car No. BORE #1 ZRS

Gravity 51.0
I.B.P. 106
5%
10% 160
20% 194
30% 226
40% 256
50% 298
60% 342
70% 390
75% —
80% 428
85% —
90% 474
95% —
D.P.
E.P. 576
RON
MON
R+M
2

Kind
Flash (O.C.)
" (T.C.C.)
" (Foster)
" (P.M.)
Cetane
Vis. @
C.T.
Color
Doctor
Sulfur 0.21/0.11
B.S. & W. %
C.R.
Stability
W. Cloud
M. Cloud
Pour Point
Reid V.P.

% Rec. 97 % Res. % Loss

(Signed)
Bryan Printers & Stationers, Inc. Form No. 155

DISTILLATION RECORD

PLANT
Date 10/7/91
Tank No.
Tank Car No. BOREHOLE #12

Gravity 52.6
I.B.P. 110
5%
10% 158
20% 182
30% 208
40% 232
50% 262
60% 300
70% 348
75%
80% 394
85%
90% 466
95%
D.P. ~~[illegible]~~
E.P. 572
RON
MON
R+M
2

Kind
Flash (O.C.)
" (T.C.C.)
" (Foster)
" (P.M.)
Cetane
Vis. @
C.T.
Color
Doctor Dist
Sulfur 0.23/0.16
B.S. & W. %
C.R. ~~[illegible]~~
Stability
W. Cloud
M. Cloud
Pour Point
Reid V.P.

TEL 0.166
Aromatics = 21.6
olefins 4.9

% Rec. 96 % Res. 3 % Loss

(Signed)
Bryan Printers & Stationers, Inc. Form No. 155

APPENDIX E

APPENDIX E

Land Survey

NAVAJO REFINERY
LOCATION OF MONITOR WELLS
SECTIONS 9, 10, 15, AND 16
T.17S., R.26E., N.M.P.M.,
EDDY COUNTY, NEW MEXICO

WELL	ELEVATION			CASING SIZE	COORDINATES	
	A	B	C		NORTHING	EASTING
KWB-1A	3351.07	49.10	48.7	2"	5171.71	5193.86
KWB-1B	3351.06	49.18	48.8	4"	5172.42	5181.92
KWB-2A	3366.18	64.03	63.8	2"	1659.24	3905.78
KWB-2B	3366.40	64.12	63.9	4"	1646.63	3905.71
KWB-3A	3345.49	45.49	45.3	2"	2183.45	7907.17
KWB-3B	3345.52	45.52	45.3	4"	2193.17	7905.71
KWB-4	3368.33	65.81	65.4	4"	2811.44	3574.80
KWB-5	3363.02	60.92	60.6	4"	2928.10	4245.94
KWB-6	3358.71	56.41	56.1	4"	2652.58	5161.82
KWB-7	3344.14	41.80	41.6	2"	3484.17	8055.72
KWB-8	3348.59	46.22	45.8	2"	3211.93	6875.69
KWB-9	3352.67	49.90	49.8	4"	1838.15	6600.55

NOTE: BASIS OF BEARING, COORDINATES AND ELEVATIONS ARE DERIVED FROM NAVAJO REFINING CONTROL.

JOHN D. JAQUESS & ASSOCIATES
CONSULTING ENGINEERS
ROSWELL **NEW MEXICO**

RECEIVED
JUN 25 1992
OIL CONSERVATION DIV.
SANTA FE

SURVEYOR'S CERTIFICATE AND AFFIDAVIT

State of New Mexico)
County of Chaves)

I, John D. Jaquess, Professional Engineer and Land Surveyor, licensed under the laws of the State of New Mexico, hereby certify that the accompanying plat was prepared from an actual bona fide field survey and have found the lines and marked them as shown on the accompanying plat, and that the survey and plat are true and correct to the best of my knowledge and belief.

John D. Jaquess
John D. Jaquess, P.E. & P.S.
New Mexico License No. 6290

REVISED 5-12-92
REVISED 4-7-92

APPENDIX F

APPENDIX F

Logs of Borings

BORING LOG

PROJECT: 622092001-237 (B67)
CLIENT: Navajo Refinery
BORING NUMBER: B67
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 27'
DATE COMPLETED: 03/03/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 29'

DESCRIPTION

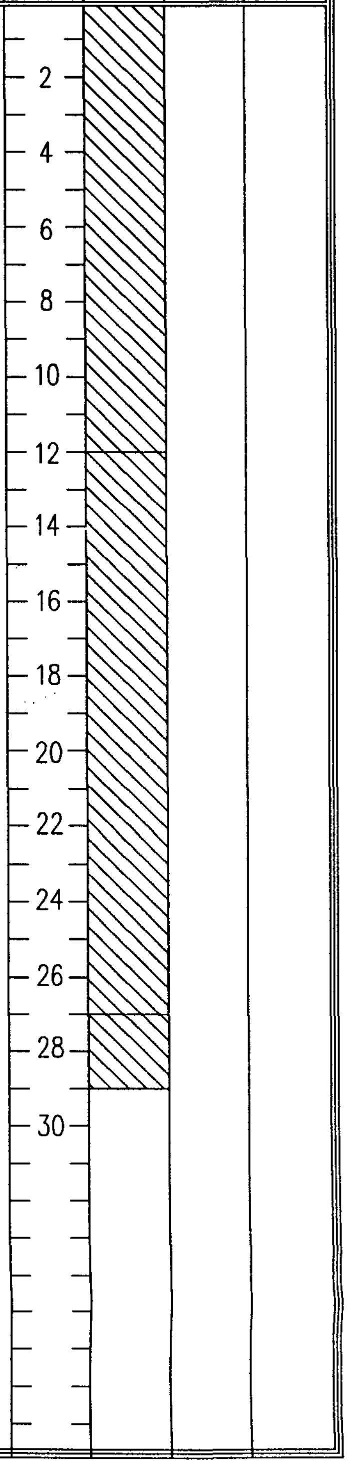
DEPTH (ft.) | SYMBOL | SAMPLE | WELL DESIGN

0-12' SANDY CLAY, dark brown to brown, moist to dry, increasing pebble content with depth, plastic to stiff.

12-27' SANDY CLAY, gray hydrocarbon staining beginning at 12' becoming a bluish-gray color in a zone from 14-16', strong hydrocarbon odor, moist, color becoming lighter gray after 16'.

27-29' SANDY CLAY, gray, saturated, strong hydrocarbon odor, some gravel.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Thickness
3/4/92	-	23.35'	film (<1/16")



KWBES

BORING LOG

PROJECT: 622092001-237 (B68)
CLIENT: Navajo Refinery
BORING NUMBER: B68
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 26'
DATE COMPLETED: 03/02/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 28'

DESCRIPTION

0-11' SANDY CLAY, dark brown to brown, moist to dry, increasing pebble content with depth, plastic to stiff.

11-16' CLAY, tan, with small pockets of fine white sand, moist, occasional small pebbles.

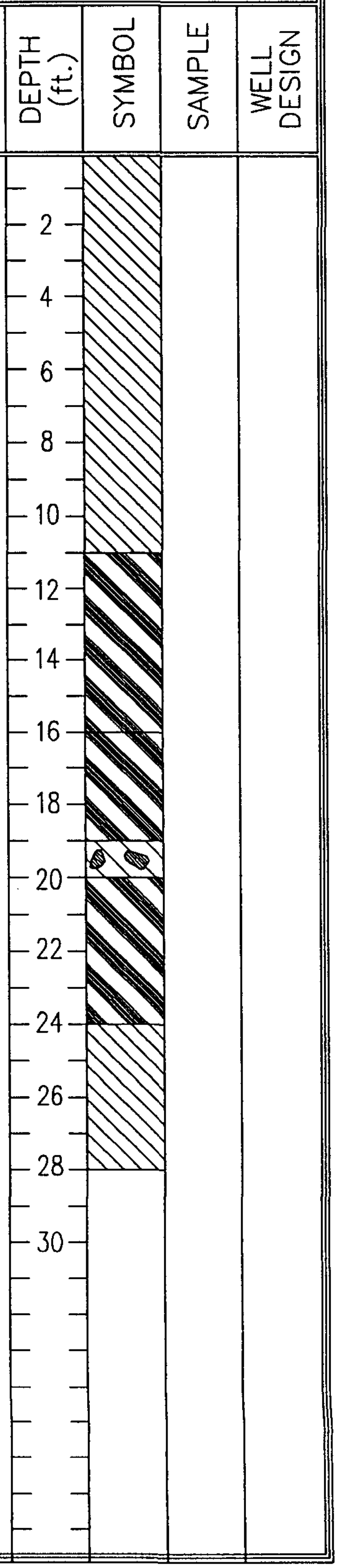
16-19' CLAY, brown, with small pockets of fine white sand and pebbles, moist.

19-20' GRAVEL with clay mix, gray hydrocarbon staining noticeable in clay, slight odor.

20-24' CLAY, progressively darker staining, increasing moisture content and odor.

24-28' CLAY TO SANDY CLAY, gray hydrocarbon staining, interspersed thin gravel seams, saturated sandy clay at 26'.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/4/92	-	22.79'	film (<1/16")



KWBES

BORING LOG

PROJECT: 622092001-237 (B69)
CLIENT: Navajo Refinery
BORING NUMBER: B69
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 28'
DATE COMPLETED: 03/03/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 29'

DESCRIPTION

0-8' SANDY CLAY, dark brown to brown, moist to dry, plastic to stiff.

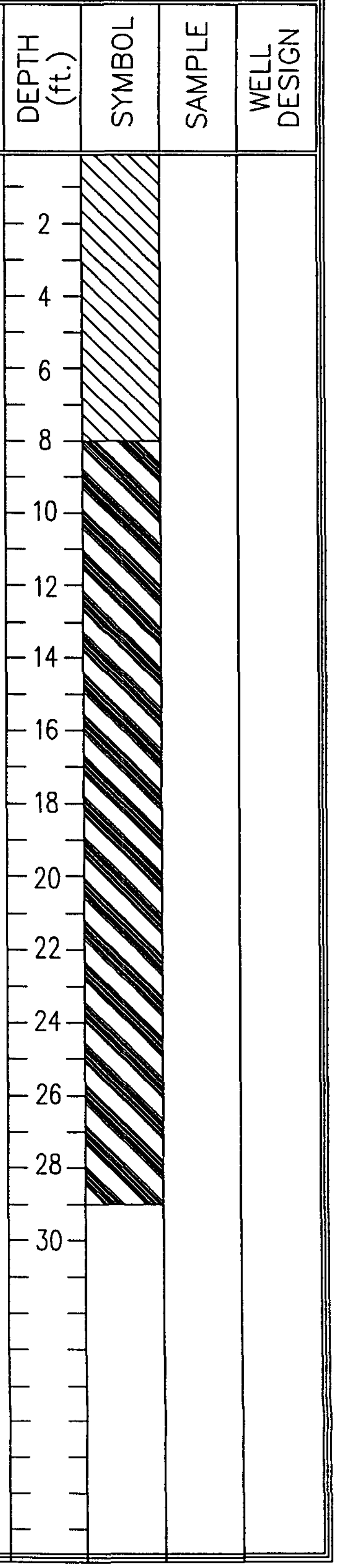
8-14' CLAY, tan, with small pockets of fine white sand, moist, occasional pebbles.

14-26' CLAY, brown, moist, plastic, some small pockets of fine white sand, occasional pebbles.

26-29' CLAY, brown, at 28', increasing pebble content and moisture, saturated, slight gray hydrocarbon staining and odor from 26-29',

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/4/92	22.27'	22.83'	0.56'

NOTE: When auger removed from hole, brownish colored free product was on last flight.



BORING LOG

PROJECT: 622092001-237 (B70)
CLIENT: Navajo Refinery
BORING NUMBER: B70
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 26'
DATE COMPLETED: 03/02/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 29'

DESCRIPTION

DEPTH (ft.) | SYMBOL | SAMPLE | CUTTING

0-10' SANDY CLAY, dark brown to brown, moist to dry, plastic to stiff.

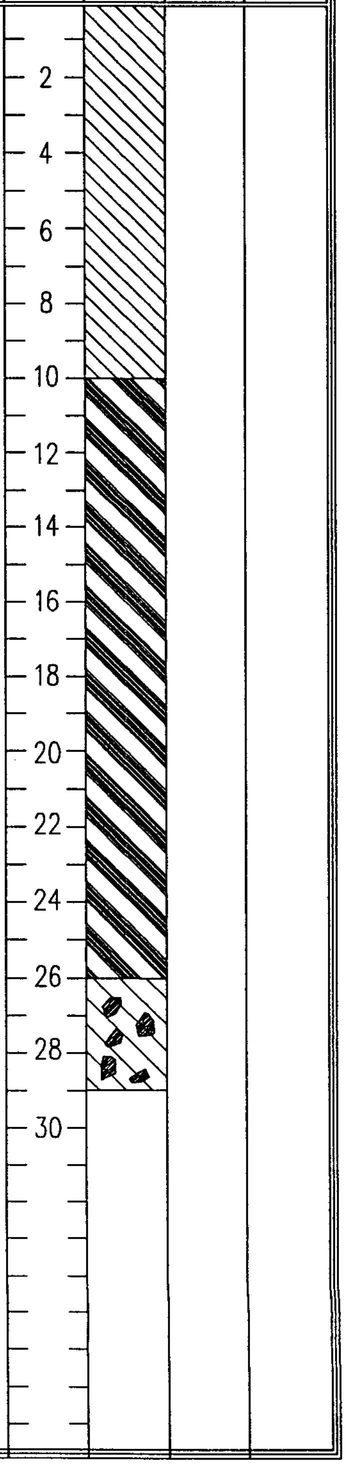
10-14' CLAY, reddish brown, with occasional small pockets of fine white sand, moist, plastic.

14-16' CLAY, tan, with small pebbles throughout, moist, plastic.

21-26' CLAY, brown, with occasional pockets of fine sand and pebbles, moist, plastic.

26-29' GRAVEL mixed with CLAY, gray hydrocarbon staining, saturated, rocks to 2 inches in diameter, strong odor.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/4/92	22.04'	22.08'	0.04'



KWBES

BORING LOG

PROJECT: 622092001-237 (B71)
CLIENT: Navajo Refinery
BORING NUMBER: B71
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 24'
DATE COMPLETED: 03/03/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 25'

DESCRIPTION

0-7' SANDY CLAY, dark brown to brown, moist to dry, plastic to stiff.

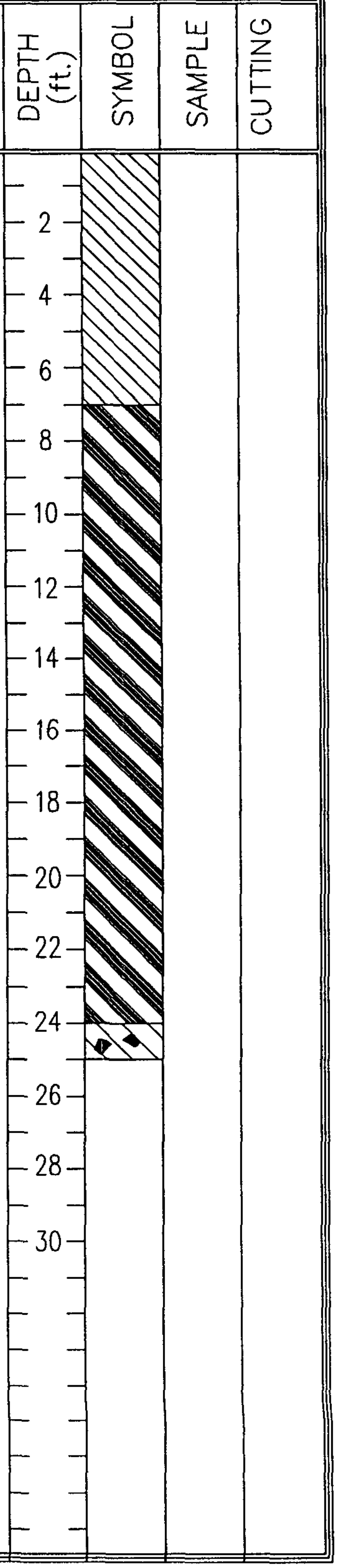
7-11' CLAY with SAND, tan, moist, plastic, occasional pebbles.

11-17' CLAY, brown, with some small pockets of fine white sand, moist, plastic.

17-24' CLAY, gray hydrocarbon staining, moist, color is darker with depth, some pebbles.

24-25' GRAVEL mixed with CLAY, gray staining, saturated.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/4/92	18.12'	20.34'	2.22'



KWBES

BORING LOG

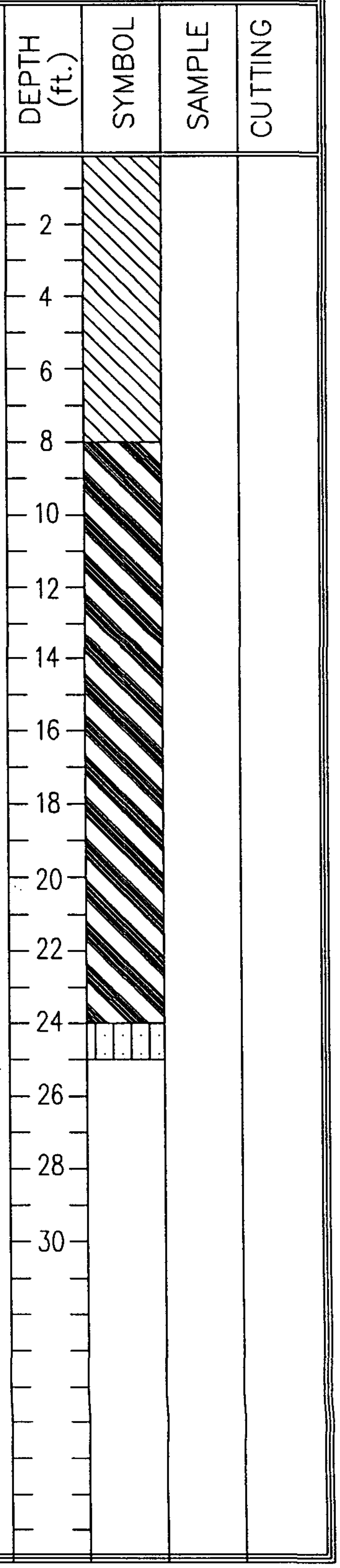
PROJECT: 622092001-237 (B72)
CLIENT: Navajo Refinery
BORING NUMBER: B72
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 24'
DATE COMPLETED: 03/03/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 25'

DESCRIPTION

0-8'	SANDY CLAY, dark brown to brown, moist, plastic.
8-15'	CLAY, tan, with some small pockets of fine white sand, moist, occasional small pebbles, plastic.
15-16'	CLAY, brown, moist, plastic, occasional small pebbles.
16-24'	CLAY, gray hydrocarbon staining, moist, plastic, occasional small pebbles, color becoming darker with depth.
24-25'	SILTY SAND, gray hydrocarbon staining, saturated, strong odor.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/4/92	18.53'	18.55'	0.02'



KWBES

BORING LOG

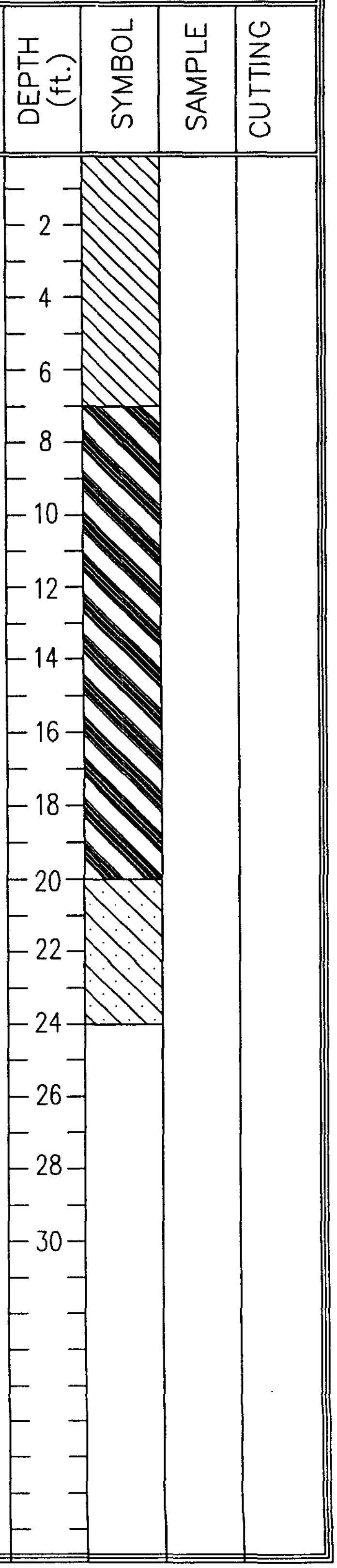
PROJECT: 622092001-237 (B73)
CLIENT: Navajo Refinery
BORING NUMBER: B73
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 20'
DATE COMPLETED: 03/03/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 24'

DESCRIPTION

0-7'	SANDY CLAY, dark brown to brown, moist, plastic.
7-11'	CLAY, tan, with some small pockets of fine white sand, moist, plastic.
11-20'	CLAY, brown, with small pockets of fine sand and occasional pebbles, moist, plastic.
20-24'	CLAYEY SAND, gray hydrocarbon staining, saturated, increasing odor with depth.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/4/92	-	19.34'	Film (<1/16")



KWBES

BORING LOG

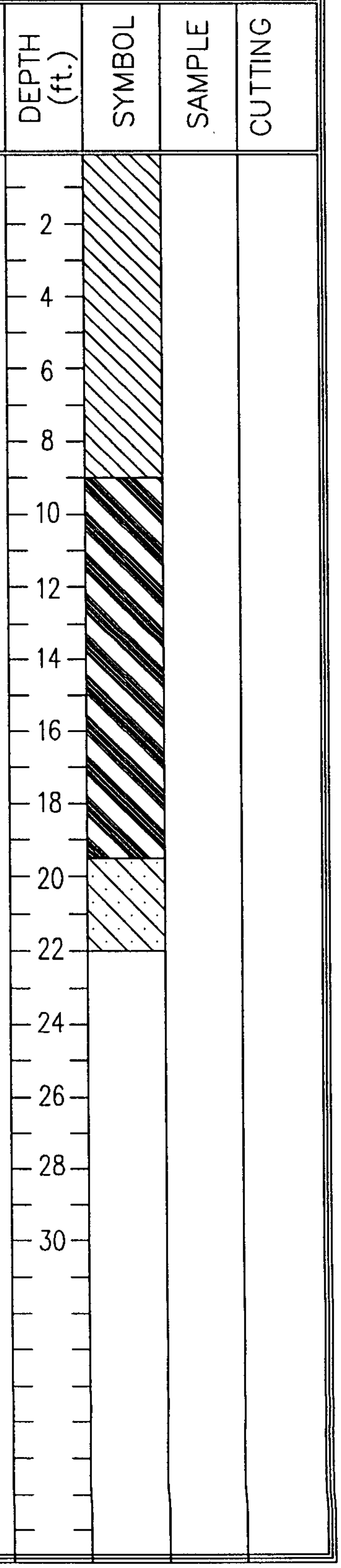
PROJECT: 622092001-237 (B74)
CLIENT: Navajo Refinery
BORING NUMBER: B74
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 19.5'
DATE COMPLETED: 03/04/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 22'

DESCRIPTION

0-9'	SANDY CLAY, dark brown to brown, moist to dry, plastic.
9-11'	CLAY, tan, moist, plastic.
11-19.5'	CLAY, gray hydrocarbon staining, moist, plastic, color becoming darker with depth, very strong hydrocarbon odor.
19.5-22'	CLAYEY SAND, dark gray staining, saturated, brown colored free product coming to surface on auger flights.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/5/92	15.89'	18.80'	2.91'



KWBES

BORING LOG

PROJECT: 622092001-237 (B75)
CLIENT: Navajo Refinery
BORING NUMBER: B75
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 21'
DATE COMPLETED: 03/04/92

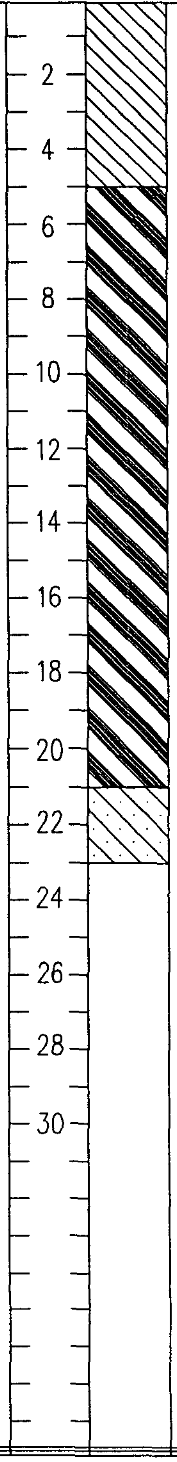
SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 23'

DESCRIPTION

DEPTH (ft.) | SYMBOL | SAMPLE | CUTTING

0-5'	SANDY CLAY, dark brown to brown, moist to dry, plastic.
5-16'	CLAY, tan, with occasional pockets of fine sand, moist, plastic.
16-21'	CLAY, gray hydrocarbon staining, moist, plastic, color becoming darker with depth, pronounced odor increase with depth.
21-23'	CLAYEY SAND, gray staining, saturated, strong hydrocarbon odor, brown colored free product evident on auger.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/5/92	16.42'	16.63'	0.21'



KWBES

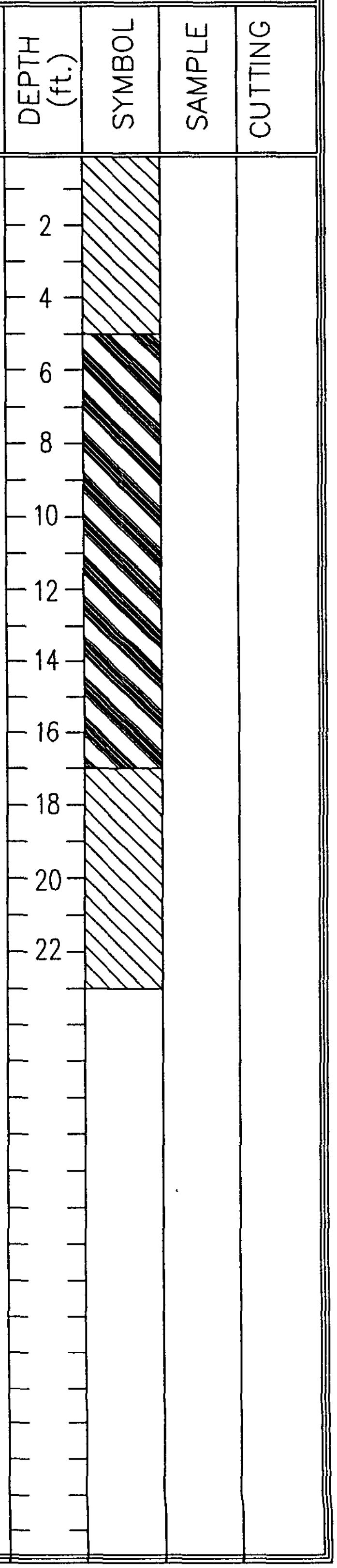
BORING LOG

PROJECT: 622092001-237 (B76)
CLIENT: Navajo Refinery
BORING NUMBER: B76
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 22'
DATE COMPLETED: 03/04/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 23'

DESCRIPTION

0-7'	SANDY CLAY, dark brown to brown, moist to dry, plastic.
7-17'	CLAY, tan, with occasional small pockets of fine white sand, moist, plastic.
17-23'	SANDY CLAY, tan, moist, saturated at 22', very faint hydrocarbon smell, no visible staining.



Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/5/92	17.26'	17.27'	0.01'

KWBES

BORING LOG

PROJECT: 622092001-237 (B77)
CLIENT: Navajo Refinery
BORING NUMBER: B77
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 26'
DATE COMPLETED: 03/04/92

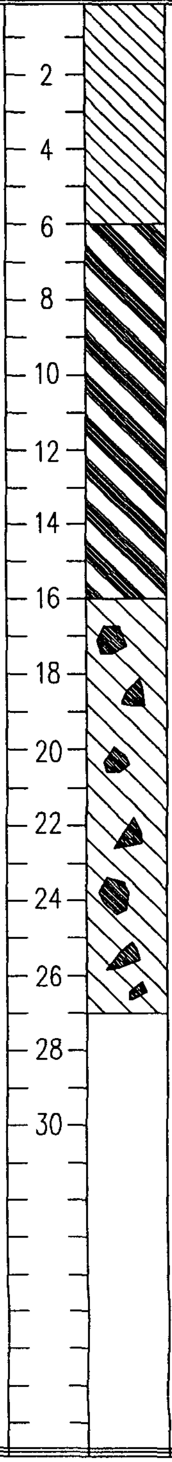
SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 27'

DESCRIPTION

DEPTH (ft.) | SYMBOL | SAMPLE | CUTTING

0-6'	SANDY CLAY, dark brown to brown, moist, plastic.
6-11'	CLAY, tan, with occasional pockets of fine sand and small pebbles, moist, plastic.
11-13'	CLAY, brown, with occasional pockets of fine sand and small pebbles, moist, plastic.
13-16'	CLAY, gray hydrocarbon staining, moist, plastic, odor increasing with depth.
16-27'	GRAVEL mixed with CLAY, gray staining, rock up to 3" diameter, moist until 26', saturated from 26-27'.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/5/92	-	19.72'	-



KWBES

BORING LOG

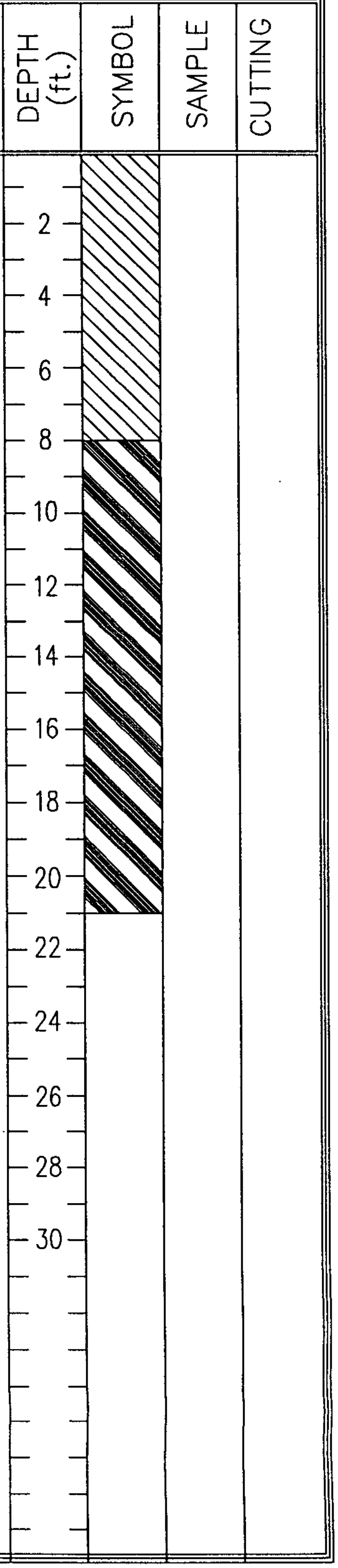
PROJECT: 622092001-237 (B78)
CLIENT: Navajo Refinery
BORING NUMBER: B78
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 17'
DATE COMPLETED: 03/05/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 21'

DESCRIPTION

0-8'	SANDY CLAY, dark brown to brown, moist, plastic.
8-17'	CLAY, gray hydrocarbon staining, moist, plastic, color becoming darker with depth, odor increasing.
17-21'	CLAY, dark gray hydrocarbon staining, saturated, brown colored free product coating auger flights.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/6/92	13.03'	17.67'	4.64'



KWBES

BORING LOG

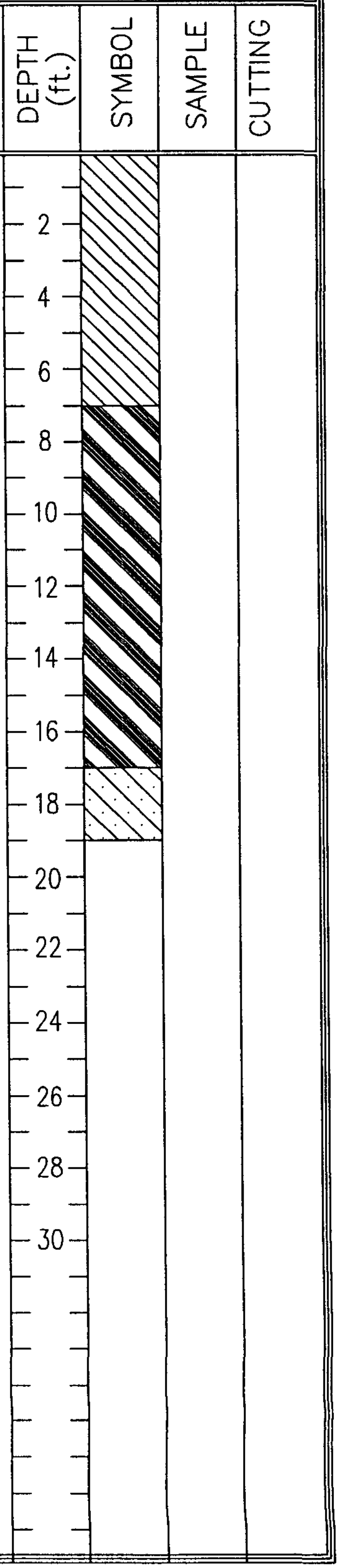
PROJECT: 622092001-237 (B79)
CLIENT: Navajo Refinery
BORING NUMBER: B79
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 17'
DATE COMPLETED: 03/05/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 19'

DESCRIPTION

0-7'	SANDY CLAY, dark brown to brown, moist, plastic.
7-17'	CLAY, gray hydrocarbon staining, moist, plastic, odor and darker color increasing with depth.
17-19'	CLAYEY SAND, gray staining, saturated.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/6/92	14.04'	16.51'	2.47'



KWBES

BORING LOG

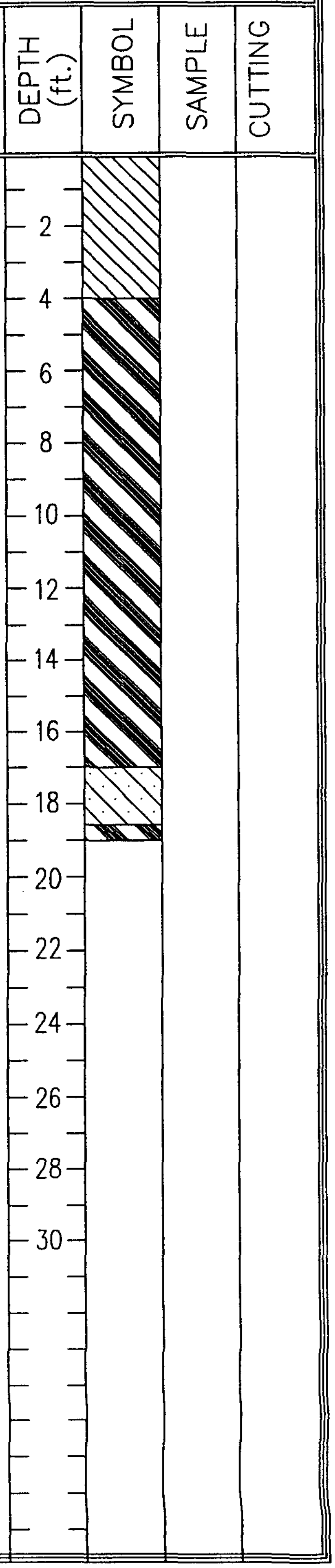
PROJECT: 622092001-237 (B80)
CLIENT: Navajo Refinery
BORING NUMBER: B80
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 17'
DATE COMPLETED: 03/05/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 19'

DESCRIPTION

0-4'	SANDY CLAY, dark brown to brown, moist, plastic.
4-7'	CLAY with SAND, moist, plastic.
7-17'	CLAY, gray hydrocarbon staining, moist, plastic, color becoming darker with depth, blue-gray staining beginning at 10'.
17-18.5'	CLAYEY SAND, saturated, blue-gray staining, strong odor.
18.5-19'	CLAY, blue-gray staining, saturated at 19'.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/5/92	14.69'	17.25'	2.56'



KWBES

BORING LOG

PROJECT: 622092001-237 (B81)
CLIENT: Navajo Refinery
BORING NUMBER: B81
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 21'
DATE COMPLETED: 03/05/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 24'

DESCRIPTION

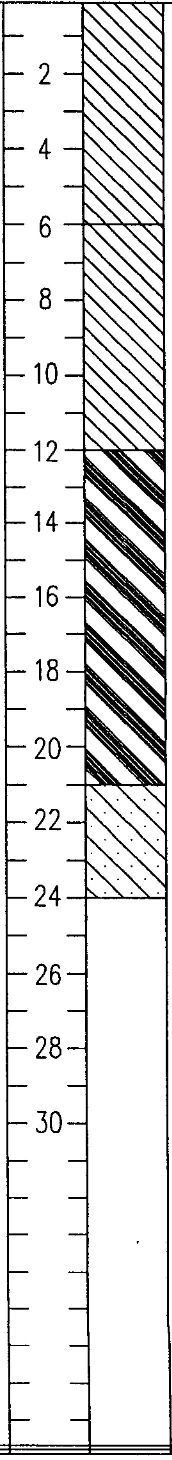
DEPTH (ft.) | SYMBOL | SAMPLE | CUTTING

0-6' SANDY CLAY, dark brown to brown, moist, plastic.

6-12' CLAY, tan, with occasional pockets of fine sand, moist, plastic.

12-21' CLAY, gray hydrocarbon staining, moist, plastic, odor and darker coloration increasing with depth.

21-24' CLAYEY SAND, saturated, brown colored free product on auger flights.



Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/6/92	15.62'	17.97'	2.35'

KWBES

BORING LOG

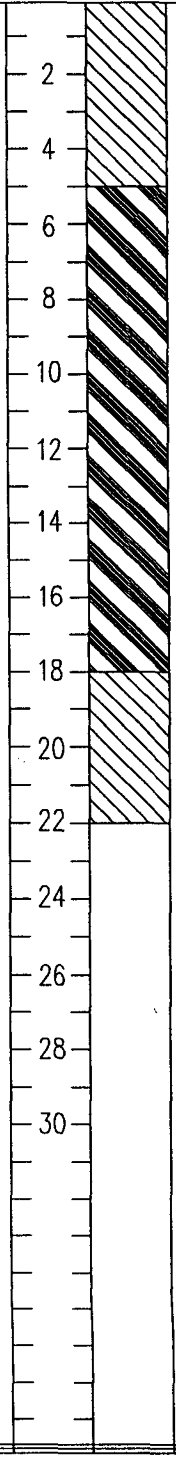
PROJECT: 622092001-237 (B82)
CLIENT: Navajo Refinery
BORING NUMBER: B82
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 21'
DATE COMPLETED: 03/05/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 22'

DESCRIPTION

DEPTH (ft.) | SYMBOL | SAMPLE | CUTTING

0-5'	SANDY CLAY, brown, dry, stiff.
5-11'	CLAY, brown, dry to moist, stiff to plastic, occasional lighter colored bands and small caliche pebbles.
11-18'	CLAY, gray hydrocarbon staining, moist, plastic, odor and darker coloration increasing with depth.
18-22'	SANDY CLAY, gray, moist to saturated by 21'.



Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/6/92	–	14.04'	Film (<1/16")

KWBES

BORING LOG

PROJECT: 622092001–237 (B83)
CLIENT: Navajo Refinery
BORING NUMBER: B83
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 20'
DATE COMPLETED: 03/05/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 21'

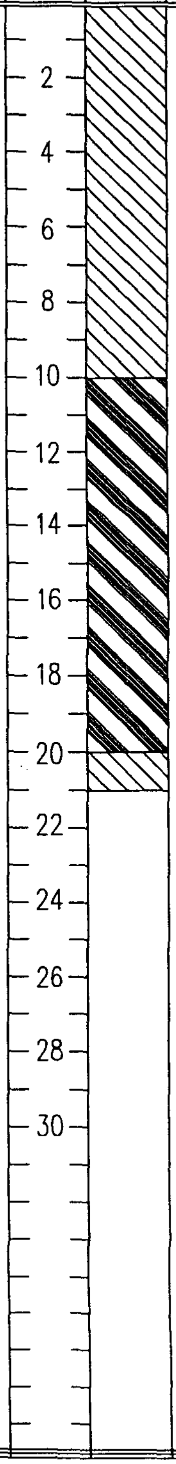
DESCRIPTION	DEPTH (ft.)	SYMBOL	SAMPLE	CUTTING

0–10' SANDY CLAY, brown, dry to moist, stiff to plastic.

10–15' CLAY, tan, moist, plastic.

15–20' CLAY, gray hydrocarbon staining, moist, plastic.

20–21' SANDY CLAY, gray, saturated.



Date	(D–T–P) Depth to Product	(D–T–W) Depth to Water	Product Thickness
3/6/92	–	13.34'	–

KWBES

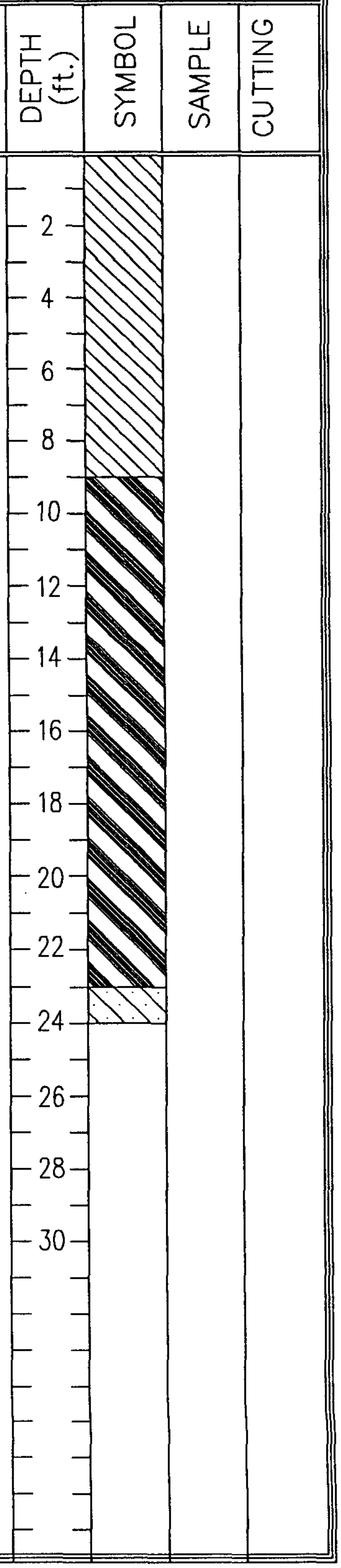
BORING LOG

PROJECT: 622092001-237 (B84)
CLIENT: Navajo Refinery
BORING NUMBER: B84
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 23'
DATE COMPLETED: 03/06/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 24'

DESCRIPTION

0-9'	SANDY CLAY, dark brown to brown, moist, plastic.
9-15'	CLAY, tan, dryer, stiff to plastic, occasional small caliche nodules.
15-23'	CLAY, gray hydrocarbon staining, moist, plastic, odor and darker coloration increasing with depth.
23-24'	CLAYEY SAND, saturated, gray staining, strong odor.



Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/7/92	17.40'	20.33'	2.93'

BORING LOG

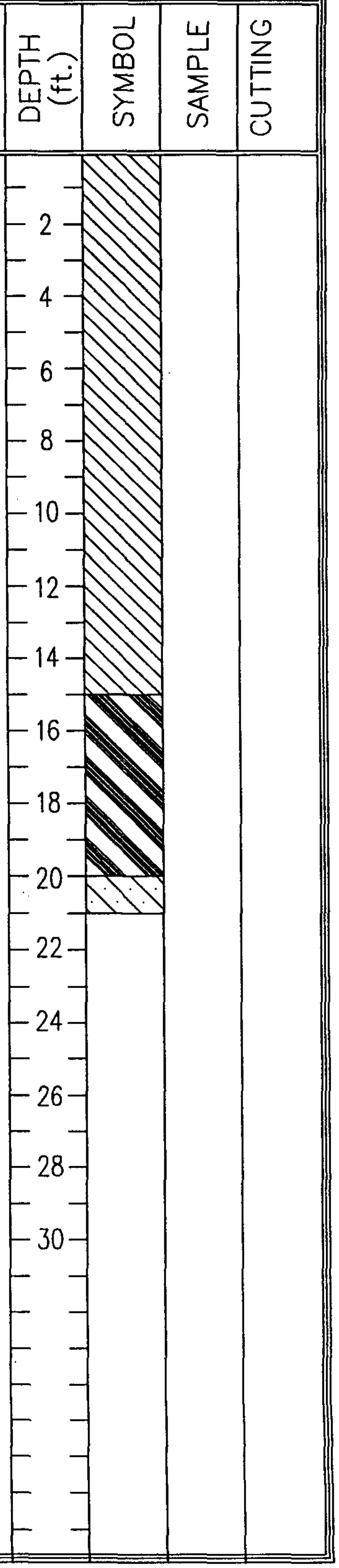
PROJECT: 622092001–237 (B85)
CLIENT: Navajo Refinery
BORING NUMBER: B85
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 20'
DATE COMPLETED: 03/06/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 21'

DESCRIPTION

0–8'	SANDY CLAY, dark brown to brown, moist, plastic.
8–15'	CLAY with SAND, gray hydrocarbon staining, moist, plastic, odor and darker coloration increasing with depth.
15–20'	CLAY, gray staining, moist, very sticky.
20–21'	CLAYEY SAND, gray, saturated, strong odor, brown colored free product on augers.

Date	(D–T–P) Depth to Product	(D–T–W) Depth to Water	Product Thickness
3/7/92	16.05'	19.82'	3.77'



KWBES

BORING LOG

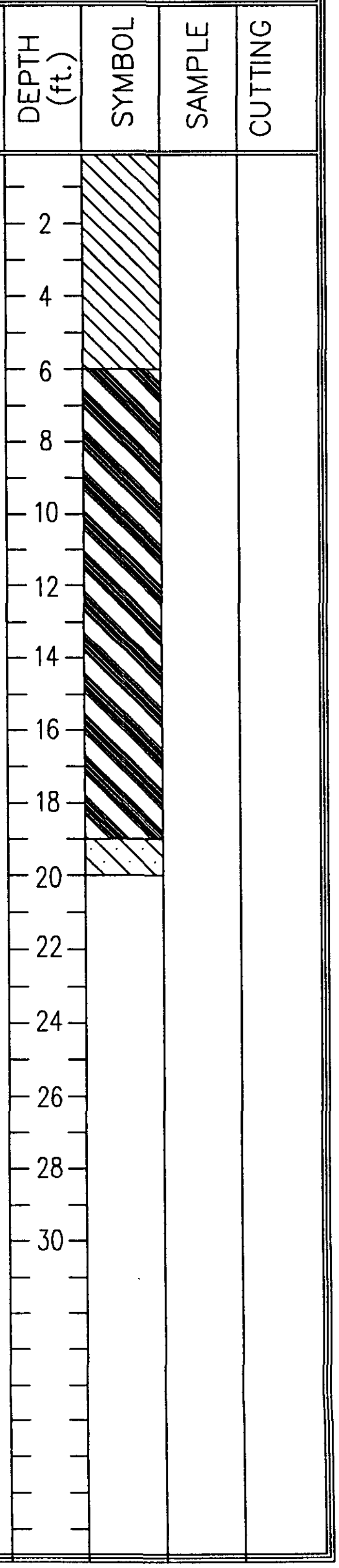
PROJECT: 622092001-237 (B86)
CLIENT: Navajo Refinery
BORING NUMBER: B86
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 19'
DATE COMPLETED: 03/06/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 20'

DESCRIPTION

0-6'	SANDY CLAY, dark brown to brown, moist, plastic.
6-19'	CLAY, gray hydrocarbon staining, moist, plastic, odor and darker discoloration increasing with depth.
19-20'	CLAYEY SAND, gray, saturated, some gravel.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/7/92	14.99'	17.48'	2.49'



KWBES

BORING LOG

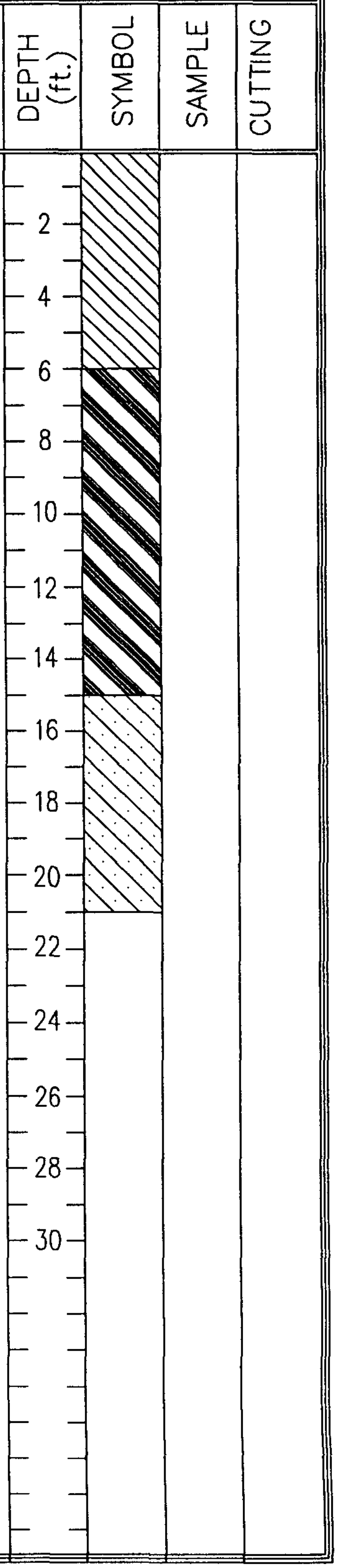
PROJECT: 622092001-237 (B87)
CLIENT: Navajo Refinery
BORING NUMBER: B87
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 20'
DATE COMPLETED: 03/06/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 21'

DESCRIPTION

0-6'	SANDY CLAY, dark brown to brown, moist, plastic, occasional pebbles and pockets of fine white sand.
6-7'	SANDY CLAY, gray hydrocarbon staining, strong odor, moist, plastic.
7-15'	CLAY, gray to blue-gray, moist, strong odor, becoming lighter in color with depth.
15-20'	CLAYEY SAND, gray, moist, thin gravel bed around 16, plastic.
20-21'	CLAY with SAND, gray, saturated, occasional large gravel.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/7/92	14.68'	19.24'	4.56'



KWBES

BORING LOG

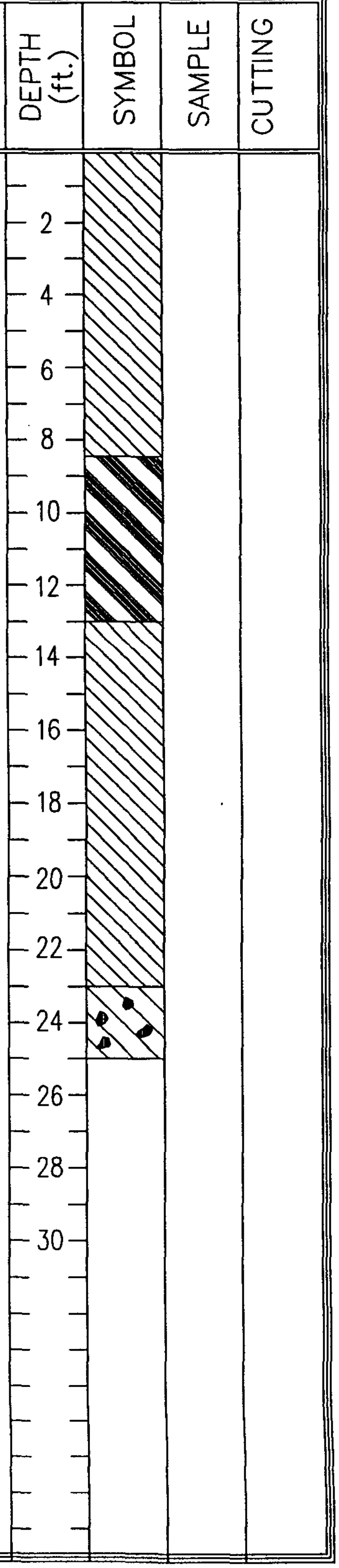
PROJECT: 622092001-237 (B88)
CLIENT: Navajo Refinery
BORING NUMBER: B88
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 23'
DATE COMPLETED: 03/07/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 25'

DESCRIPTION

0-8.5'	SANDY CLAY, dark brown to brown, dry to moist, stiff to plastic.
8.5-13'	CLAY, gray hydrocarbon staining, moist, plastic, slight odor.
13-23'	SANDY CLAY, gray, moist, plastic, strong hydrocarbon odor.
23-25'	GRAVEL mixed with SANDY CLAY, saturated, gray discoloration.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/8/92	17.01'	19.59'	2.58'



KWBES

BORING LOG

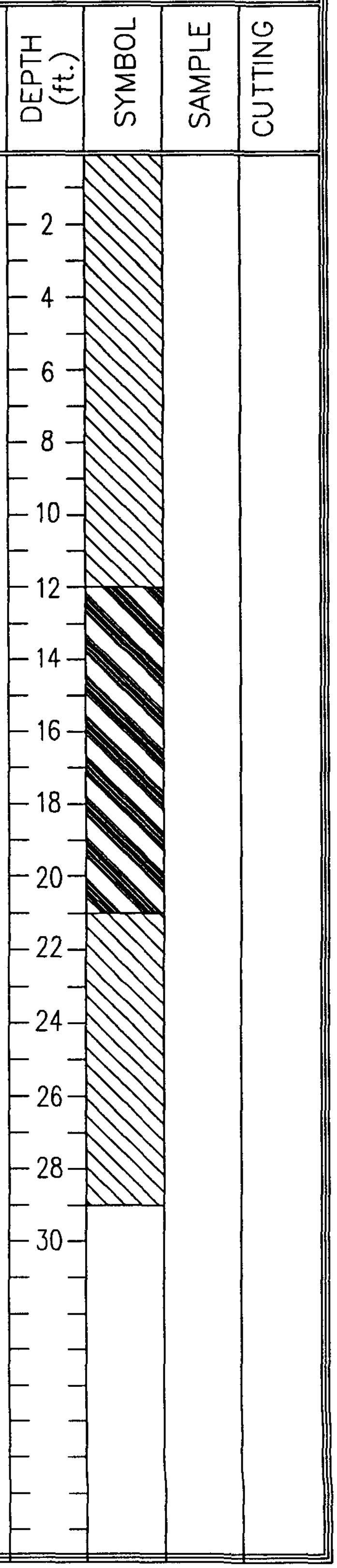
PROJECT: 622092001-237 (B89)
CLIENT: Navajo Refinery
BORING NUMBER: B89
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 28'
DATE COMPLETED: 03/07/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 29'

DESCRIPTION

0-12'	SANDY CLAY, dark brown to brown, moist, plastic, becoming dryer with depth.
12-13'	SANDY CLAY, gray staining, strong hydrocarbon odor, dry, appears to be old staining.
13-21'	GRAY STAINED CLAY, moist, plastic, intermittent thin gravel layers.
21-23'	CLAY with some SAND, gray hydrocarbon staining, moist, plastic.
23-28'	CLAYEY SAND, gray hydrocarbon staining, moist to very moist, plastic, strong hydrocarbon odor.
28-29'	CLAYEY SAND, gray, saturated.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/8/92	23.71'	23.74'	0.03'



KWBES

BORING LOG

PROJECT: 622092001-237 (B90)
CLIENT: Navajo Refinery
BORING NUMBER: B90
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 20'
DATE COMPLETED: 03/07/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 21'

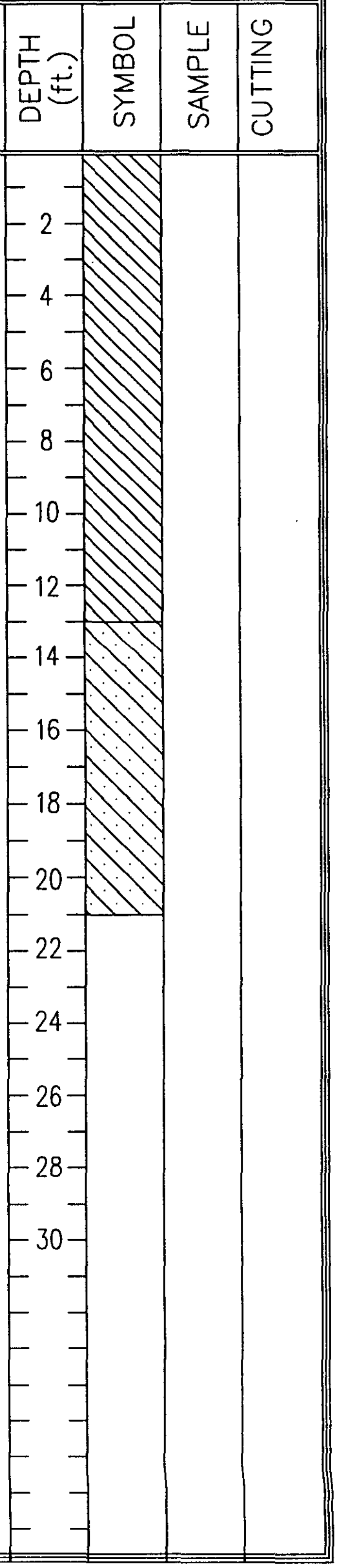
DESCRIPTION

0-6' SANDY CLAY, dark brown to reddish brown, moist to dry, plastic to stiff with occasional caliche nodules.

6-13' CLAY with SAND, tan, moist, plastic.

13-21' CLAYEY SAND, gray, hydrocarbon staining, moist, plastic, strong odor, becoming darker in color with depth, saturated at 20'.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/8/92	-	14.11'	-



KWBES

BORING LOG

PROJECT: 622092001-237 (B91)
CLIENT: Navajo Refinery
BORING NUMBER: B91
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 20'
DATE COMPLETED: 03/07/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 22'

DESCRIPTION

0-4' SANDY CLAY, dark brown to brown, moist, plastic.

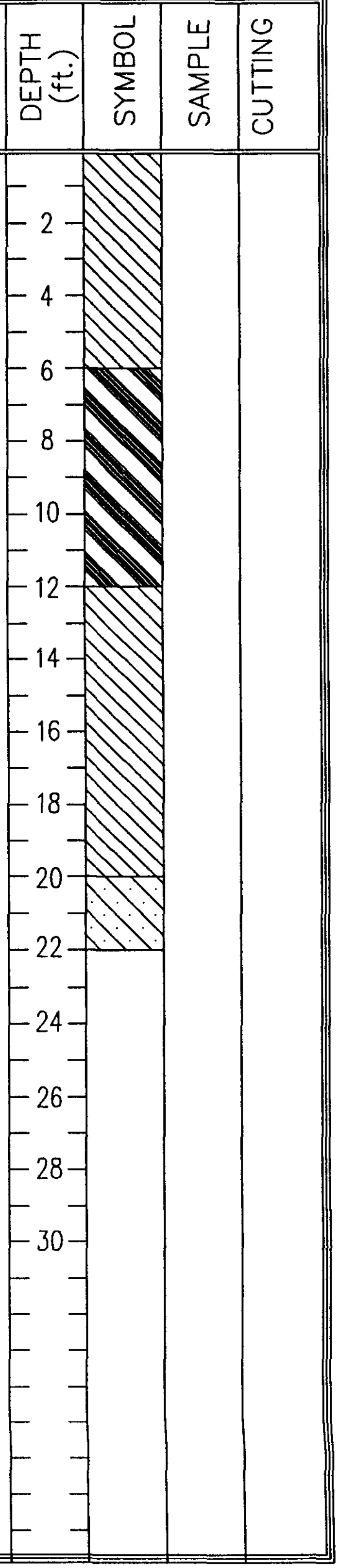
4-6' CLAY with SAND, reddish-brown, moist, plastic, occasional small white caliche nodules.

6-12' CLAY, tan, with occasional pockets of fine sand, moist, plastic.

12-20' SANDY CLAY, gray staining, strong hydrocarbon odor, moist, plastic, increasing gravel content with depth.

20-22' SAND with some CLAY, gray, saturated, strong odor.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/8/92	15.15'	16.19'	1.04'



KWBES

BORING LOG

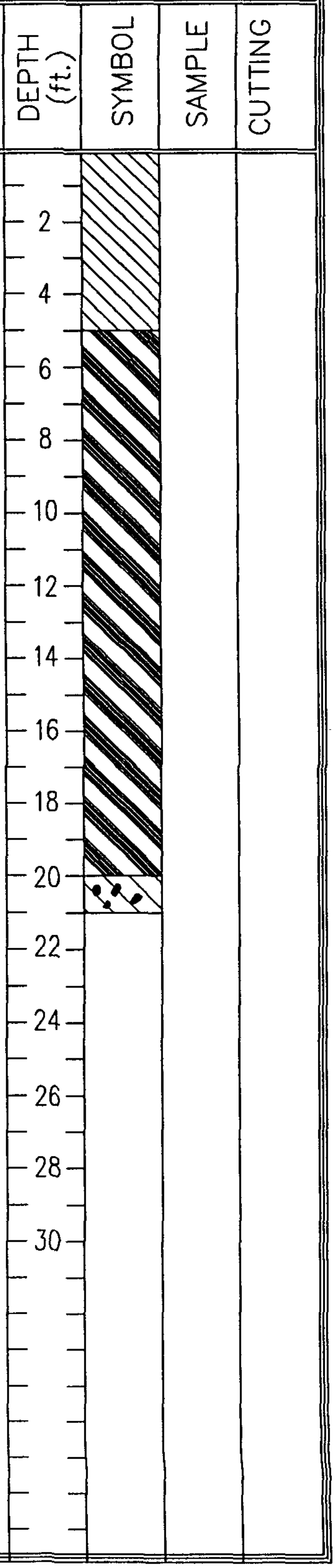
PROJECT: 622092001-237 (B92)
CLIENT: Navajo Refinery
BORING NUMBER: B92
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 20'
DATE COMPLETED: 03/07/92

SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 21'

DESCRIPTION

0-5'	SANDY CLAY, dark brown to brown, moist, plastic.
5-16'	CLAY with SAND, tan, dry to moist, stiff to plastic, hydrocarbon odor detectable in soil at 12' but no color change.
16-20'	CLAY with SAND, brown, moist, plastic, hydrocarbon odor stronger but no discoloration noted.
20-21'	GRAVEL mixed with CLAY, saturated, odor, no color change.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/10/92	20.32'	21.10'	0.78'



KWBES

BORING LOG

PROJECT: 622092001-237 (B93)
CLIENT: Navajo Refinery
BORING NUMBER: B93
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 22'
DATE COMPLETED: 03/09/92

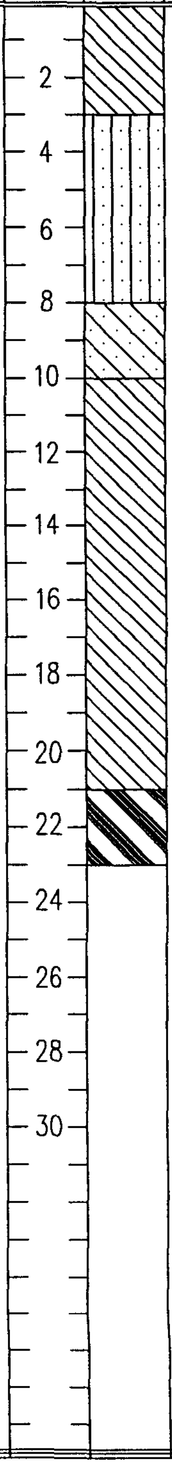
SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 23'

DESCRIPTION

DEPTH (ft.) | SYMBOL | SAMPLE | CUTTING

0–3'	SANDY CLAY, dark brown, moist, plastic.
3–8'	SILTY SAND, tan, moist to dry.
8–10'	CLAYEY SAND, brown, moist, plastic.
10–19'	SANDY CLAY, brown, moist, plastic, occasional small white caliche nodules.
19–21'	CLAY, brown, very moist, plastic.
21–23'	CLAY, gray hydrocarbon staining, saturated at 22', odor strong.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/10/92	21.1'	21.6'	0.5'



KWBES

BORING LOG

PROJECT: 622092001-237 (B94)
CLIENT: Navajo Refinery
BORING NUMBER: B94
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 25'
DATE COMPLETED: 03/09/92

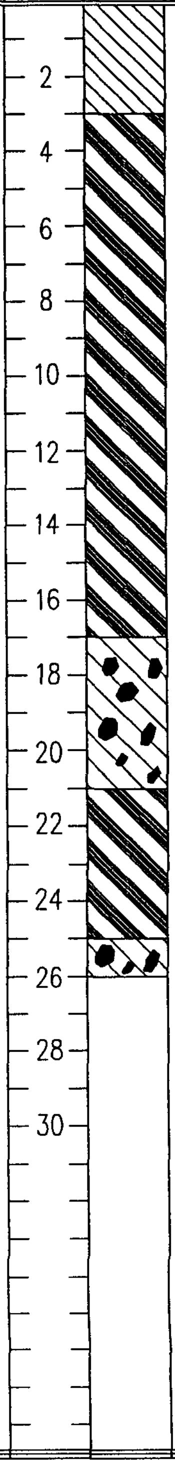
SHEET: 1 of 1
DRILLED BY: Pool Envir.
LOGGED BY: PWC
SURF. ELEV: N/A
TOTAL DEPTH: 26'

DESCRIPTION

DEPTH (ft.) | SYMBOL | SAMPLE | CUTTING

0-3'	SANDY CLAY, dark brown, moist, plastic.
3-8'	CLAY with SAND, tan, moist, plastic.
8-17'	CLAY, brown, moist, plastic.
17-21'	GRAVEL with CLAY, moist.
21-25'	CLAY, reddish-brown, moist, plastic.
25-26'	GRAVEL with CLAY, saturated, no odor or staining.

Date	(D-T-P) Depth to Product	(D-T-W) Depth to Water	Product Thickness
3/10/92	-	22.66'	-



KWBES

APPENDIX G

APPENDIX G

Photograph Log

PHOTOGRAPH LOG — NAVAJO REFINERY FIELD INVESTIGATIONS
January — March 1992

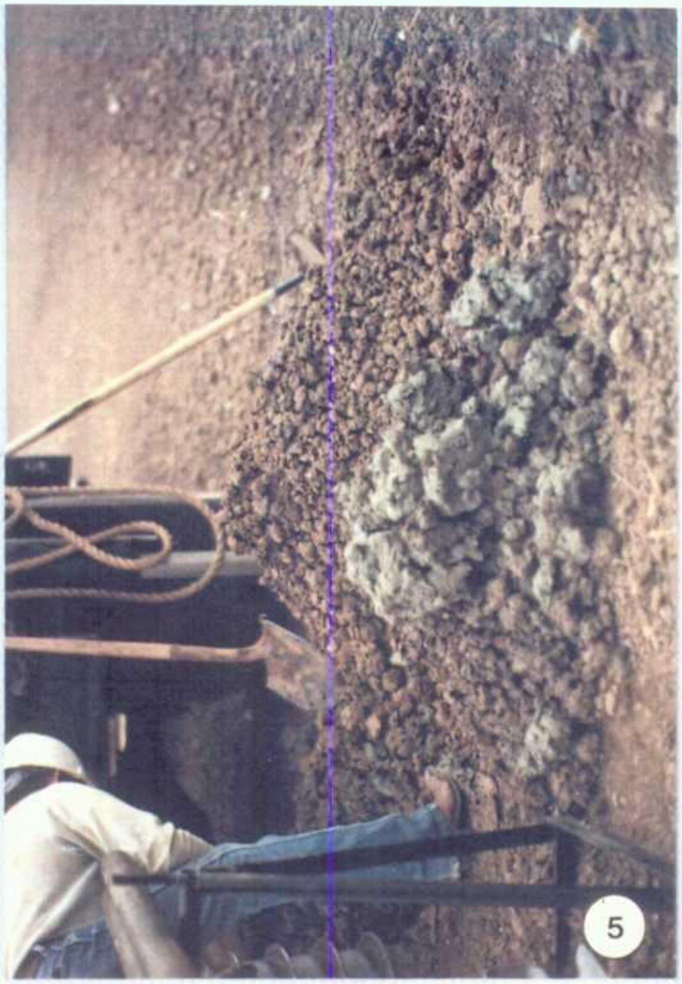
Photograph number	Date	Description
1	March 1992	KWBES monitor wells KWB 3A and 3B located on the Joy farm southeast of refinery. Hermit data logger set up for operation.
2	March 1992	Close-up photo of Hermit data logger and sensors reels. Box at right houses the Grunflos submersible pump controller.
3	March 1992	Pump test underway on KWB-1A and KWB-1B.
4	March 1992	Flow meter at outlet for submersible pump.
5	March 1992	Boring by Pool Environmental drillers. Note gray hydrocarbon staining of soil in foreground.
6	March 1992	Pool Environmental drillers preparing for boring B89 near Coll house.
7	March 1992	KWBES geologist checking borehole with oil/water interface meter to determine apparent product thickness.


1


2


3


4



5

6

7

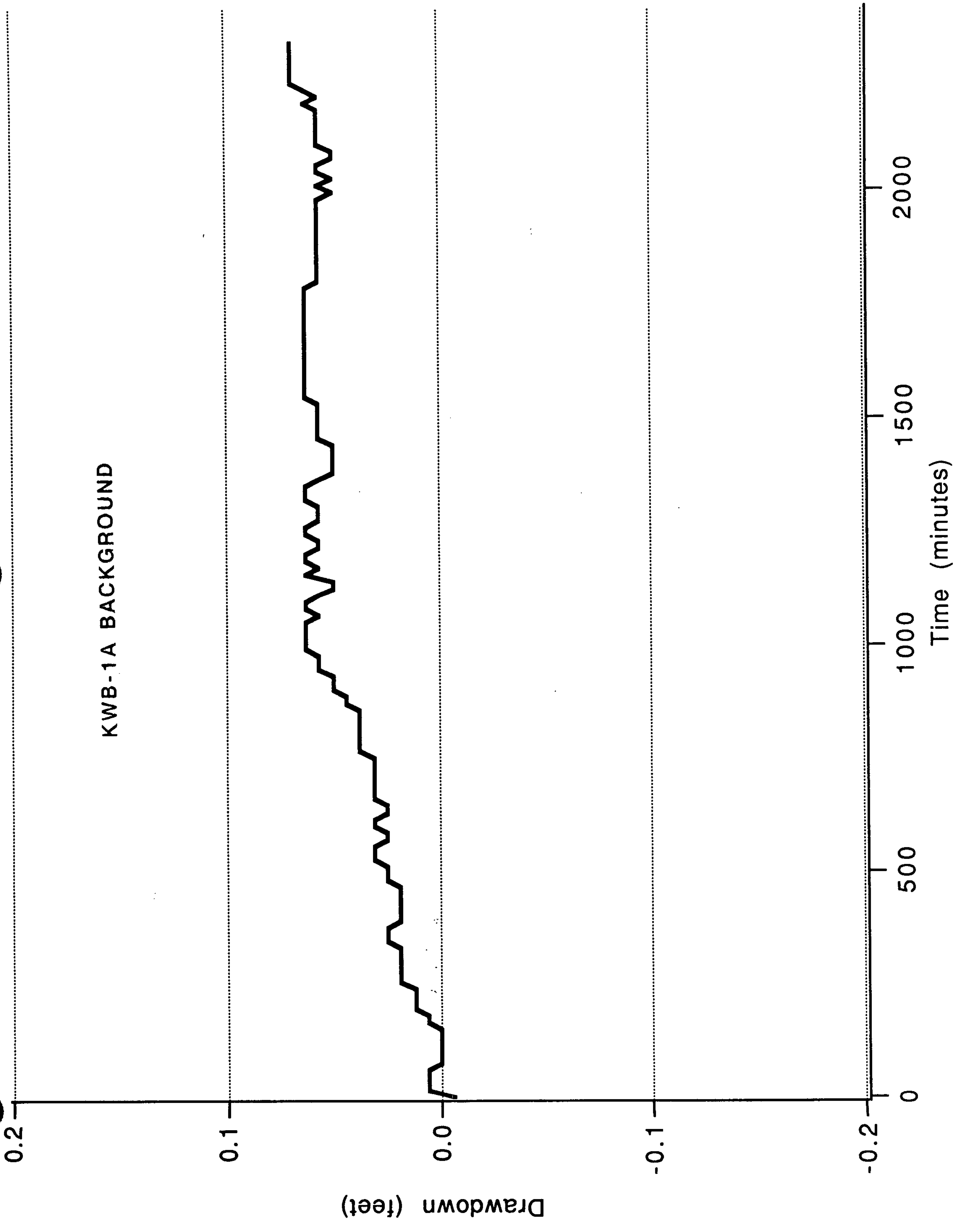
APPENDIX H

APPENDIX H

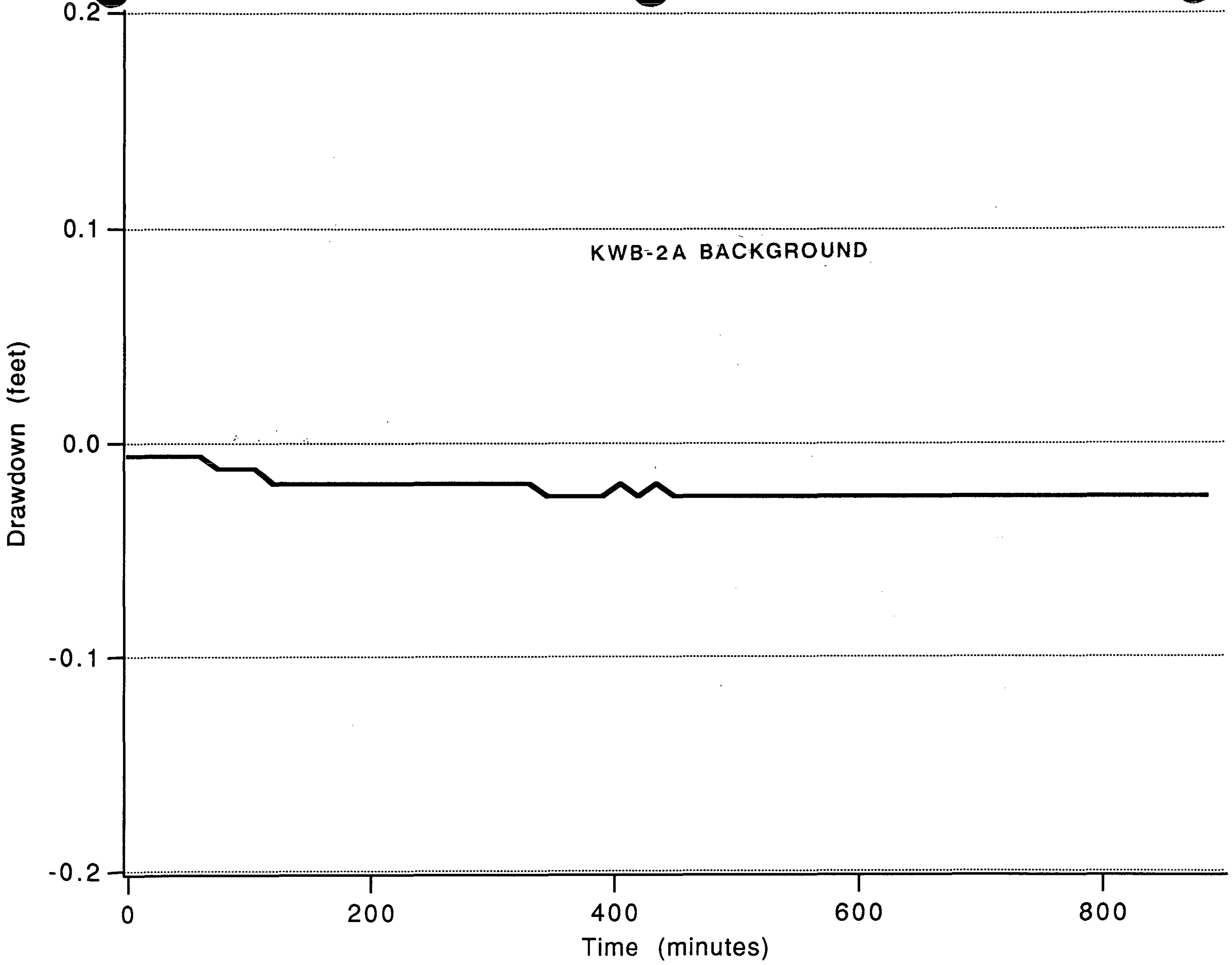
Aquifer Tests

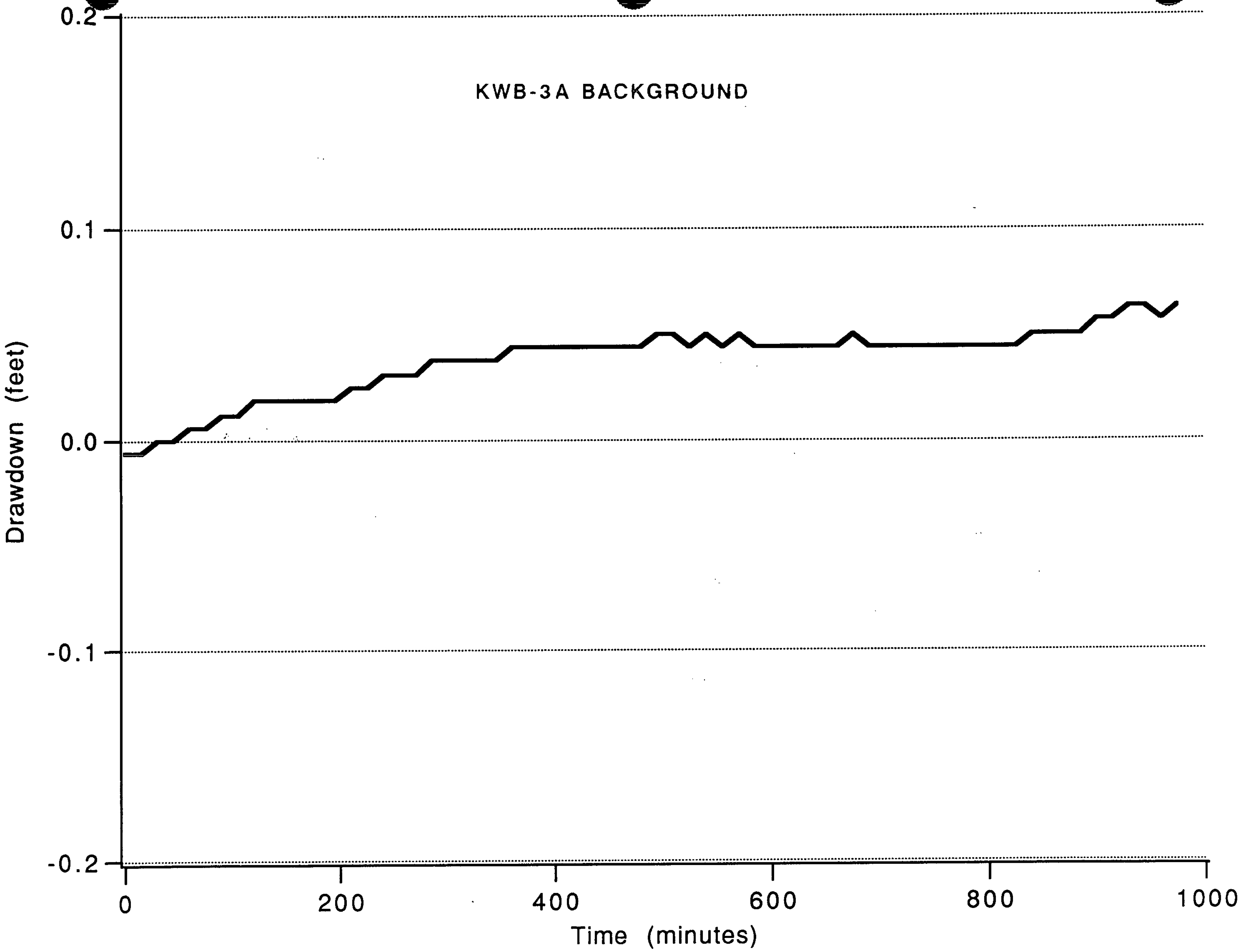
APPENDIX H-1

Background Data



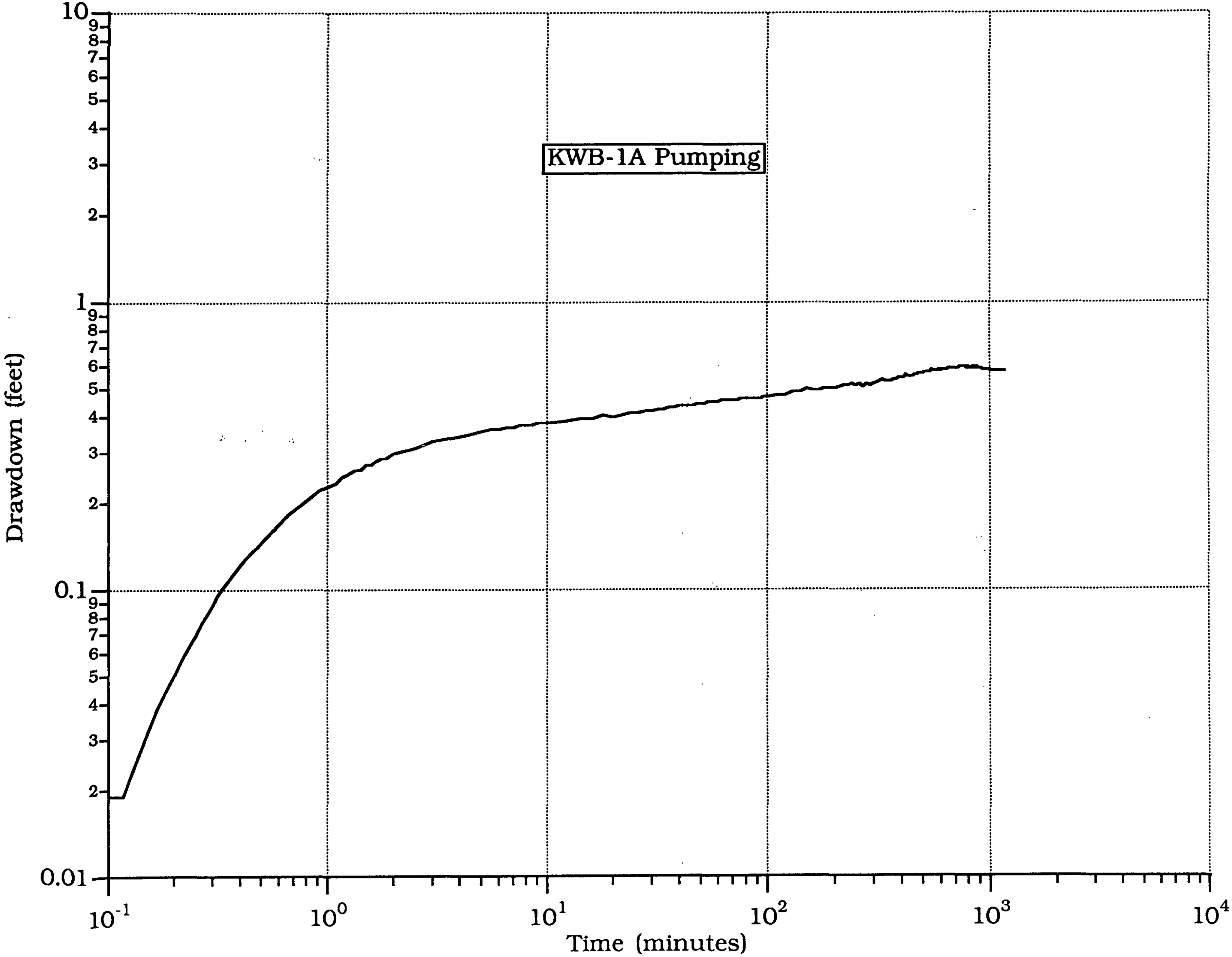
KWB-1A BACKGROUND
Drawdown (feet)
0.2
0.1
0.0
-0.1
-0.2
Time (minutes)
0
500
1000
1500
2000

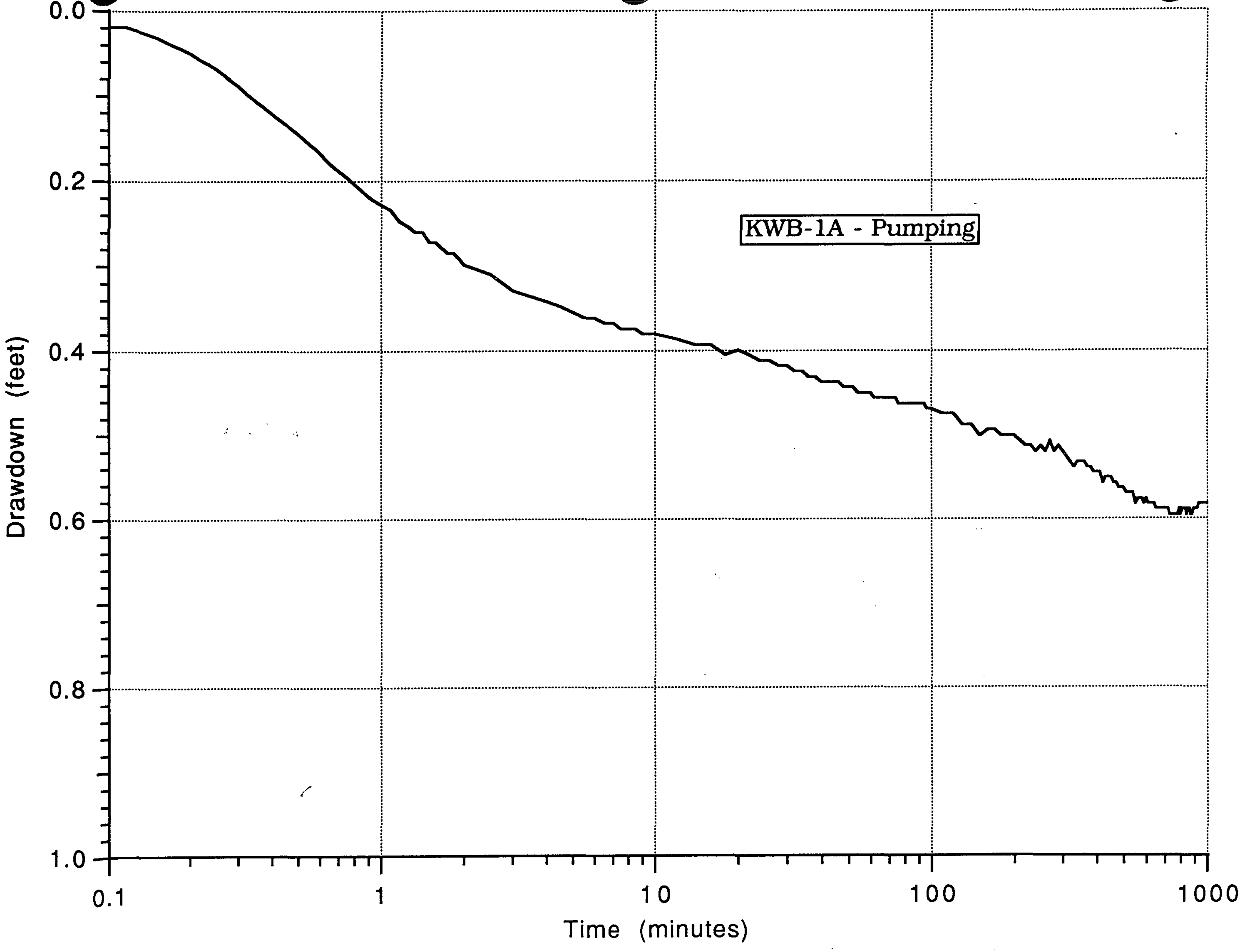

KWB-2A BACKGROUND
Drawdown (feet)
0.2
0.1
0.0
-0.1
-0.2
0
200
400
600
800
Time (minutes)

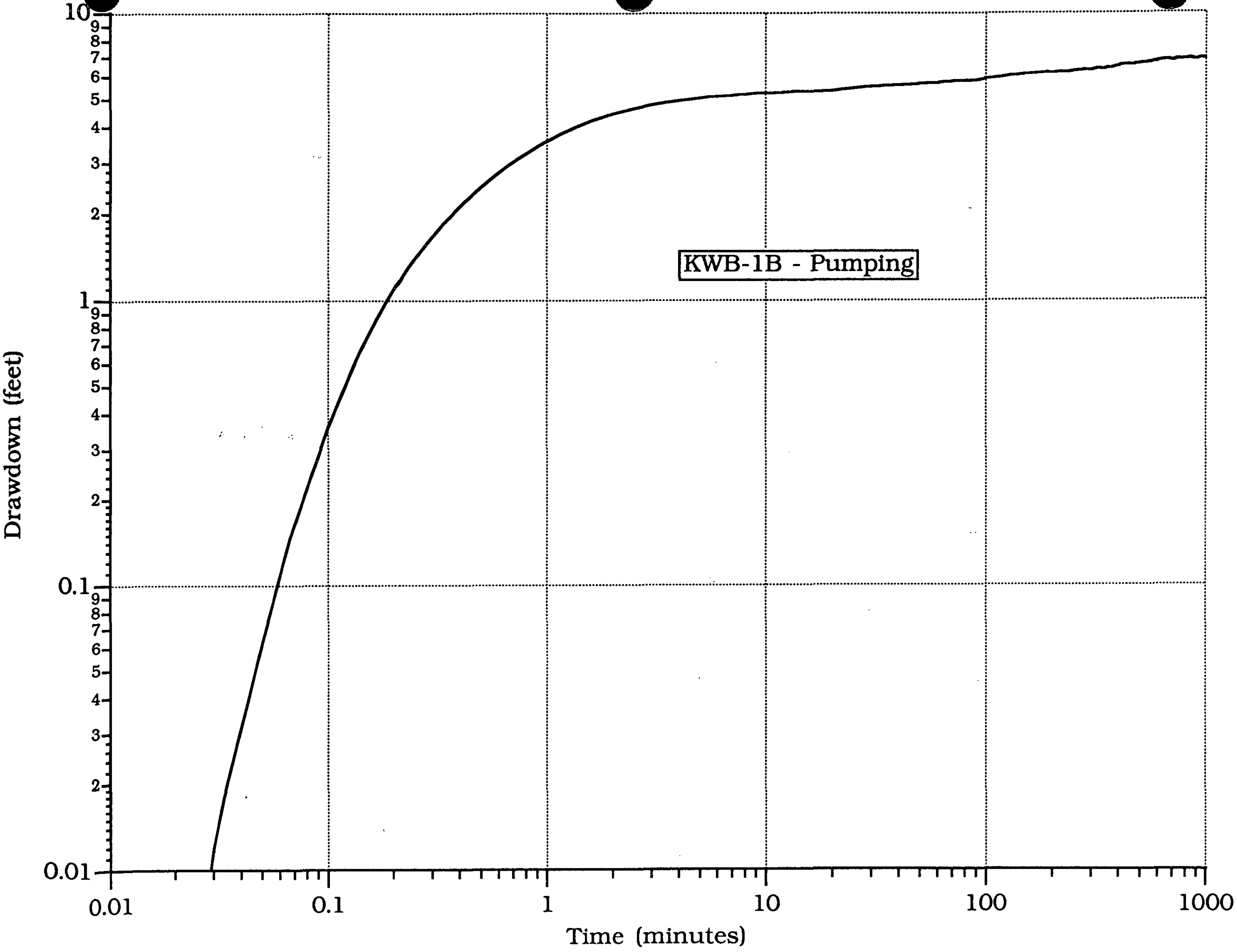

KWB-3A BACKGROUND
Drawdown (feet)
0.2
0.1
0.0
-0.1
-0.2
0
200
400
600
800
1000
Time (minutes)

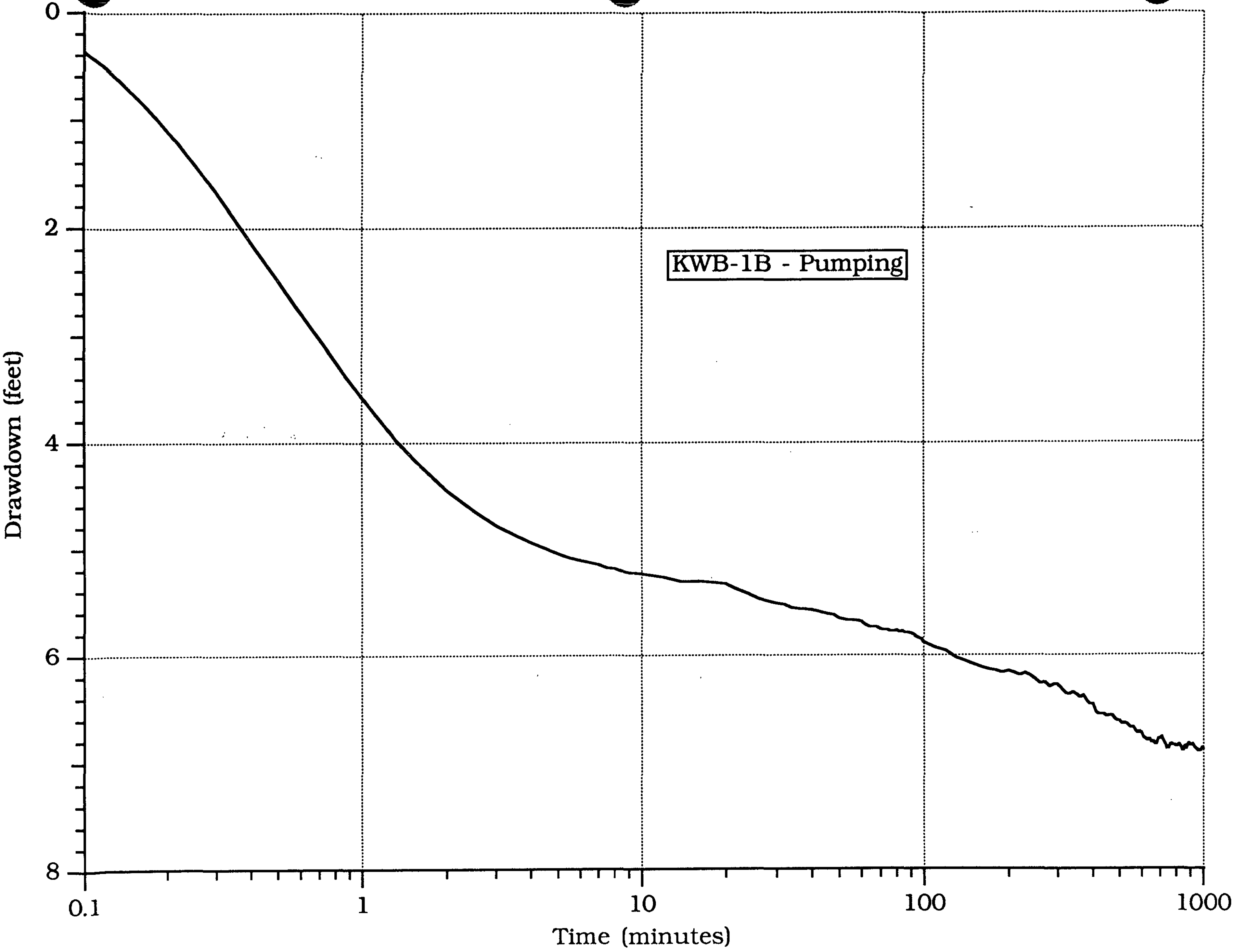
APPENDIX H-2

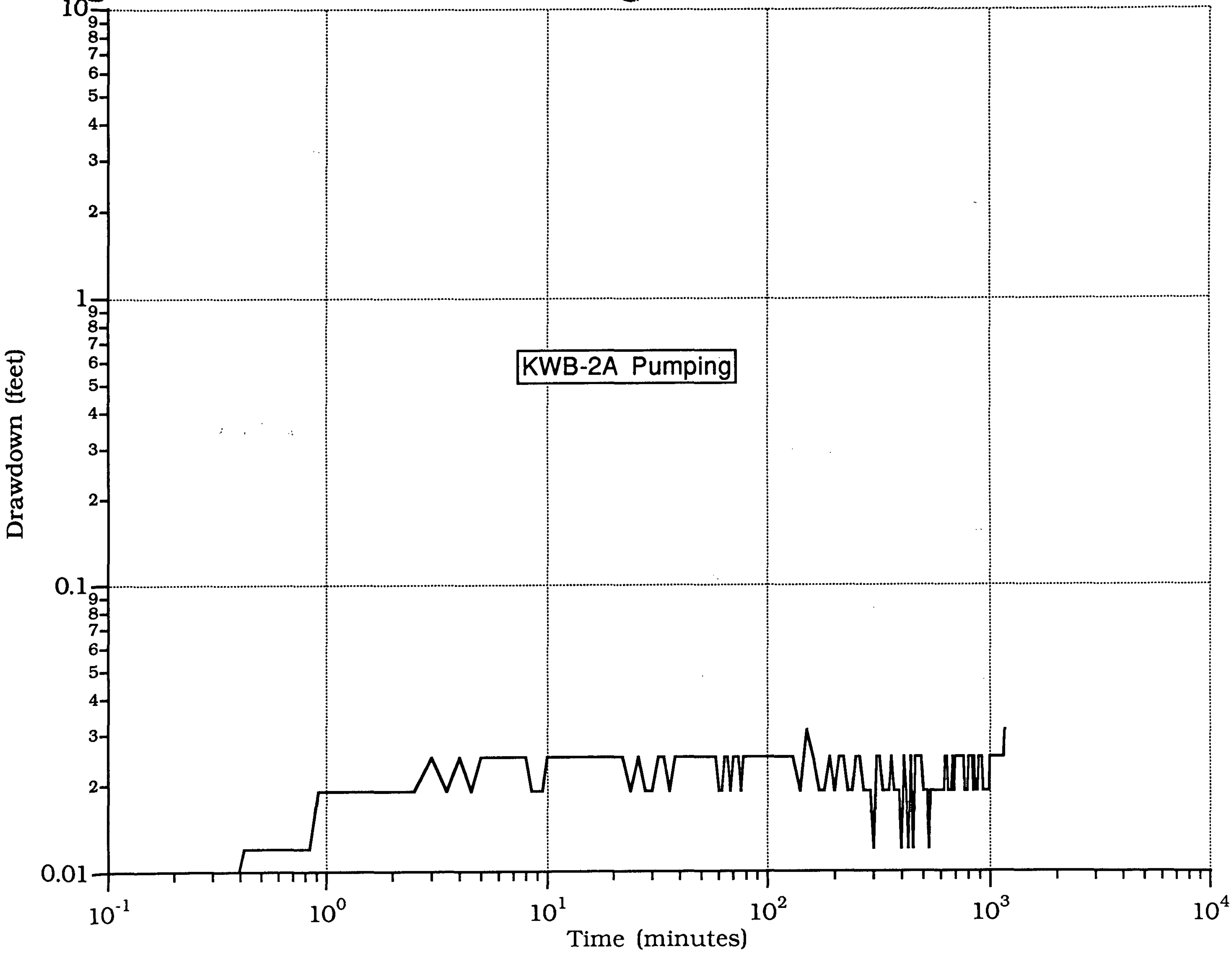
Pumping Data

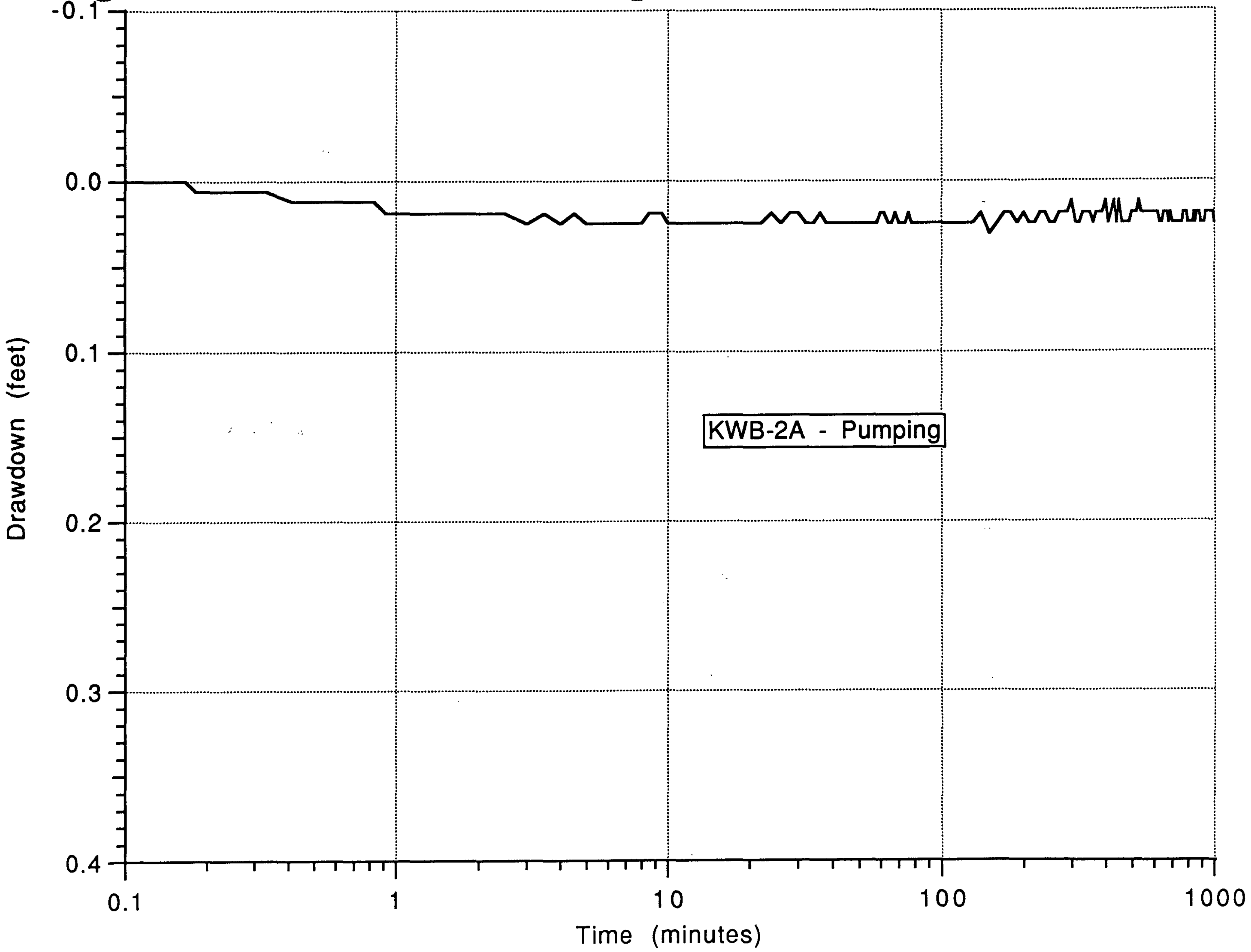

KWB-1A Pumping
Drawdown (feet)
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
0.1
9
8
7
6
5
4
3
2
0.01
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Time (minutes)

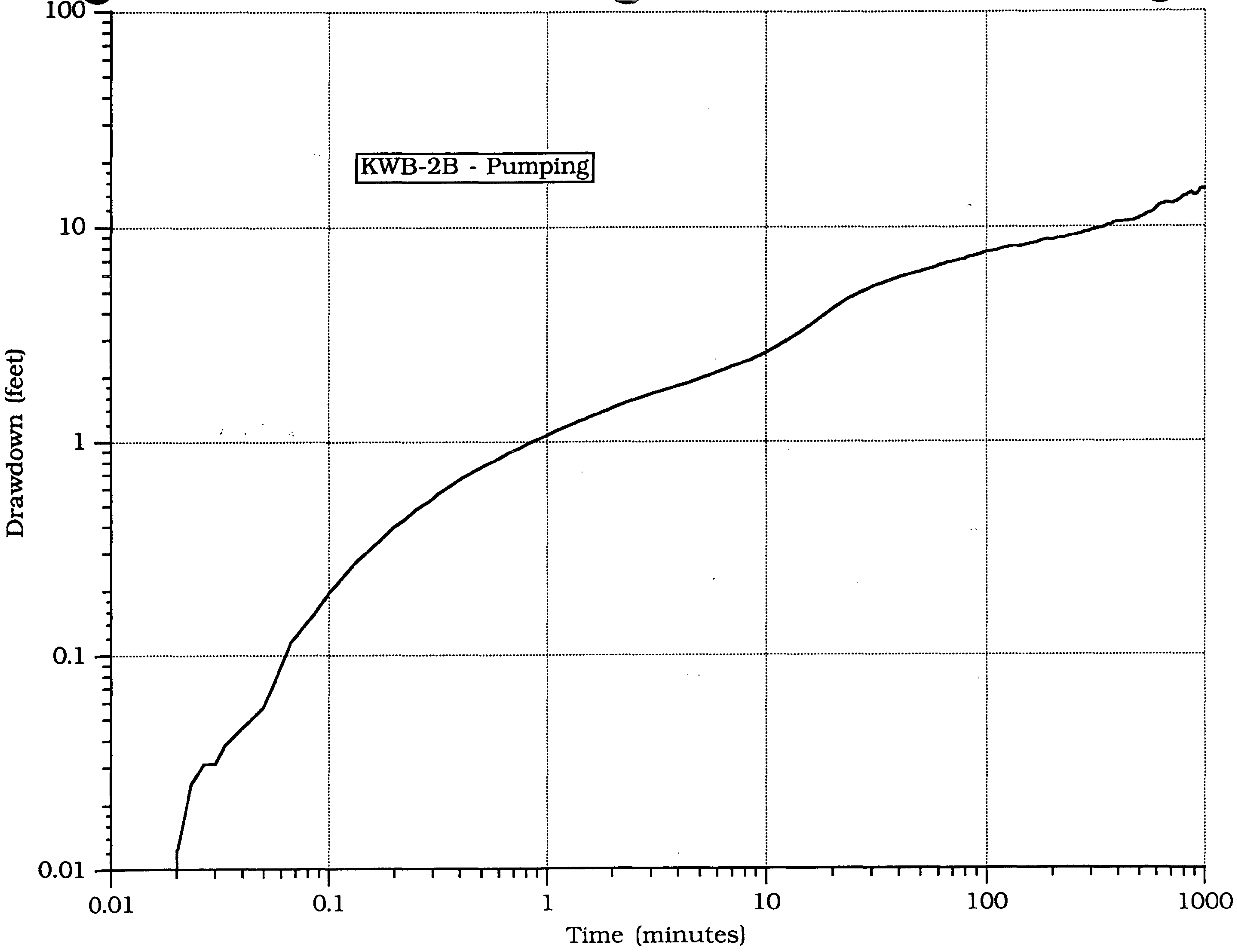

KWB-1A - Pumping
Drawdown (feet)
0.0
0.2
0.4
0.6
0.8
1.0
Time (minutes)
0.1
1
10
100
1000

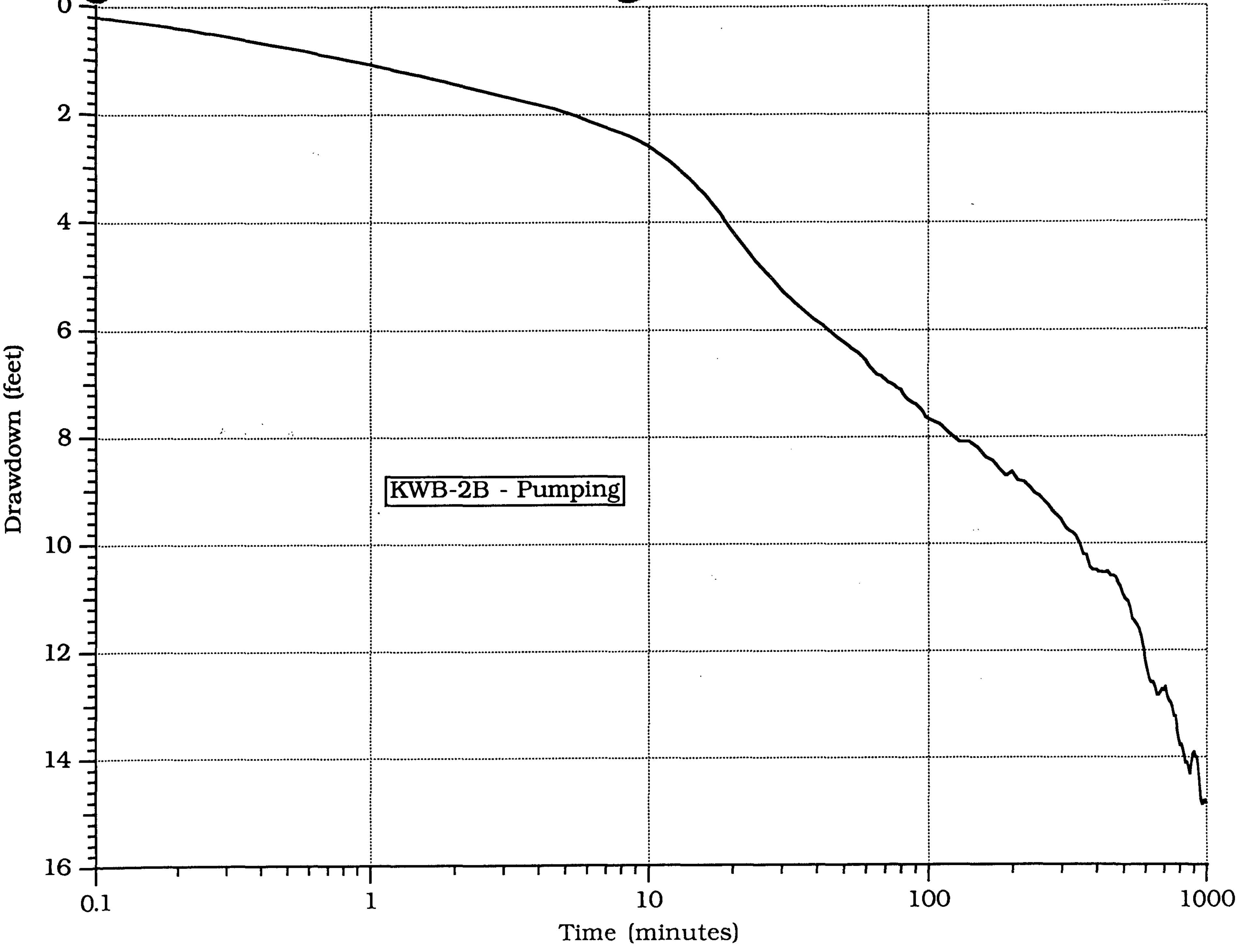

KWB-1B - Pumping
Drawdown (feet)
10
1
0.1
0.01
9
8
7
6
5
4
3
2
Time (minutes)
0.01
0.1
1
10
100
1000


KWB-1B - Pumping
Drawdown (feet)
0
2
4
6
8
0.1
1
10
100
1000
Time (minutes)

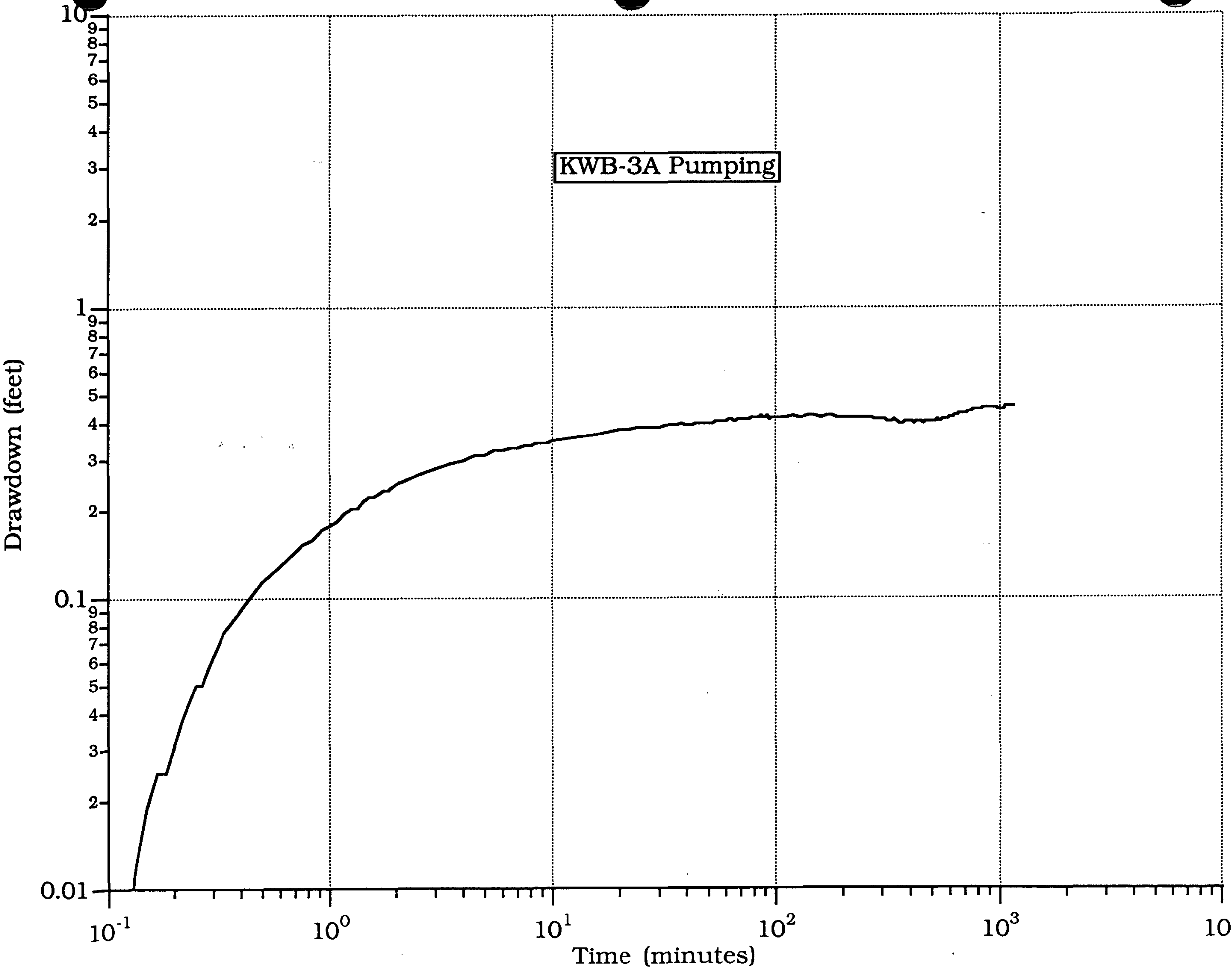

KWB-2A Pumping
Drawdown (feet)
10
9
8
7
6
5
4
3
2
1
0.1
0.01
Time (minutes)
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}

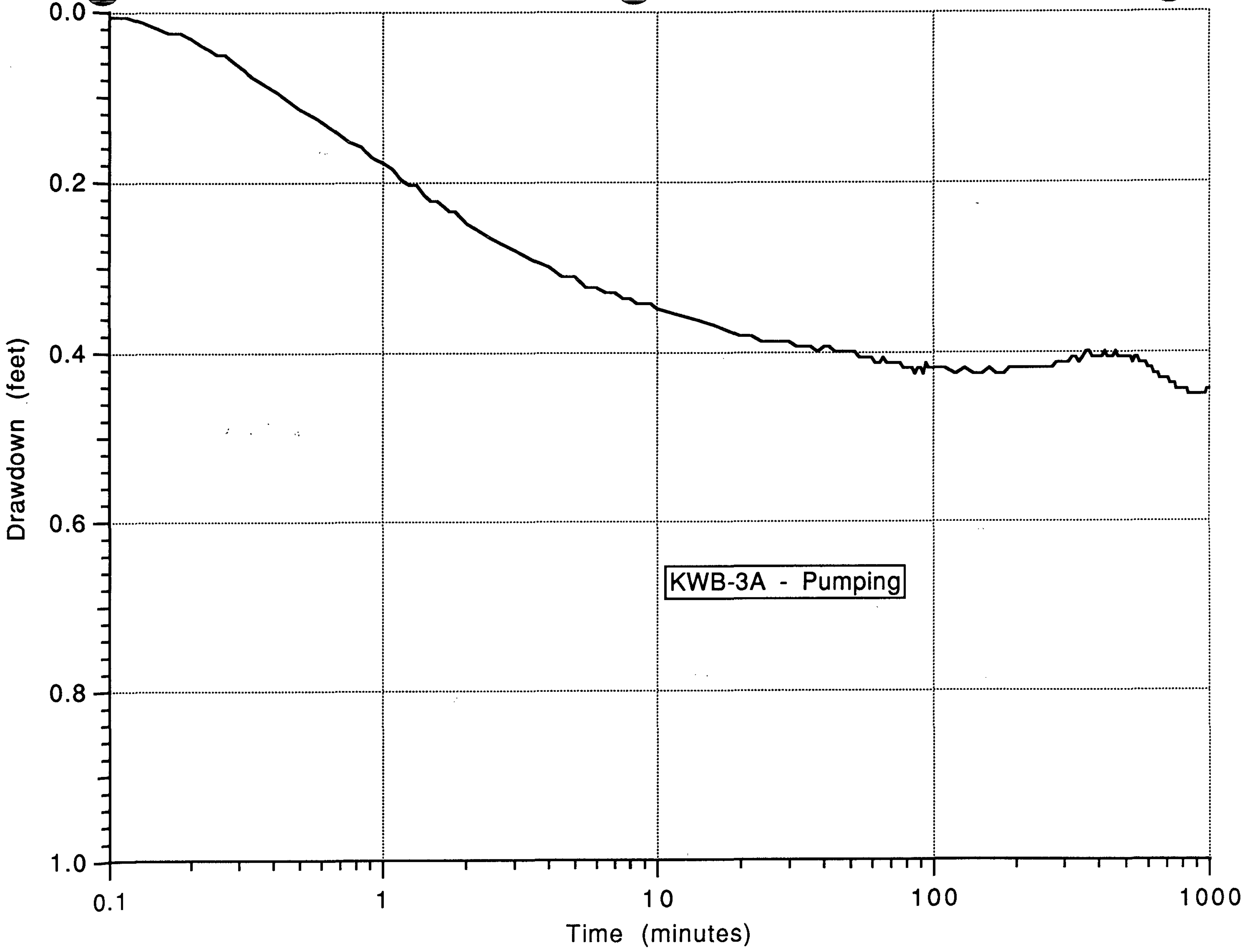

KWB-2A - Pumping
Drawdown (feet)
-0.1
0.0
0.1
0.2
0.3
0.4
Time (minutes)
0.1
1
10
100
1000

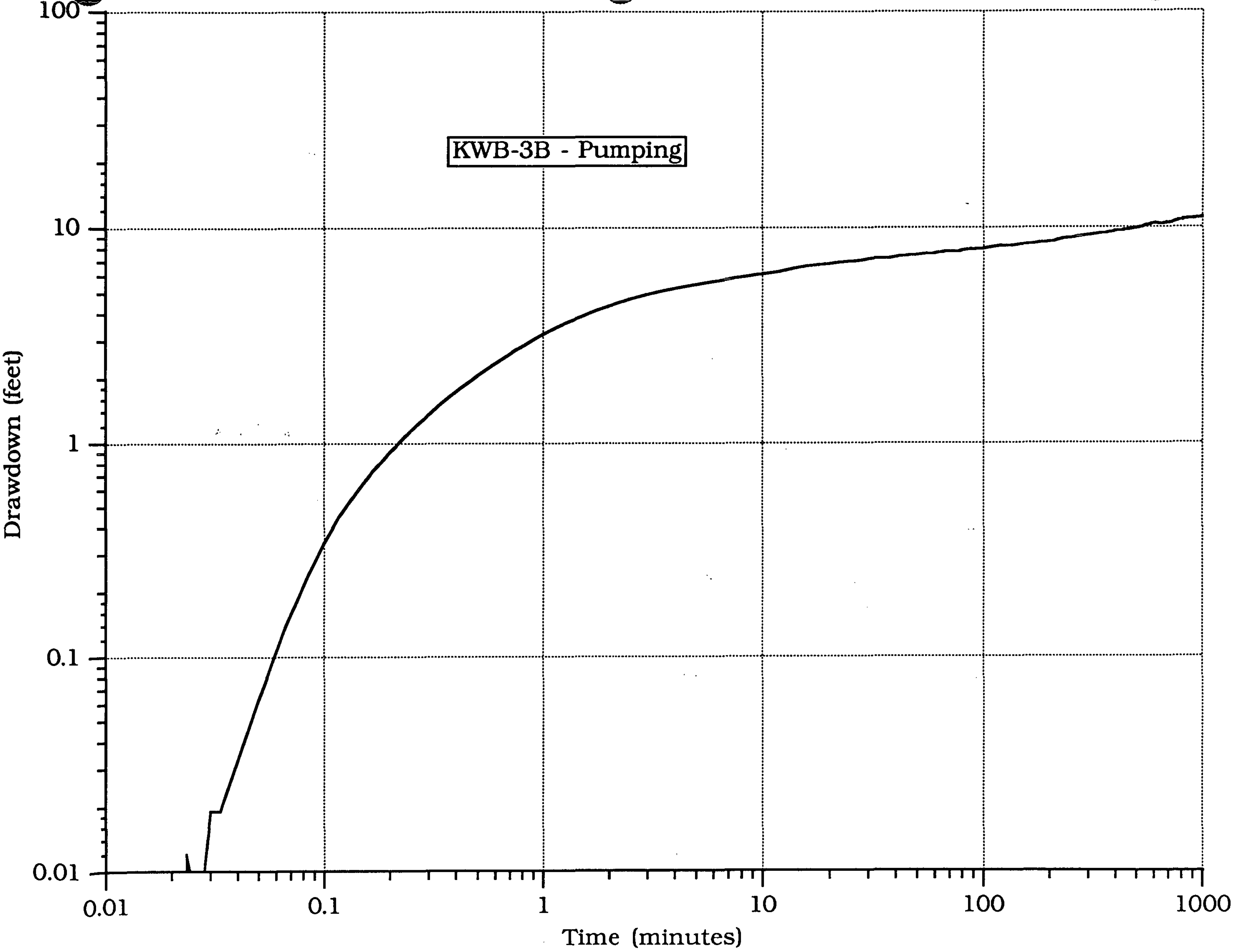

KWB-2B - Pumping
Drawdown (feet)
100
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
Time (minutes)

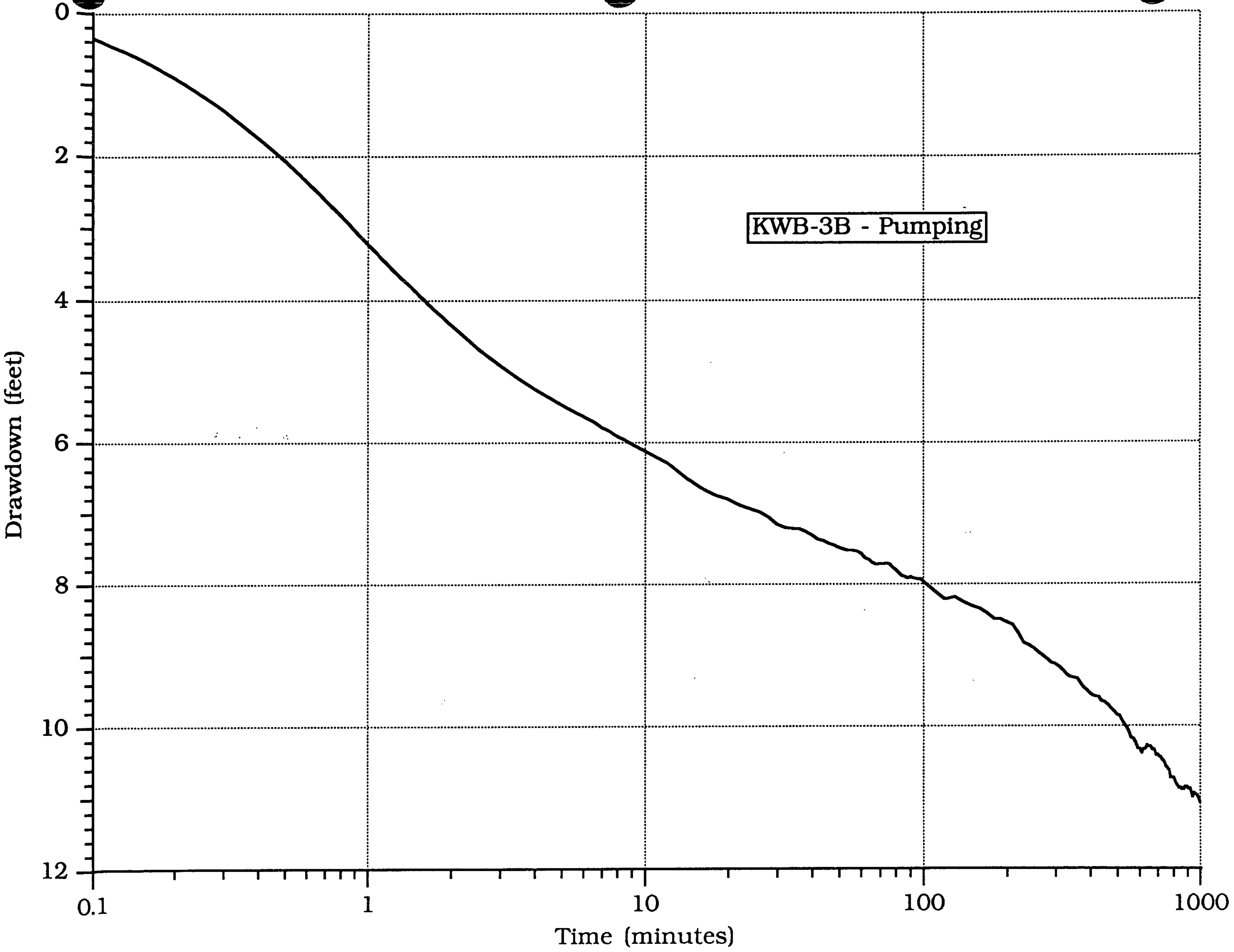


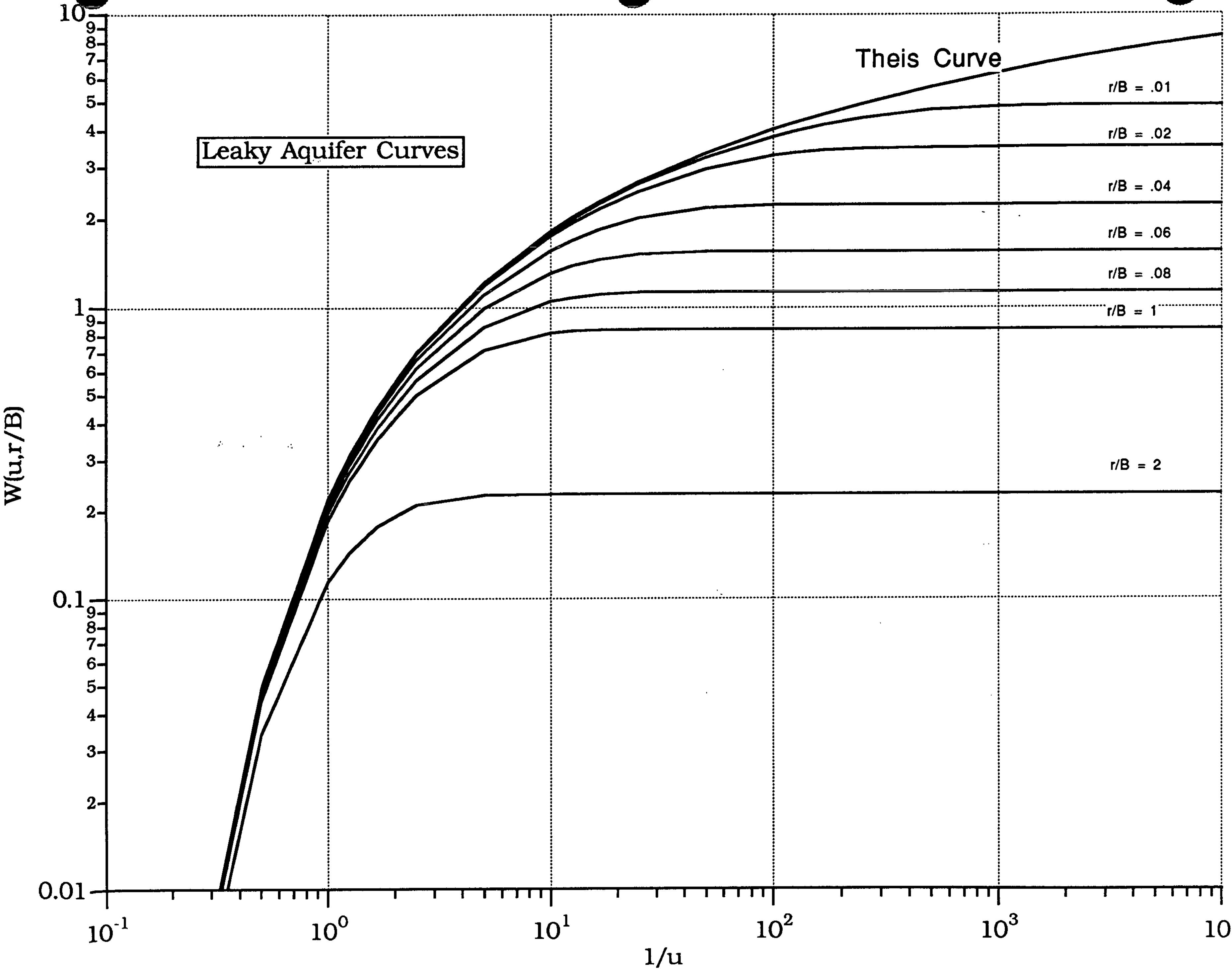
KWB-2B - Pumping
Drawdown (feet)
0
2
4
6
8
10
12
14
16
0.1
1
10
100
1000
Time (minutes)


KWB-3A Pumping
Drawdown (feet)
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
0.1
9
8
7
6
5
4
3
2
0.01
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Time (minutes)


KWB-3A - Pumping
Drawdown (feet)
0.0
0.2
0.4
0.6
0.8
1.0
Time (minutes)
0.1
1
10
100
1000

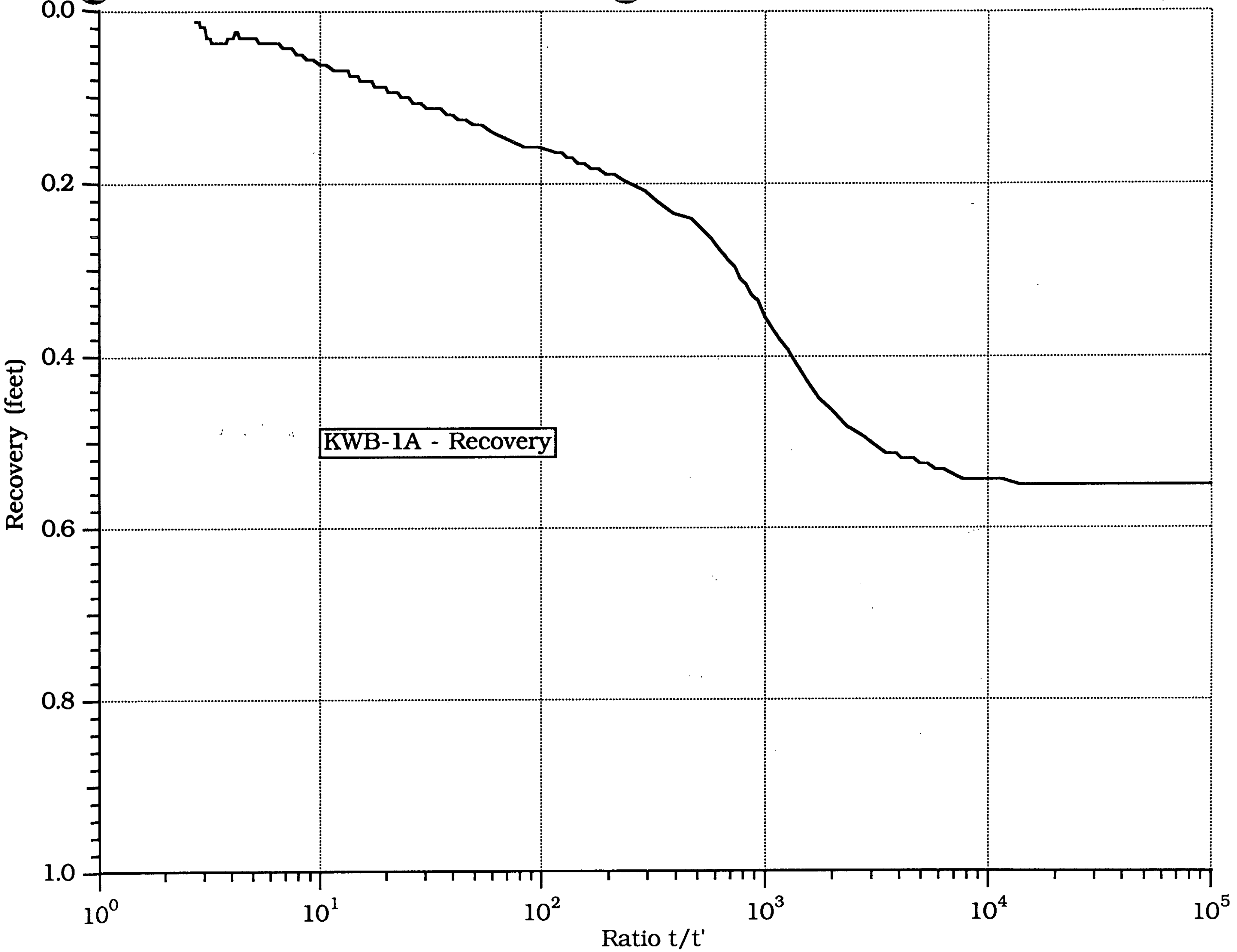

KWB-3B - Pumping
Drawdown (feet)
100
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
Time (minutes)

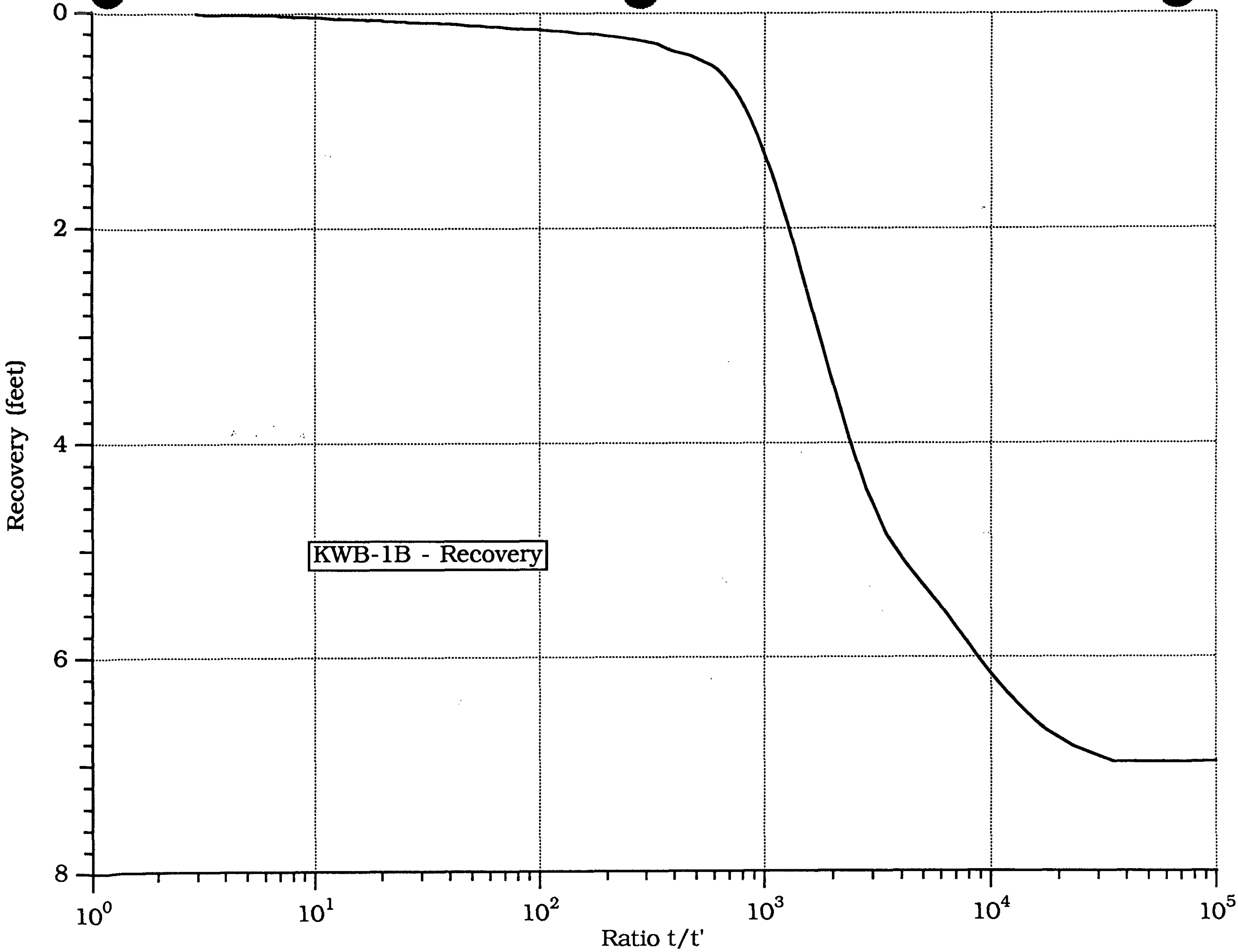

KWB-3B - Pumping
Drawdown (feet)
0
2
4
6
8
10
12
Time (minutes)
0.1
1
10
100
1000

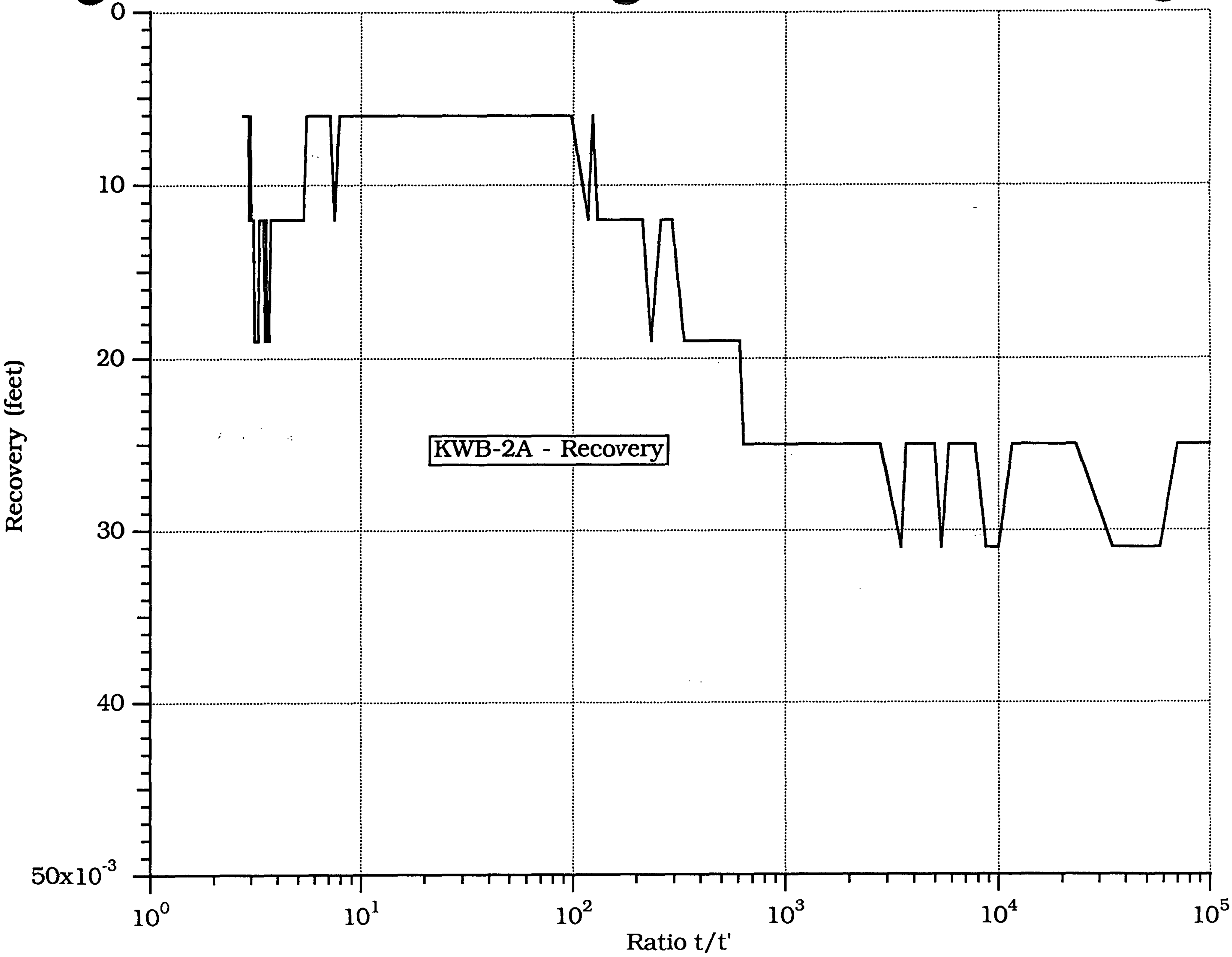

Leaky Aquifer Curves
Theis Curve
r/B = .01
r/B = .02
r/B = .04
r/B = .06
r/B = .08
r/B = 1
r/B = 2
W(u,r/B)
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
0.1
9
8
7
6
5
4
3
2
0.01
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
1/u

APPENDIX H-3

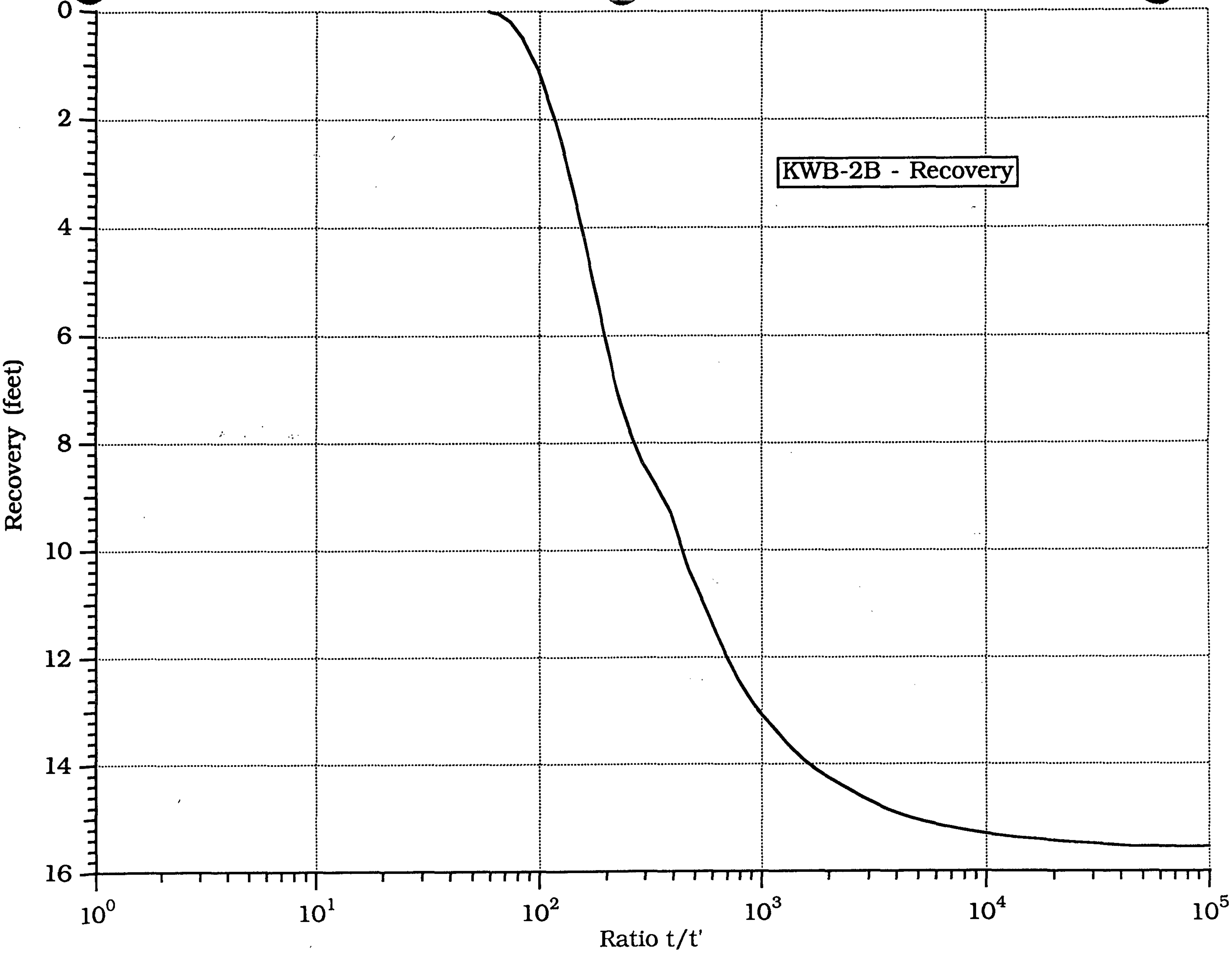
Recovery Data

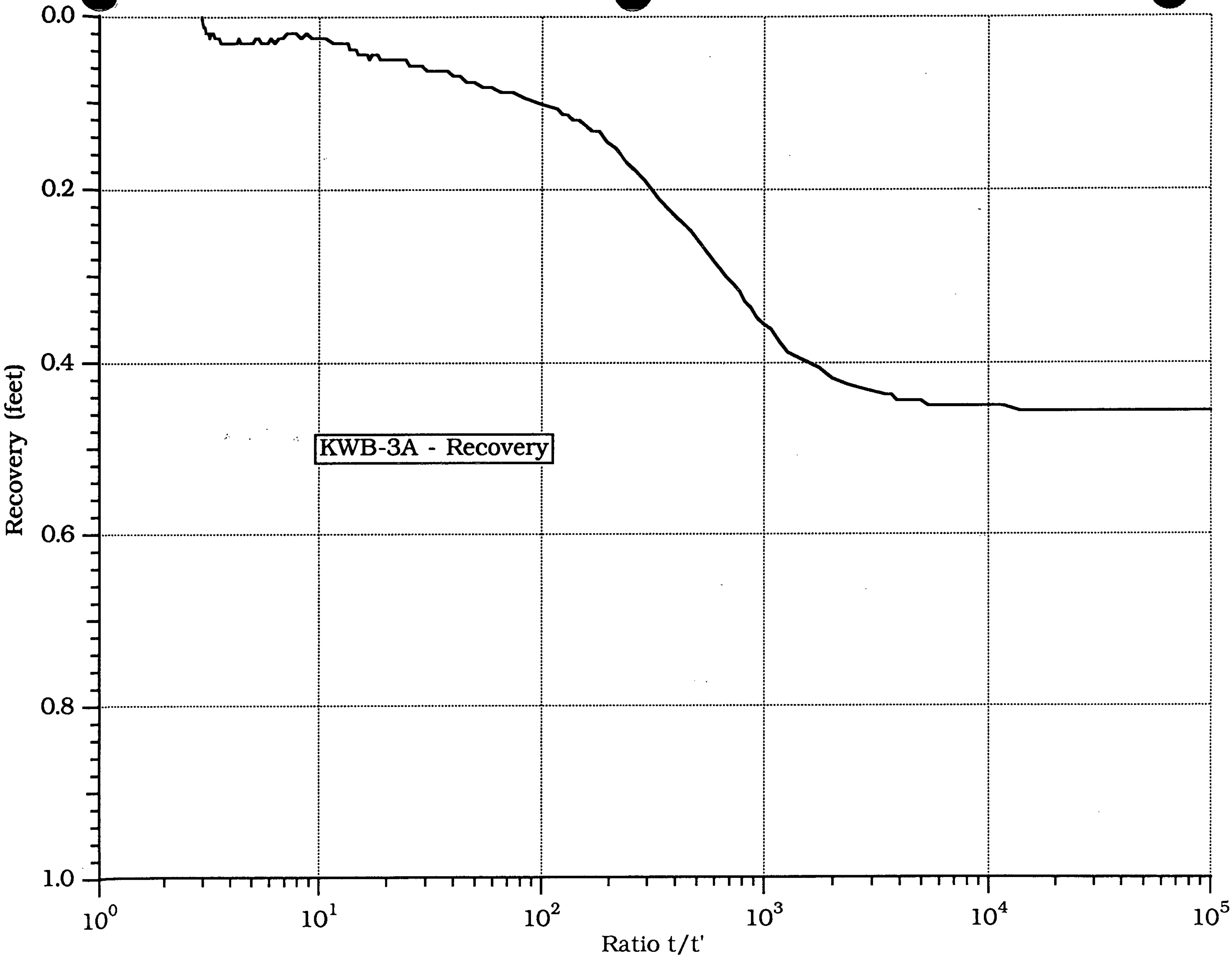

KWB-1A - Recovery
Recovery (feet)
0.0
0.2
0.4
0.6
0.8
1.0
Ratio t/t'
10^0
10^1
10^2
10^3
10^4
10^5


0
2
4
6
8
Recovery (feet)
KWB-1B - Recovery
10^0
10^1
10^2
10^3
10^4
10^5
Ratio t/t'

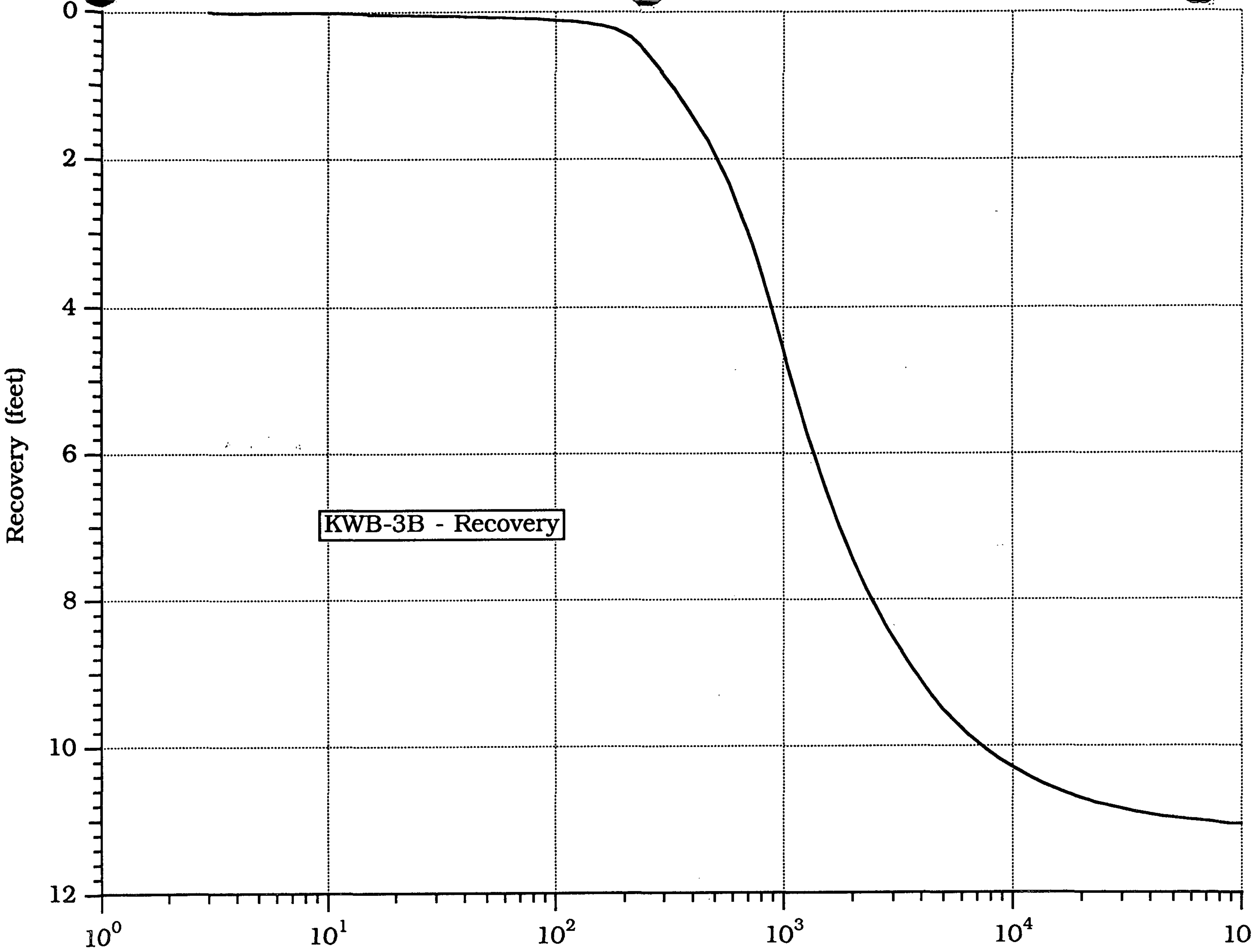


KWB-2A - Recovery
Recovery (feet)
0
10
20
30
40
50x10^{-3}
10^0
10^1
10^2
10^3
10^4
10^5
Ratio t/t'


KWB-2B - Recovery
Recovery (feet)
0
2
4
6
8
10
12
14
16
10^0
10^1
10^2
10^3
10^4
10^5
Ratio t/t'



KWB-3A - Recovery
Recovery (feet)
0.0
0.2
0.4
0.6
0.8
1.0
Ratio t/t'
10^0
10^1
10^2
10^3
10^4
10^5


KWB-3B - Recovery
Recovery (feet)
0
2
4
6
8
10
12
10^0
10^1
10^2
10^3
10^4
10^5
Ratio t/t'

REPORT ON NORTHEAST AREA HYDROCARBON CONTAMINATION

Navajo Refining Company
Artesia Refinery
Artesia, New Mexico

RECEIVED
OCT 06 1997
Environmental Bureau
Oil Conservation Division

prepared for:

David G. Griffin, Manager
Environmental Affairs for Water and Waste
Navajo Refining Company
501 East Main Street
P. O. Drawer 159
Artesia, New Mexico 88210

January 27, 1997

Los Alamos Technical Associates, Inc.
2400 Louisiana Blvd., NE / Building 1, Suite 400 / Albuquerque, NM 87110 / (505) 884-3800

LATA Los Alamos Technical Associates, Inc.

2400 Louisiana Blvd., NE, Building 1, Suite 400 / Albuquerque, NM 87110 / Telephone (505) 884-3800 / FAX (505) 880-3560

January 27, 1997

Mr. David G. Griffin, Manager
Environmental Affairs for Water and Waste
Navajo Refining Company
501 East Main Street
P.O. Drawer 159
Artesia, New Mexico 88211-0159

Re: Report on Northeast Area Hydrocarbon Contamination,
Navajo Refining Company, Artesia, New Mexico

Dear David:

This letter report presents the results of the exploratory drilling performed in late October and November 1996 to locate the downgradient extent of hydrocarbon product contamination in the area north of the KWB-1 series of wells. In addition to drilling conducted in 1996, results from the October 1995 investigatory drilling also are discussed.

Field Investigation

Exploratory drilling in October 1995 was performed in the area west of Bolton Road and south of Eagle Draw to locate permeable gravels for possible use as a recharge zone for reinjection of treated water from the Bolton Road recovery trenches (Figure 1). During this drilling, a zone of hydrocarbon product was located within a 10-feet thick gravel zone in a boring (OS 95-34) drilled along a dirt farm field road 525 feet north of the KWB-1 series wells. The hydrocarbon product was found only in this borehole. The north-south lateral extent of the gravels in the vicinity of the boring was found to be approximately 250 - 300 feet.

During drilling for EM survey verification in late October and mid-November of 1996, nine additional borings (OS 96-04 through 96-12) were located in an alfalfa field east of, and in proximity to, OS 95-34 to delineate the maximum downgradient extent of the hydrocarbon plume. The distance between borings was approximately 50 to 65 feet and the furthermost boring was located approximately 300 feet northeast of OS 95-34. Also, as part of the EM survey verification, four other holes were drilled west of this boring in an uncultivated pasture (OS 96-15 through 96-18). Drilling logs for all referenced borings are included as enclosures to this letter.

Results

Although hydrocarbon odor and traces of hydrocarbon product contamination were known to exist in the vicinity of the current boneyard fence as far back as 1991 (from drilling performed by Zeke Sherman), it was not believed to extend as far north and east as the area of OS 95-34. Its presence is due to a series of northeast-trending gravel zones which serve as very permeable channels for conducting fluids.

Using information collected during the investigations described above, I have constructed a series of cross-sections showing the subsurface lithology. Figure 2 shows the locations of the cross-sections. Sections A-A' and B-B' (Figures 3 and 4) are southwest-northeast cross-sections along the gravel trends while sections C-C' and D-D' (Figures 5 and 6) are cross-sections approximately perpendicular to the gravels. The solid lines on the cross-sections outline the vertical extent of the gravels.

East of boring OS 95-34, gravel thickness ranges from 4 feet at OS 96-04 to 14 feet at OS 96-06. The average thickness of the gravels (where present) is approximately 8 feet. The upper boundary of the gravels is at a depth of approximately 11 feet; the lower boundary ranges from 17 feet at boring OS 96-12 to 24 feet at OS 96-06. The gravels are confined above and below by clay and silty clay. Exact gravel thicknesses and boundaries could not be determined because the borings were logged from drill cuttings which blurred precise boundary delineation.

Hydrocarbons were detected in 2 of the 9 boreholes drilled east of OS 95-34. Detections included petroleum odor and sheen in OS 96-09 and odor only in OS 96-10. In the vicinity of OS 96-12, a narrow range of borehole spacing (from 50 to 65 feet versus a minimum of 75 feet in 1995), leads to the presumption that the leading edge of the hydrocarbon plume has been determined. The area of the observed hydrocarbon contamination, as determined from current drilling information, is outlined in Figure 1.

If a recovery trench system is to be utilized for hydrocarbon recovery, the most favorable location for its installation would be adjacent to the farm field road separating the Navajo pasture from the Coll field. Figure 7 presents a north-south cross-section along the road; the figure was constructed with data collected during the 1995 exploratory drilling. The location of the cross-section is shown on Figure 1.

Conclusions and Recommendations

1. In the vicinity of OS 95-34 a gravel zone of variable thickness exists at depths from about 11 to 24 feet. The average thickness is approximately 8 feet.

2. The gravels generally trend northeasterly; the north-south width of the gravels at this location is approximately 250 to 300 feet.

3. For the gravel zone located between OS 95-31 and OS 95-34, hydrocarbon contamination (consisting of odor, sheen, or product) was observed only in gravels located along the southern edge of the gravel zone.

4. In November 1996 the zone of known hydrocarbon contamination extended a maximum distance of approximately 100 feet east of the electric fence separating the Navajo pasture from the Coll alfalfa field.

5. The maximum north-south width of known hydrocarbon contamination is also about 100 feet and located between boreholes OS 95-30 on the north and OS 95-34 on the south.

6. To capture existing and future hydrocarbon contamination in this area, a north-south recovery trench approximately 300 to 350 feet in length should be installed in the gravel zone from north of OS 95-31 to south of OS 95-34. For a 350 feet long trench, the north and south ends should be located approximately 800 and 450 feet north of the KWB-1 wells, respectively.

7. Based on current drilling information, the maximum depth of the trench would be less than 25 feet and likely less than 23 feet.

8. Because hydrocarbon contamination has been located only in the gravel zone in the vicinity of OS 95-30 and OS 95-34, the trench should be segmented such that the hydrocarbons can be isolated and the efficiency of skimming and/or pumping of hydrocarbon product and water can be maximized. The northern extent of the gravels (located between OS 95-32 and OS 95-31) should be determined and construction started at the north end of the trench. Installation should continue southward until hydrocarbon contamination is encountered. The first segment of the trench would conclude with an in-trench barrier placed to prevent north-south fluid migration. Installation would continue with the second segment until the southern limit of the gravels is encountered. Completion would include wet wells and observation ports placed in both segments to monitor operation.

9. Current drilling information has shown movement of hydrocarbon contamination for just a short distance east of the Navajo pasture fence. Also, no evidence was found that indicates the presence of large amounts of free-phase hydrocarbons east of the fence. Timely installation of a recovery trench coupled with skimming and/or water recovery operations will prevent further movement of hydrocarbon product in a northeasterly direction. Without further free-phase contribution, existing downgradient product movement will diminish and eventually cease. Dissolved-phase transport may continue for some additional distance, but the large mass of water moving through the gravels will act to attenuate BTEX constituents thorough dispersion, volatilization, and natural biodegradation. Therefore, given prompt initiation of recovery efforts, it is very unlikely that downgradient surface water or currently used drinking water will be impacted by hydrocarbon contamination at this location.

If you have questions regarding this report, or wish additional information and/or interpretation, please do not hesitate to contact me. After January 28, I can be reached at (505) 281-8591 in Cedar Crest, NM.

Sincerely,

David G. Boyer, P.G.
Project Manager

Enclosures

ENCLOSURE 1

Figures and Geologic Cross-Sections

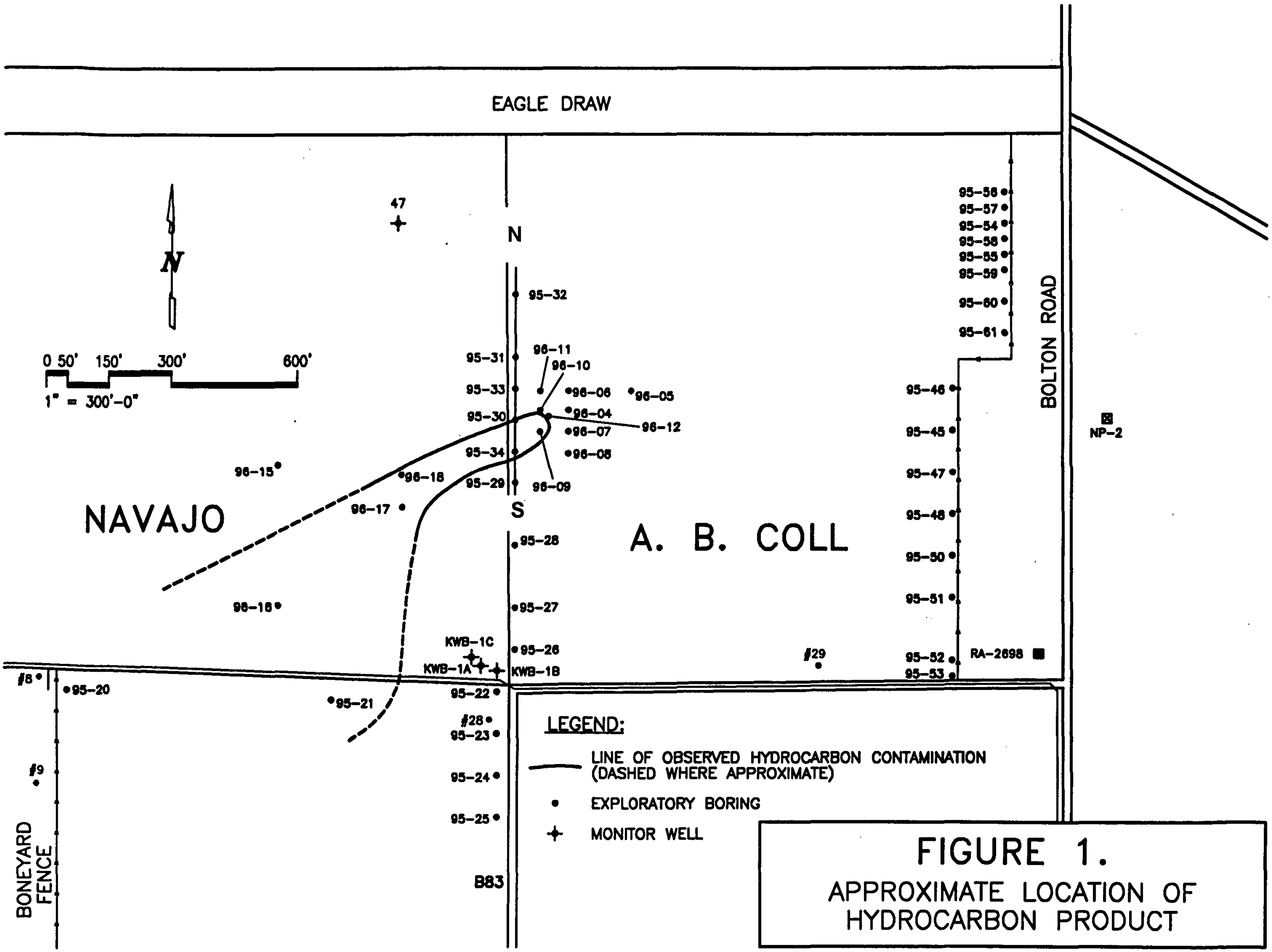


FIGURE 1.
APPROXIMATE LOCATION OF HYDROCARBON PRODUCT

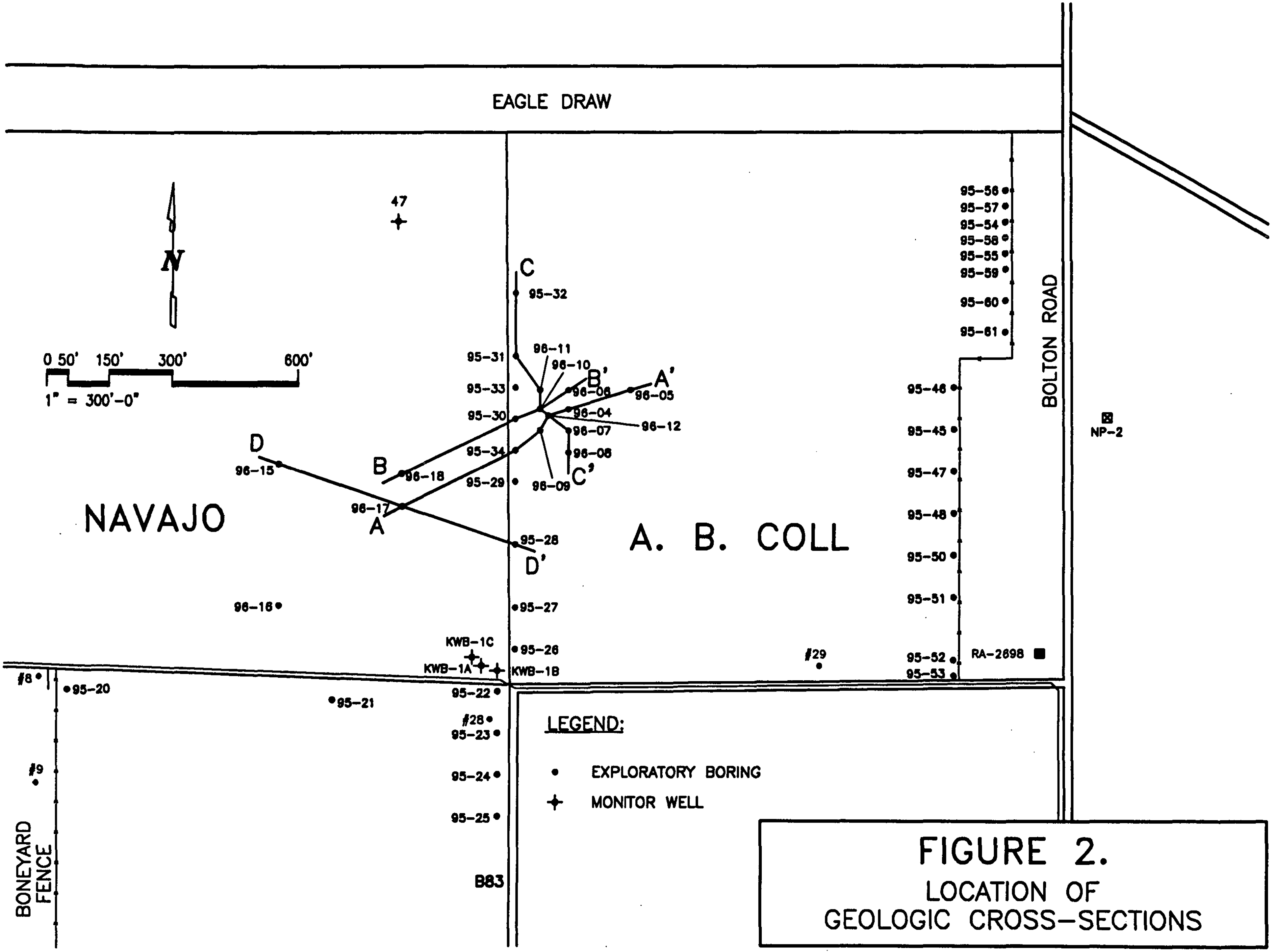
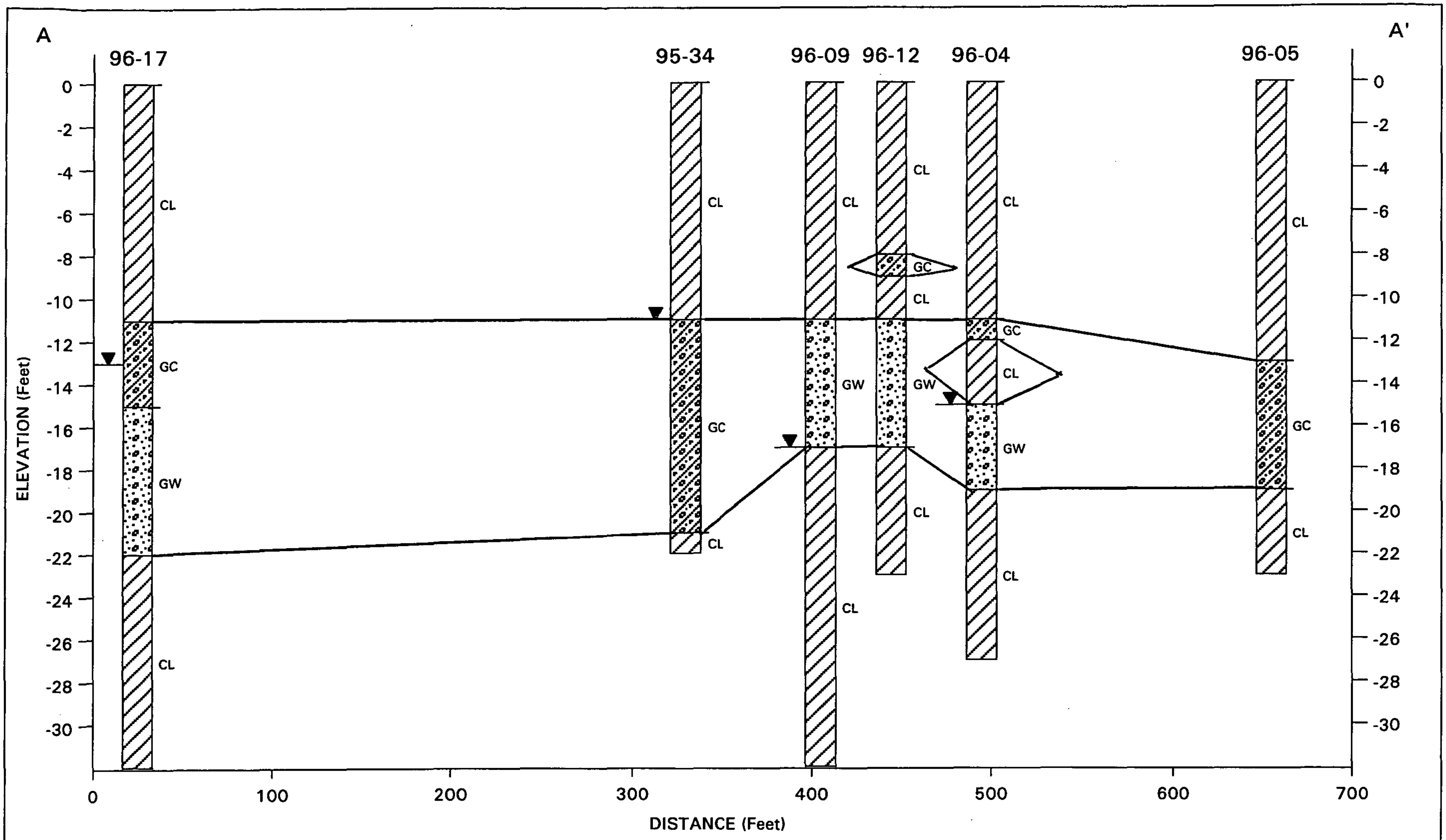


FIGURE 2.
LOCATION OF
GEOLOGIC CROSS-SECTIONS



Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Figure 3

GEOLOGIC CROSS SECTION
Section A-A'
Southwest-Northeast
Lithologic Borings

LEGEND

GW Gravels, gravel-sand mixtures

GC Clayey gravels, gravel-sand-clay mixtures

CL Medium plasticity clays, gravelly, sandy, or silty clays

Note 1: Solid lines outline gravel zones

Note 2: Water depths approximate

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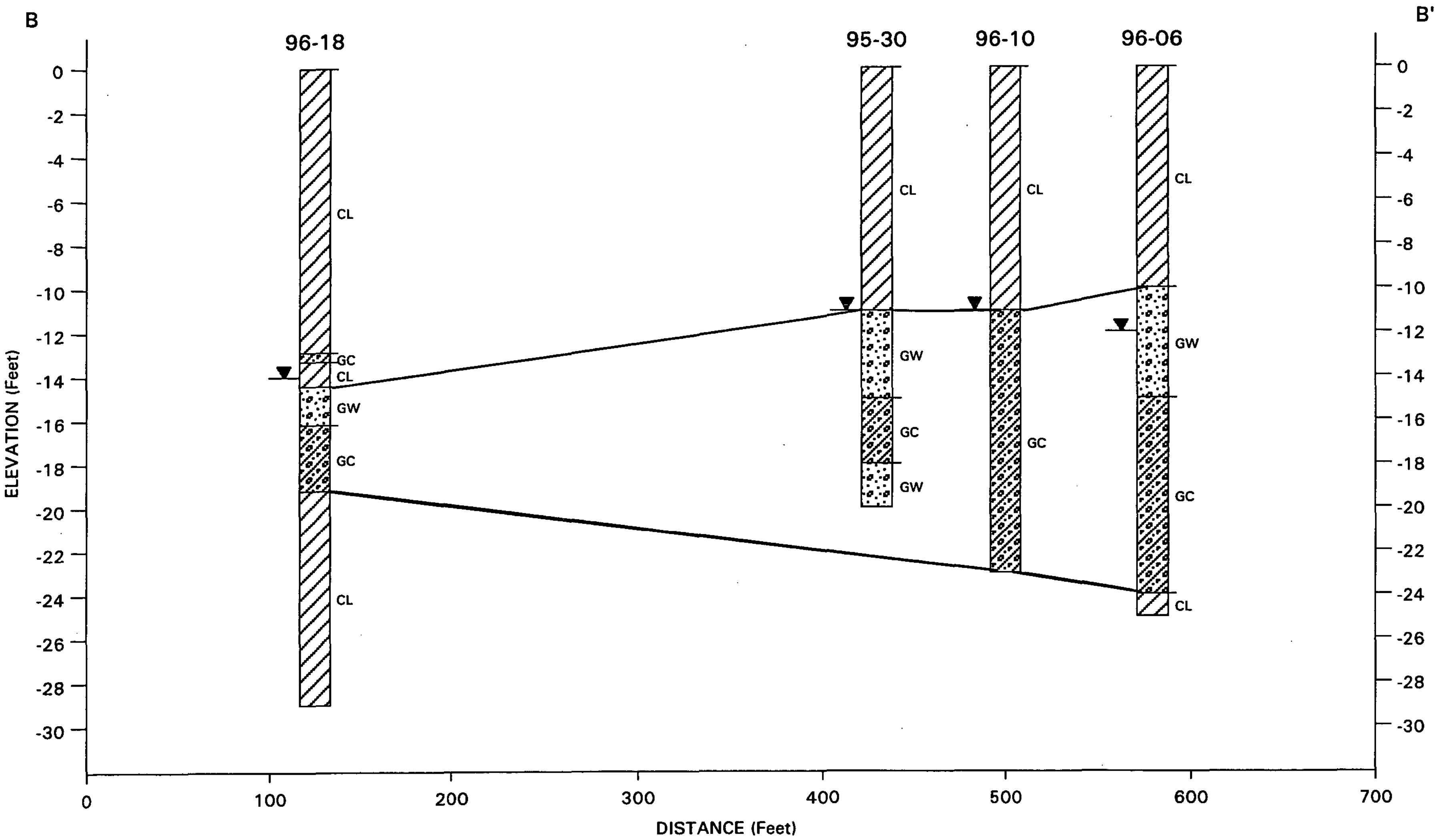

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Navajo

Figure 4

GEOLOGIC CROSS SECTION

Section B-B'
Southwest-Northeast
Lithologic Borings

LEGEND

GW	Gravels, gravel-sand mixtures
GC	Clayey gravels, gravel-sand-clay mixtures
CL	Medium plasticity clays, gravelly, sandy, or silty clays

Note 2: Water depths approximate

Note 1: Solid lines outline gravel zones

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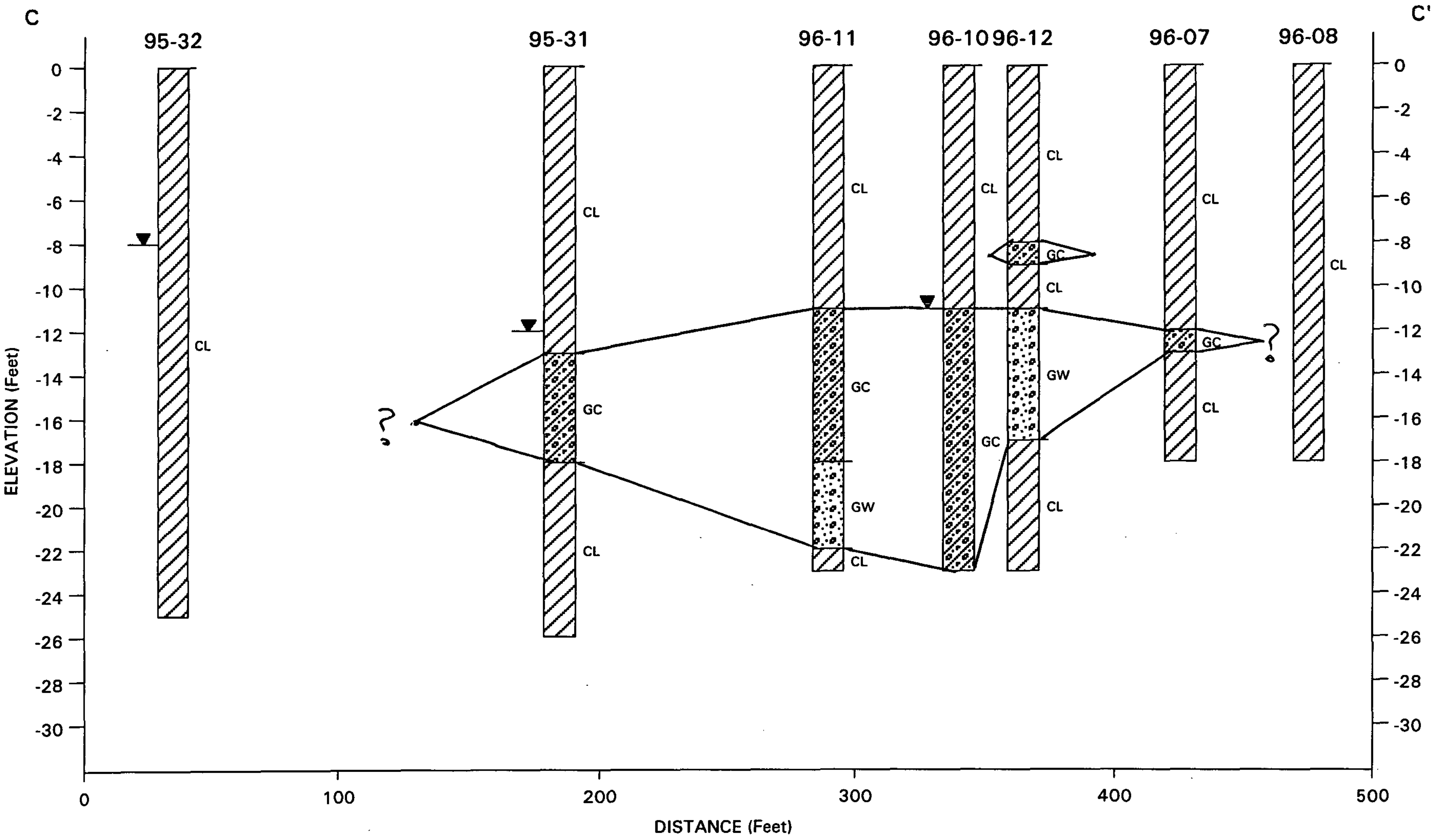

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Figure 5

GEOLOGIC CROSS SECTION

Section C-C'
North-South
Lithologic Borings

LEGEND

GW	Gravels, gravel-sand mixtures
GC	Clayey gravels, gravel-sand-clay mixtures
CL	Medium plasticity clays, gravelly, sandy, or silty clays

Note 1: Solid lines outline gravel zones

Note 2: Water depths approximate

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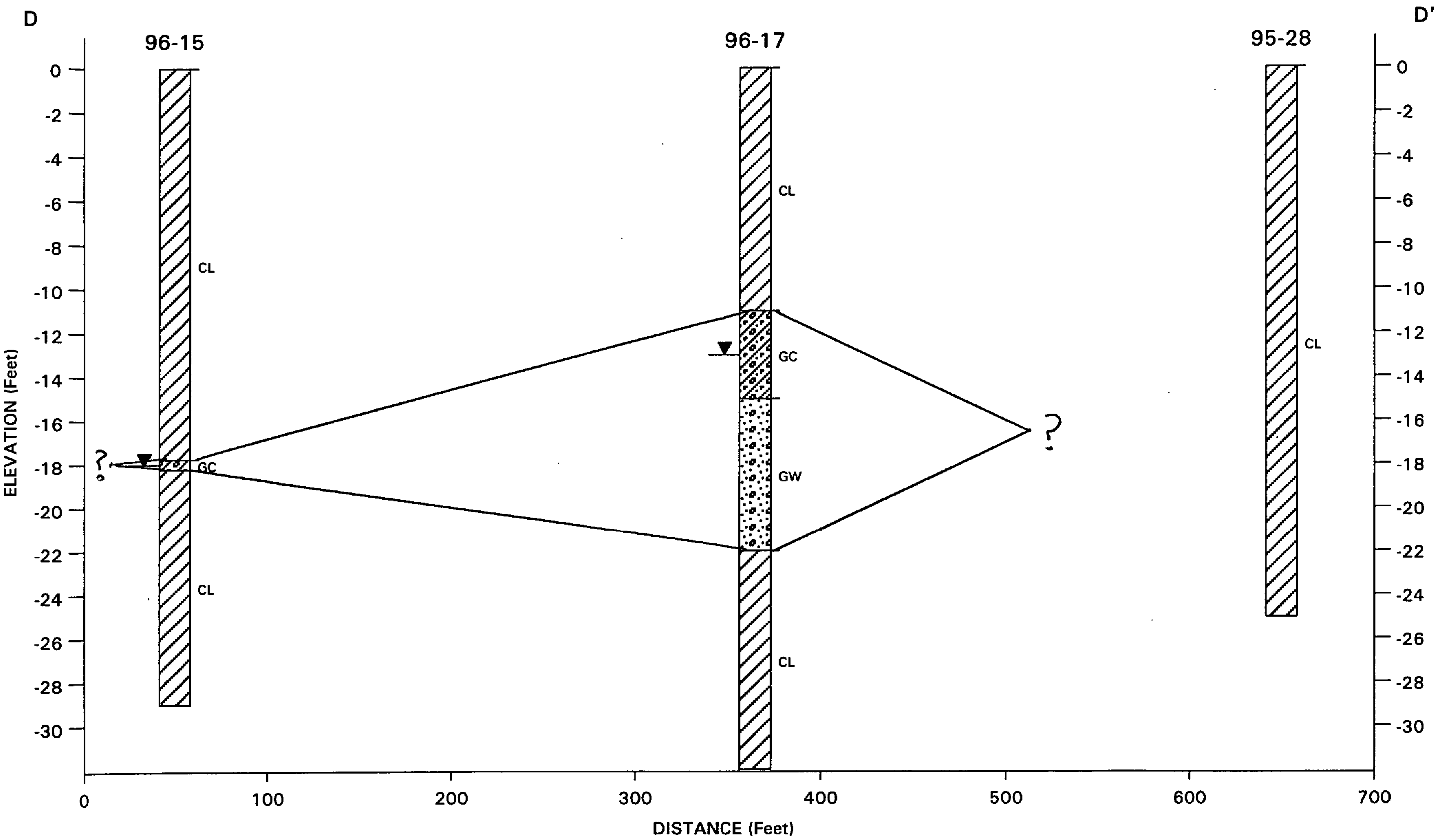

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Figure 6

GEOLOGIC CROSS SECTION
Section D-D'
Northwest-Southeast
Lithologic Borings

LEGEND

GW	Gravels, gravel-sand mixtures
GC	Clayey gravels, gravel-sand-clay mixtures
CL	Medium plasticity clays, gravelly, sandy, or silty clays

Note 1: Solid lines outline gravel zones

Note 2: Water depths approximate

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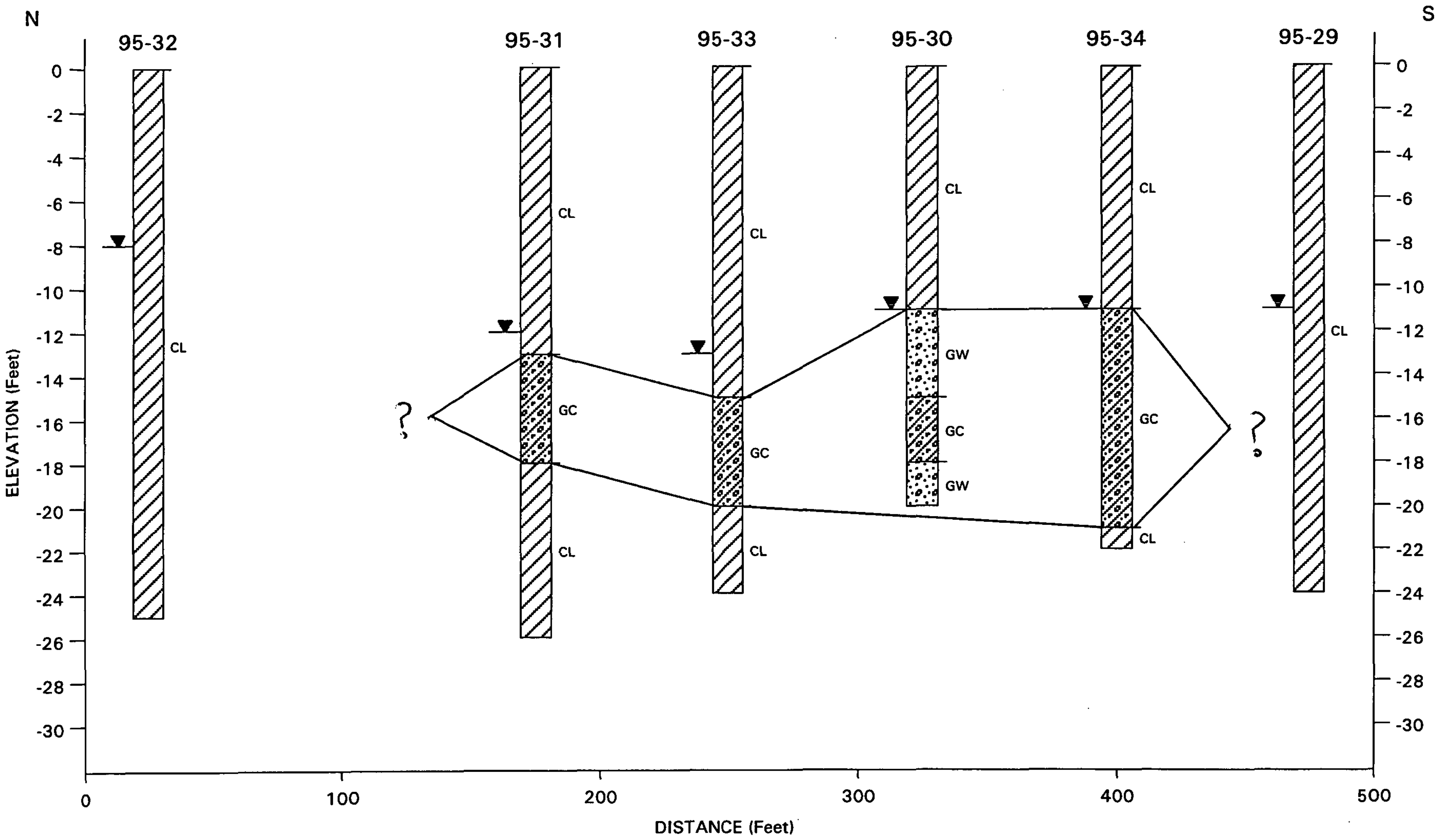

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Figure 7

GEOLOGIC CROSS SECTION
Section N-S
North-South
Lithologic Borings

LEGEND

GW	Gravels, gravel-sand mixtures
GC	Clayey gravels, gravel-sand-clay mixtures
CL	Medium plasticity clays, gravelly, sandy, or silty clays

Note 1: Solid lines outline gravel zones

Note 2: Water depths approximate

1-28-1997 \mtech4\navoff96\n-x-sect\cross-ee.cro

ENCLOSURE 2

Copies of Borehole Lithologic Logs Used in Drawing Cross-Sections

Navajo

LOG OF BORING 95-29

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started:	: 10/18/95	Drilling Method:	: Solid Stem Auger
Time Started	: 1650	Sampling Method:	: Cuttings
Date Completed	: 10/18/95	Drilled By:	: Frank's Rathole Srv.
Hole Diameter:	: 13"	Logged By:	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨		CROSS-SECTION SHEET
		▨		0-6 ft. Top soil
5	Cuttings	▨		
		▨		6-10 ft. Clay, brown
10		▨		
		▨		10-12 ft. Clay with increasing gravel, saturated, no H/C odor noted
		▨	CL	
		▨		12-14 ft. Clay with caliche gravel
15		▨		14-17 ft. Clay, very stiff, no gravel
	Cuttings	▨		
		▨		17-21 ft. Clay, very stiff, no gravel
20		▨		
		▨		21-24 ft. Clay, brown
25				
30				
35				
40				

Notes:

Hole located 450 ft. north of KWB-1 monitor wells, 13 ft. east of electric fence along dirt road.

Refinery workers plugged back hole with cuttings.

H/C = Petroleum hydrocarbon

1-28-1997 \mtech4\navoff96\n-x-sect\off95-29.ge4

LOG OF BORING 95-30

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started:	: 10/18/95	Drilling Method:	: Solid Stem Auger
Time Started	: 1715	Sampling Method:	: Cuttings
Date Completed	: 10/18/95	Drilled By:	: Frank's Rathole Srv.
Hole Diameter:	: 13"	Logged By:	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨	CL	CROSS-SECTION SHEET 0-6 ft. Top soil
5	Cuttings			
				6-10 ft. Clay, brown, moist
10				10-11 ft. Clay with river gravels, saturated, no H/C odor noted
		⁙	GW	11-15 ft. River gravel, large (2-3 in. diameter)
15	Cuttings	▨	GC	15-18 ft. Gravel with some clay
		⁙	GW	18-20 ft. Gravel, can not drill deeper due to auger binding by gravel
20				
25				
30				
35				
40				

Notes:

Hole located 600 ft. north of KWB-1 monitor wells, 13 ft. east of electric fence along dirt road.

At completion water depth at 12 ft. with caving. Refinery workers plugged back hole with cuttings.

H/C = Petroleum hydrocarbon

12-20-1996 \mtech4\navoff96\n-x-sect\off95-30.ge4

LOG OF BORING 95-31

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started:	: 10/18/95	Drilling Method:	: Solid Stem Auger
Time Started	: 1735	Sampling Method:	: Cuttings
Date Completed	: 10/18/95	Drilled By:	: Frank's Rathole Srv.
Hole Diameter:	: 13"	Logged By:	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨		CROSS-SECTION SHEET
				0-6 ft. Top soil
5	Cuttings		CL	
				6-10 ft. Clay, light brown, stiff
10				10 ft. Auger refusal, check for metal, none
				10-13 ft. Clay with caliche gravel, some water, no H/C odor noted
		▩		13-14 ft. Gravel and clay (river gravels)
15			GC	14-18 ft. Clayey gravel
20	Cuttings	▨		18-22 ft. Gravelly clay (but auger may be dragging down gravel)
			CL	22-26 ft. Gravelly clay (but auger may be dragging down gravel)
25				
30				
35				
40				

Notes:

Hole located 750 ft. north of KWB-1 monitor wells, 13 ft. east of electric fence along dirt road.

Refinery workers plugged back hole with cuttings.

H/C = Petroleum hydrocarbon

Navajo

LOG OF BORING 95-32

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started:	: 10/19/95	Drilling Method:	: Solid Stem Auger
Time Started	: 0845	Sampling Method:	: Cuttings
Date Completed	: 10/19/95	Drilled By:	: Frank's Rathole Srv.
Hole Diameter:	: 13"	Logged By:	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨		CROSS-SECTION SHEET
				0-6 ft. Top soil to approximately 6 ft.
5	Cuttings			
				6-10 ft. Caliche clay, water at approximately 8 ft.
10				
				10-13 ft. Clay, light brown, moist, no gravel, no H/C odor
			CL	
				13-16 ft. Clay, light brown, plastic, very stiff
15				
				16-18 ft. Clay, light brown
	Cuttings			18-19 ft. Clay, light brown, increasing small caliche gravel
20				19-21 ft. Clay, light brown, very stiff, small caliche gravel
				21-25 ft. Clay, light brown, less gravel (occasional caliche gravel)
25				
30				
35				
40				

Notes:

Hole located 900 ft. north of KWB-1 monitor wells, 13 ft. east of electric fence along dirt road.

Refinery workers plugged back hole with cuttings.

H/C = Petroleum hydrocarbon

12-20-1996 \mtech4\navoff96\n-x-sect\off95-32.ge4

LOG OF BORING 95-33

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started: : 10/19/95
Time Started : 0925
Date Completed : 10/19/95
Hole Diameter: : 13"

Drilling Method: : Solid Stem Auger
Sampling Method: : Cuttings
Drilled By: : Frank's Rathole Srv.
Logged By: : D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨		CROSS-SECTION SHEET
				0-6 ft. Top soil
5	Cuttings			
			CL	6-10 ft. Clay, brown, stiff, moist, occasional caliche gravel
10				10-13 ft. Clay, brown, stiff, moist, caliche gravel increasing in size and frequency
				13-15 ft. Gravelly clay, water at 13 ft, no H/C odor
15		▩		15-16 ft. Clayey gravel, river gravels to 3 in. diameter
	Cuttings		GC	16-18 ft. Clayey gravel, gravel smooth, well rounded
				18-20 ft. Clayey gravel, increasing clay at 20 ft.
20		▨		20-21 ft. Clay, stiff, no gravel
			CL	21-24 ft. Clay, light brown, very stiff
25				
30				
35				
40				

Notes:

Hole located 675 ft. north of KWB-1 monitor wells, 13 ft. east of electric fence along dirt road.

Refinery workers plugged back hole with cuttings.

H/C = Petroleum hydrocarbon

1-28-1997 \mtech4\navoff96\n-x-sect\off95-33.ge4

Navajo

LOG OF BORING 95-34

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started: : 10/19/95
Time Started : 0945
Date Completed : 10/19/95
Hole Diameter: : 13"

Drilling Method: : Solid Stem Auger
Sampling Method: : Cuttings
Drilled By: : Frank's Rathole Srv.
Logged By: : D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0 5 10	Cuttings	▨	CL	CROSS-SECTION SHEET 0-6 ft. Top soil to approximately 6 ft. 6-10 ft. Clay, brown 10-11 ft. Clay and caliche clay, small caliche gravels, color gray-brown, strong H/C odor on dirt
15 20	Cuttings	▩	GC	11-14 ft. Clayey gravel, strong H/C odor throughout 14-21 ft. Clayey gravel, free H/C product on auger
		▨	CL	22 ft. Clay, light brown, stiff, auger jamming, pulled out, total depth 22 ft.
25 30 35 40				

Notes:

Hole located 525 ft. north of monitor well KWB-1 wells, 13 ft. east of electric fence along dirt road.

At 1400 hrs., measured 0.5 ft. of gasoline. Refinery workers plugged back hole with cuttings.

H/C = Petroleum hydrocarbon

12-20-1996 \mtech4\navoff96\n-x-sect\off95-34.ge4

LOG OF BORING 96-04

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 10/30/96	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1551, 1615	Drill Equipment	: Ingersoll-Rand A-300
Transect & Location	: Not Applicable	Drilled By	: Atkins Eng. Assoc.
Hole Diameter	: 6"	Logged By	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨		CROSS-SECTION SHEET
		▨		0-5 ft. Silty clay, brown, no H/C odor
5	Cuttings	▨	CL	5-11 ft. Clay and silty clay, light brown; small, rounded gravels at 7 ft.
10		▨		
		▨	GC	11-12 ft. Gravels
		▨	CL	12-15 ft. Clay, soft, plastic
15		⁙	GW	15-19 ft. River gravels, limestone, to 3" diameter, water at 15 ft., no H/C odor
20	Cuttings	▨	CL	19-27 ft. Silty Clay, saturated, no H/C odor
25		▨		
30				

Notes:

Boring 96-04 located in field northeast of well KWB-1, 670 ft. south of the Eagle Creek fence and 150 ft. east of electric fence. At completion, drillers plugged back hole with cuttings.
H/C = Petroleum Hydrocarbon

12-20-1996 \mtech4\navoff96\n-x-sect\off96-04.ge4

Navajo

LOG OF BORING 96-05

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 10/30/96	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1630, 1650	Drill Equipment	: Ingersoll-Rand A-300
Transect & Location	: Not Applicable	Drilled By	: Atkins Eng. Assoc.
Hole Diameter	: 6"	Logged By	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨		CROSS-SECTION SHEET
0-5	Cuttings	▨	CL	0-5 ft. Silty clay, dry
5-10		▨		5-10 ft. Clay, light brown, damp at 10 ft., no H/C odor
10-13		▨		10-13 ft. Clay, light brown
13-15		⁘	GC	13-15 ft. Gravel at approx. 13 ft., no H/C odor
15-19	Cuttings	⁘		15-19 ft. Gravel, clay matrix(?), not making as much water as 96-03, no H/C odor
19-23		▨	CL	20-23 ft. Clay, some water, no H/C odor

Notes:

Boring 96-05 located in field northeast of well KWB-1, 620 ft. south of the Eagle Creek fence and 300 ft. east of electric fence. At completion, drillers plugged back hole with cuttings.

H/C = Petroleum Hydrocarbon

Navajo

LOG OF BORING 96-06

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Drilled : 10/31/96
Time Start, Finish : 0730, 0810
Transect & Location : Not Applicable
Hole Diameter : 6"

Drilling Method : Hollow Stem Auger
Drill Equipment : Ingersoll-Rand A-300
Drilled By : Atkins Eng. Assoc.
Logged By : D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨		CROSS-SECTION SHEET
		▨		0-5 ft. Topsoil, silty clay, brown, no H/C odor
5	Cuttings	▨	CL	
		▨		5-10 ft. Clay, light brown to chalk color, no H/C odor
10		░	GW	10-15 ft. Gravel, river gravel 2-3" diameter, water at approx. 12 ft., no H/C odor
15	Cuttings	▩		15-20 ft. Gravel, matrix uncertain (clay?), no H/C odor
20		▩	GC	
		▩		20-24 ft. Gravel, no H/C odor
		▨	CL	24-25 ft. Clay, no H/C odor
25				
30				

Notes:

Boring 96-06 located in field northeast of well KWB-1, 620 ft. south of the Eagle Creek fence and 150 ft. east of electric fence. At completion, drillers plugged back hole with cuttings.

H/C = Petroleum Hydrocarbon

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LOG OF BORING 96-07

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 10/31/96	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 0820, 0840	Drill Equipment	: Ingersoll-Rand A-300
Transect & Location	: Not Applicable	Drilled By	: Atkins Eng. Assoc.
Hole Diameter	: 6"	Logged By	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0				CROSS-SECTION SHEET
				0-5 ft. Topsoil, clay and silty clay, brown
5	Cuttings		CL	
				5-12 ft. Clay, light brown to chalk color, no H/C odor
10				
			GC	12-13 ft. Gravel, no H/C odor
	Cuttings			
15			CL	13-18 ft. Clay, saturated, no H/C odor
20				
25				
30				

Notes:

Boring 96-07 located in field northeast of well KWB-1, 720 ft. south of the Eagle Creek fence and 150 ft. east of electric fence. At completion, drillers plugged back hole with cuttings.

H/C = Petroleum Hydrocarbon

12-20-1996 \mtech4\navoff96\n-x-sect\off96-07.ge4

Navajo

LOG OF BORING 96-08

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Drilled : 10/31/96
Time Start, Finish : 0850, 0910
Transect & Location : Not Applicable
Hole Diameter : 6"

Drilling Method : Hollow Stem Auger
Drill Equipment : Ingersoll-Rand A-300
Drilled By : Atkins Eng. Assoc.
Logged By : D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨		CROSS-SECTION SHEET
		▨		0-5 ft. Topsoil, clay and silty clay, brown
5	Cuttings	▨		
		▨		5-10 ft. Clay, small caliche gravels at approx. 10 ft., no water, no H/C odor
		▨	CL	
10		▨		
		▨		10-15 ft. Clay, light brown, stiff, plastic, no H/C odor
	Cuttings	▨		
15		▨		
		▨		15-18 ft. Clay, same as above, no H/C odor
20				
25				
30				

Notes:

Boring 96-08 located in field northeast of well KWB-1, 770 ft. south of the Eagle Creek fence and 150 ft. east of electric fence. At completion, drillers plugged back hole with cuttings.

H/C = Petroleum Hydrocarbon

LOG OF BORING 96-09

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 10/31/96	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 0920, 0950	Drill Equipment	: Ingersoll-Rand A-300
Transect & Location	: Not Applicable	Drilled By	: Atkins Eng. Assoc.
Hole Diameter	: 6"	Logged By	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0 5 10	Cuttings	▨	CL	CROSS-SECTION SHEET 0-5 ft. Topsoil, clay, brown, small caliche gravels 5-11 ft. Clay, brown, darker at approx. 7 ft., no H/C odor
15		⁘	GW	11-17 ft. River gravels, moderate H/C odor, stronger from 15-17 ft.
20 25 30	Cuttings	▨	CL	17-25 ft. Clay, saturated, gravel noted at 23 ft., no evidence of free product on auger, water, or clays, but H/C odor 25-30 ft. Clay, gravel at approx. 27 ft., occasional sheen on clay slurry from augers, H/C odor 30-33 ft. Clay, occasional gravel felt by driller, clay slurry lighter color, no sheen, no odor
35 40				

Notes:

Boring 96-09 located in field northeast of well KWB-1, 720 ft. south of the Eagle Creek fence and 85 ft. east of electric fence. At completion, drillers plugged back hole with cuttings.

H/C = Petroleum Hydrocarbon

12-20-1996 \mtech4\navoff96\n-x-sect\off96-09.ge4

LOG OF BORING 96-10

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Drilled : 10/31/96
Time Start, Finish : 1010, 1040
Transect & Location : Not Applicable
Hole Diameter : 6"

Drilling Method : Hollow Stem Auger
Drill Equipment : Ingersoll-Rand A-300
Drilled By : Atkins Eng. Assoc.
Logged By : D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨		CROSS-SECTION SHEET
				0-5 ft. Topsoil and clay, brown, no H/C odor
5	Cuttings		CL	
				5-10 ft. Clay, light brown, slightly moist, plastic, small caliche gravel at approx. 9 ft., no H/C odor
10				10-11 ft. Clay as above
		▩		11-15 ft. Gravel, water at approx. 11 ft., no H/C odor
15				
	Cuttings		GC	15-20 ft. Gravels, no odor
20				
				20-23 ft. Gravel, H/C odor on clays returned to surface on auger, no water/slurry returned to surface
25				
30				

Notes:

Boring 96-10 located in field northeast of well KWB-1, 670 ft. south of the Eagle Creek fence and 85 ft. east of electric fence. At completion, spotted H/C sheen on water in hole. Drillers plugged back hole with cuttings.

H/C = Petroleum Hydrocarbon

LOG OF BORING 96-11

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 10/31/96	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1050, 1115	Drill Equipment	: Ingersoll-Rand A-300
Transect & Location	: Not Applicable	Drilled By	: Atkins Eng. Assoc.
Hole Diameter	: 6"	Logged By	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨		CROSS-SECTION SHEET
5	Cuttings	▨	CL	0-9 ft. Topsoil and clay, brown, no H/C odor
10		▨		9-11 ft. Caliche clay, light brown, no H/C odor
15	Cuttings	▨	GC	11-18 ft. Gravel and clay, no H/C odor
20		⁘	GW	18-22 ft. Gravel, no H/C odor
		▨	CL	22-23 ft. Clay, no H/C odor on soil or clay slurry
25				
30				

Notes:

Boring 96-11 located in field northeast of well KWB-1, 620 ft. south of the Eagle Creek fence and 85 ft. east of electric fence. At completion drillers plugged back hole with cuttings.

H/C = Petroleum Hydrocarbon

12-20-1996 \mtech4\navoff96\n-x-sect\off96-11.ge4

LOG OF BORING 96-12

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Drilled : 10/31/96
Time Start, Finish : 1125, 1155
Transect & Location : Not Applicable
Hole Diameter : 6"

Drilling Method : Hollow Stem Auger
Drill Equipment : Ingersoll-Rand A-300
Drilled By : Atkins Eng. Assoc.
Logged By : D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▨		CROSS-SECTION SHEET
		▨		0-6.5 ft. Topsoil, brown
		▨	CL	
5	Cuttings	▨		
		▨		6.5-8 ft. Clay, light brown, very soft, very plastic
		▨	GC	8-9 ft. Gravel
10		▨	CL	9-11 ft. Clay, no H/C odor
		∴	GW	11-17 ft. Gravel, no H/C odor
15		∴		
	Cuttings	▨		
20		▨	CL	17-23 ft. Clay, no H/C odor in hole
25				
30				

Notes:

Boring 96-12 located in field northeast of well KWB-1, 685 ft. south of the Eagle Creek fence and 107 ft. east of electric fence. At completion drillers plugged back hole with cuttings.

H/C = Petroleum Hydrocarbon

12-20-1996 \mtech4\navoff96\n-x-sect\off96-12.ge4

LOG OF BORING 96-15

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date, Time Started : 11/19/96, 1500
Date, Time Finish : 11/20/96, 0815
Transect & Location : #14, 775 ft. South
Hole Diameter : 6 inch
Drilling Method : Hollow Stem Auger
Drill Equipment : Ingersoll-Rand A-300
Drilled By : Atkins Eng. Assoc.
Logged By : D.G. Boyer

Sample Condition	Sampler Type
☒ Remoulded	SS Split Spoon
▨ Undisturbed	ST Shelby Tube
■ Lost	CT Auger Cuttings
▦ Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample Type	Recvy. (ft)	Sample Taken?	Sample Interval (ft)	GRAPHIC	USCS	DESCRIPTION
0						▨		CROSS-SECTION SHEET
5		CT		No		▨		0-9 ft. Clay, brown, soft, moist, plastic, from cuttings
10	▨	CB	1.7	No		▨	CL	9-14 ft. Clay, light brown, dry, very stiff, some caliche and crystals, no H/C odor
15	■	CB	0.5	No		▨		14-19 ft. No recovery except 6" slough material
	■					▦	GC	18 ft. Driller reports small gravels, water on auger cuttings, no H/C odor
20	▨	CB	1.8	No		▨		19-21 ft. Clay, brown, dry; put 4" swivel on drill string, auger refusal at 21 ft., hard, dry clay in tip; removed swivel, added 6" piece to and rotated tip
	▨	CB	1.7	No		▨		21-23.5 ft. Caliche clay, chalk white, hard, dry, auger refusal, no H/C odor
	▨	CB	1.7	No		▨	CL	23-24 ft. Same as above with small gravel inclusions
25	▨	CB	3	No		▨		24-26 ft. Clay, light brown with white streaking, stiff, very plastic, occasional caliche seam and small gravel, no H/C odor 26-29 ft. Clay and caliche clay, light gray, hard, dry, occasional gravel, no H/C odor
30								
35								

Notes:

Boring 96-15 located in field northwest of well KWB-1, 795 ft. south of the Eagle Creek fence and 550 ft. west of electric fence. At completion, drillers plugged back hole with cuttings.

H/C = Petroluem hydrocarbon

12-20-1996 \mtech4\navoff96\n-x-sect\off96-15.ge4

LOG OF BORING 96-17

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 11/20/96	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1610, 1700	Drill Equipment	: Ingersoll-Rand A-300
Transect & Location	: #12, 880 ft. South	Drilled By	: Atkins Eng. Assoc.
Hole Diameter	: 6"	Logged By	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0				CROSS-SECTION SHEET
				0-5 ft. Clay, dark brown
5			CL	
				7 ft. Clay, light brown, soft, plastic
10	Cuttings			
				11 ft. Gravel lens, dry, strong H/C odor
			GC	13 ft. Gravels, strong H/C odor, water sheen and product observed on auger returns
15				15 ft. Gravels, heavy drill rig auger chatter
			GW	
20				21 ft. Gravels, heavy drill rig auger chatter
25				22-29 ft. Clay, H/C odor on returns
	Cuttings			
30			CL	
				29-39 ft. Clay and caliche clay, chalk color
35				
40				
45				

Notes:

Boring 96-17 located in field northwest of well KWB-1, 900 ft. south of the Eagle Creek fence and 250 ft. west of electric fence. At completion drillers plugged back hole with cuttings.

H/C = Petroleum Hydrocarbon

12-20-1996 \mtech4\navoff96\n-x-sect\off96-17.ge4

ENCLOSURE 3

Copies of Other Borehole Lithologic Logs

LOG OF BORING OS 95-21

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started:	: 10/18/95	Drilling Method:	: Solid Stem Auger
Time Started	: 1200	Sampling Method:	: Cuttings
Date Completed	: 10/18/95	Drilled By:	: Frank's Rathole Srv.
Hole Diameter:	: 13"	Logged By:	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0–8	Cuttings	▥	ML	0-8 ft. Top soil to approx. 8 ft. grading to light brown clay, moist
8–22	Cuttings	▨	CL	8-10 ft. Clay, light brown, moist 10-12 ft. Gravelly clay, light gray, stiff, slightly moist, strong H/C odor 12-14 ft. Same as above with less gravel, stiff 14-18 ft. Clay, light brown, occasional gravel, stiff, strong H/C odor 18-19 ft. Gravelly clay, gray, saturated, very strong gasoline odor 19-20 ft. Clay, light gray to light brown, some gravel, tight, 20-22 ft. Clay, very tight, slight odor

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40

Notes:

Boring 95-21 drilled in pasture east of "boneyard" and fire training area. Hole located in north center pasture area, approximately 50 ft. south of east-west concrete irrigation ditch and 31 ft. west of gate post located south of KWB-1 wells.

At approximatey 1800 hrs., hole reported caved to less than 10 ft. No H/C product measured. Refinery workers plugged back hole with cuttings.

H/C = Petroleum hydrocarbon

LOG OF BORING OS 95-22

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started: : 10/18/95
Time Started : 1330 (approx.)
Date Completed : 10/18/95
Hole Diameter: : 13"

Drilling Method: : Solid Stem Auger
Sampling Method: : Cuttings
Drilled By: : Frank's Rathole Srv.
Logged By: : D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▥		
5	Cuttings	▥	ML	0-8 ft. Top soil to approx. 8 ft. grading to light brown clay, moist
10		▨		8-13 ft. Clay, light brown, moist, stiff, no H/C odor
15		▨		13-16 ft. Clay, light brown, increasing gravel in clay, stiff, no H/C odor, moisture at bottom of hole.
		▨	CL	16-18 ft. Clay, light brown, stiff, caliche clay at 18 ft., water entering hole at 18 ft.
20	Cuttings	▨		18-23 ft. Clay, tight, some gravel at top, less at 23 ft.
25		▨		23-26 ft. Clay, light to dark brown, stiff, tight 26-28 ft. Same as above, very stiff, only slightly moist, no H/C odor
30				
35				
40				

Notes:

Hole located 50 ft. south of monitor well KWB-1B inside pasture.

At approximatey 1800 hrs., hole reported caved to approximately 10 ft. No H/C product measured. Refinery workers plugged back hole with cuttings.

H/C = Petroleum hydrocarbon

12-19-1996 \mtech4\navoff96\north-hc\off95-22.ge4

Navajo

LOG OF BORING OS 95-23

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started:	: 10/18/95	Drilling Method:	: Solid Stem Auger
Time Started	: 1425	Sampling Method:	: Cuttings
Date Completed	: 10/18/95	Drilled By:	: Frank's Rathole Srv.
Hole Diameter:	: 13"	Logged By:	: D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0 5	Cuttings	▥	ML	0-10 ft. Top soil to approx. 8 ft. grading to brown clay, stiff
10 15 20	Cuttings	▨	CL	10-13 ft. Clay, grading to caliche clay with small gravels in clay matrix. 13-14 ft. Clay and caliche clay with small gravels in clay matrix. 14-18 ft. Clay with less gravel and caliche 18-20 ft. Clay with increasing moisture and small gravels, no H/C odor 20-22 ft. Gravelly clay, chalk gray, gravel pea sized, saturated, no H/C odor
				22-24 ft. No recovery, hard at 24 ft. (suspect 2 to 2.5 in. gravel, ref. Frank)
25		▨	CL	24-27 ft. Clay with gravel at top decreasing with depth, no H/C odor.
30 35 40				

Notes:

Hole located 150 ft. south of monitor well KWB-1B inside pasture.

At approximatey 1800 hrs., hole reported caved to less than 10 ft. No H/C product measured. Refinery workers plugged back hole with cuttings.

H/C = Petroleum hydrocarbon

12-19-1996 \mtech4\navoff96\north-hc\off95-23.ge4

LOG OF BORING OS 95-26

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started: : 10/18/95
Time Started : 1543
Date Completed : 10/18/95
Hole Diameter: : 13"

Drilling Method: : Solid Stem Auger
Sampling Method: : Cuttings
Drilled By: : Frank's Rathole Srv.
Logged By: : D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0 5		▥	ML	0-6 ft. Top soil
	Cuttings	▨	CL	6-8 ft. Clay. Water entering hole at approximately 7 ft. from field drainage or irrigation pipe, no H/C odor noted
10		▨		8-13 ft. Clay, light brown, moist, stiff
15		▨		13-15 ft. Caliche clay, some gravel, very stiff
		▨		15-19 ft. Caliche clay, very stiff
20	Cuttings	▨		19-23 ft. Caliche clay, some gravels
25		▨		23-28 ft. Caliche clay, some gravels
30 35 40				

Notes:

Hole located 50 ft. north of KWB-1 monitor wells, 13 ft. east of electric fence along dirt road.

Refinery workers plugged back hole with cuttings.

H/C = Petroleum hydrocarbon

LOG OF BORING OS 95-27

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started: : 10/18/95
Time Started : 1615
Date Completed : 10/18/95
Hole Diameter: : 13"

Drilling Method: : Solid Stem Auger
Sampling Method: : Cuttings
Drilled By: : Frank's Rathole Srv.
Logged By: : D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0		▥		
			ML	0-6 ft. Top soil, moist at 6 ft.
5	Cuttings			
		▨		6-12 ft. Clay, light brown, moist
10				
				12-15 ft. Clay, light brown, moist
15			CL	
				15-17 ft. Clay, light brown, moist, softer at 16 ft.
	Cuttings			17-20 ft. Clay, light brown, stiff
20				
				20-25 ft. Clay, light brown, stiff
25				
30				
35				
40				

Notes:

Hole located 150 ft. north of KWB-1 monitor wells, 13 ft. east of electric fence along dirt road.

At completion DTW water approximately 7 ft. No H/C odor noted. Refinery workers plugged back hole with cuttings.

DTW = Depth to water, H/C = Petroleum hydrocarbon

Navajo

LOG OF BORING OS 95-28

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Started: : 10/18/95
Time Started : 1630
Date Completed : 10/18/95
Hole Diameter: : 13"

Drilling Method: : Solid Stem Auger
Sampling Method: : Cuttings
Drilled By: : Frank's Rathole Srv.
Logged By: : D.G. Boyer

Depth in Feet	Sample Type	GRAPHIC	USCS	DESCRIPTION
0 5	Cuttings	▥	ML	0-6 ft. Top soil, moist at 6 ft.
10	Cuttings	▨	CL	6-12 ft. Clay, light brown, moist, no H/C odor noted
		▨		12-15 ft. Clay, light brown, moist
15		▨		15-17 ft. Clay, light brown, moist, softer at 16 ft.
		▨		17-20 ft. Clay, light brown, stiff
20		▨		20-25 ft. Clay, light brown, stiff
25				
30				
35				
40				

Notes:

Hole located 300 ft. north of KWB-1 monitor wells, 13 ft. east of electric fence along dirt road.

Refinery workers plugged back hole with cuttings.

H/C = Petroleum hydrocarbon

12-19-1996 \mtech4\navoff96\north-hc\off95-28.ge4

LOG OF BORING OS 96-16

(Page 1 of 1)

Offsite Borings 1995-96
Northeast Area
Hydrocarbon Study

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 11/20/96	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 0830, 1430	Drill Equipment	: Ingersoll-Rand A-300
Transect & Location	: #14, 1,120 ft. South	Drilled By	: Atkins Eng. Assoc.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition	Sampler Type
☒ Remoulded	SS Split Spoon
▨ Undisturbed	ST Shelby Tube
■ Lost	CT Auger Cuttings
▦ Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample Type	Recvy. (ft)	Sample Taken?	Sample Interval (ft)	GRAPHIC	USCS	DESCRIPTION
0 5		CT		No				0-9 ft. No cuttings returned to surface 9-14 ft. From driller: gravels at 11-13 ft., slight H/C odor on mud returns; pulled out of hole, 2" rounded gravel in auger, H/C product in mud and on auger. Shut down until additional short center rods received. At 1230 started new hole at 5 ft. north of original.
10	▨	CB	4.2	Yes	13-14 ft	▨	CL	9-11 ft. Clay, dark brown to 9.8 then light brown 11-12.3 ft. Clay, grading to light gray and sandy with gravels at 12.3 ft.
							GW	12.3-12.8 ft. Sandy gravel, dry, strong H/C odor
							SW	12.8-14 ft. Sand, dark gray, fine grained, strong odor
15	▨						GC	14-15 ft. Gravels with sand, clay and H/C product, saturated
		CB	3.7	No		▨	CL	15-16.7 ft. Clay, dark gray at top becoming light gray at base, mottled, dry, stiff, some silt and very fine grained sand, some H/C odor 16.7-18 ft. Caliche clay, light gray to chalk color, mottled, slight H/C odor, hard, pulled core at 18 ft. 18-20 ft. Clay, light gray and brown mottled, stiff, plastic, wet zone at 20 ft., no H/C odor
20	▨	CB	3.8	Yes	18 ft.	▦	CA	20-22 ft. Caliche, white, dry, hard, pulled core at 22 ft.
25	▨	CB	3.8	No		▨	CL	22-27 ft. Clay, mottled light brown and chalk colored, dry, hard but softer at 27 ft.
30	▨	CB	27	No		▨		27-32 ft. Clay, same as above, soft from 28.3-28.5 ft. occasional small gravel in clay matrix
35								Notes: Boring 96-16 located in field northwest of well KWB-1, 1,140 ft. south of the Eagle Creek fence and 550 ft. west of electric fence. At completion, drillers plugged back hole with cuttings. H/C = Petroluem hydrocarbon

12-19-1996 \mtech4\navoff96\north-hc\off96-16.ge4